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Flaxseed—Make The Food Nutritious & Provide Natural Antioxidants

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ABSTRACT

Flaxseed is emerging as an important functional food ingredient because of its rich contents of α-linolenic acid (ALA, omega-3 fatty acid), lignans, and fiber. Flaxseed oil, fibers and flax lignans have potential health benefits such as in reduction of cardiovascular disease, atherosclerosis, diabetes, cancer, arthritis, and osteoporosis, autoimmune and neurological disorders. Flax protein helps in the prevention and treatment of heart disease and in supporting the immune system. As a functional food ingredient, flax or flaxseed oil has been incorporated into baked foods, juices, milk and dairy products, muffins, dry pasta products, macaroni and meat products. The present review focuses on the evidences of the potential health benefits of flaxseed through human and animals' recent studies and commercial use in various food products. There is currently much interest in phytochemicals as bioactive molecules of food. Functional foods are an emerging field in food science due to their increasing popularity among health conscious consumers. Flaxseed is cultivated in many parts of world for fiber, oil as well as for medicinal purposes and also as nutritional product. In this review, nutrients, anti-nutrients, functional properties, processing, metabolism and health benefits of bioactive molecules viz., essential fatty acids, lignans and dietary fiber of flaxseed are discussed.

Keywords: Flaxseed, Functional properties, Nutritional quality, Processing, Alpha-linolenic acid, Dietary fiber, Lignans, Health benefits.

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INTRODUCTION

An ounce of these slightly nutty seeds contains nearly 8g of fiber along, 12g of fatty acids, and more than a quarter of your daily recommended magnesium, which helps boost energy. The fiber helps with digestion, and there's also some evidence that flax seeds can lower high blood pressure and cholesterol. Available in either brown or golden varieties, both are equally nutritious. Flax (Linum usitassimum) belonging to family Lineaceae, is a blue flowering annual herb that produces small flat seeds varying from golden yellow to reddish brown color. Flaxseed possesses crispy texture and nutty taste (Morris 2007; Rubilar et al. 2010). Flaxseed is also known as linseed and these terms are used interchangeably. Flaxseed is often used to describe flax when consumed by humans while linseed denotes when it is used specifically for industrial applications (Morris 2007). Almost all parts of linseed plant are utilized for various purposes. Seed contains oil which after refining is used for edible purpose (Singh et al. 2011a, b). 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 (Tolkachev and Zhuchenko 2000)[1]. Currently, it is cultivated in more than 50 countries, predominantly in the Northern hemisphere. Canada is the world's largest producer and exporter of flaxseeds (Oomah 2001)3. The important flaxseed growing countries include India, China, United States, and Ethiopia (Oomah and Mazza 1998; Singh et al. 2011a, b)[2]. India ranks first among the leading flaxseed producing countries in terms of acreage accounting 23.8 % of the total and third in production contributing to 10.2 % of the world's production (Singh et al. 2011a, b). In India flaxseed is mainly cultivated in Madhya Pradesh, Maharashtra, Chhattisgarh 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 (Shakir and Madhusudan 2007)[4]. 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 (Carter 1993; Rubilar et al. 2010; Rabetafika et al. 2011)[5.] 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 (Toure and Xueming 2010). 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 (Al-Okbi 2005)[6]. 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 (Oomah 2001)[8]. ALA is one of the essential polyunsaturated fatty acid and reported to exhibit anti-inflammatory, anti-thrombotic and anti-arrhythmic properties (Simopoulos 1999)[7]. 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 (Singh et al. 2011a, b)[9]. Inspite of the multiple clinical evidences of flaxseeds, people are still unaware about its nutritional as well as therapeutic benefits.

Nutritional & Therapeutic Value

Among the functional foods, flaxseed has emerged as a potential functional food being good source of alpha-linolenic acid, lignans, high quality protein, soluble fiber and phenolic compounds (Oomah 200Flaxseed oil constitutes 98 % triacylglycerol, phospholipids and 0.1 % free fatty acids (Mueller et al. 2010)[10]. On an average it contains 21 % protein. 1). The composition of flaxseed is presented. (Morris 2007[11]; Gopalan et al. 2004[12]; Payne 2000). Chemical composition of flaxseed depends upon growing environment, genetics and processing conditions (Morris 2007). The lipid content of flaxseed varies from 37 to

45 g/100 g of the seed. Flaxseed oil constitutes 98 % triacylglycerol, phospholipids and 0.1 % free fatty acids (Mueller et al. 2010)[14]. On an average it contains 21 % protein. Flaxseed protein is rich in arginine, aspartic acid and glutamic acid, while lysine is limiting (Singh et al. 2011a, b; Chung et al. 2005)[15]. High cysteine and methionine contents improve the antioxidant levels, thus helps in reducing risk of cancer (Oomah 2001)[13]. Flaxseed is the richest source of phytoestrogens (lignans). Flaxseeds contain a good amount of phenolic compounds. These phenolic compounds are well known for anticancer and anti-oxidative properties. It serves as a good source of minerals especially, phosphorous (650 mg/100 g), magnesium (350–431 mg/100 g), calcium (236–250 mg/100 g) and has very low amount of sodium (27 mg/100 g). Flaxseed contains small amounts of water-soluble and fat-soluble vitamins. Vitamin E is present as γ-tocopherol, amounting to 39.5 mg/100 g. γ-tocopherol is an antioxidant providing protection to cell proteins and fat from oxidation; promotes sodium excretion in urine, which may help in lowering of blood pressure and heart disease risks and Alzheimer disease (Morris et al. 2005; Morris 2007)[16].

Anti-Nutrients

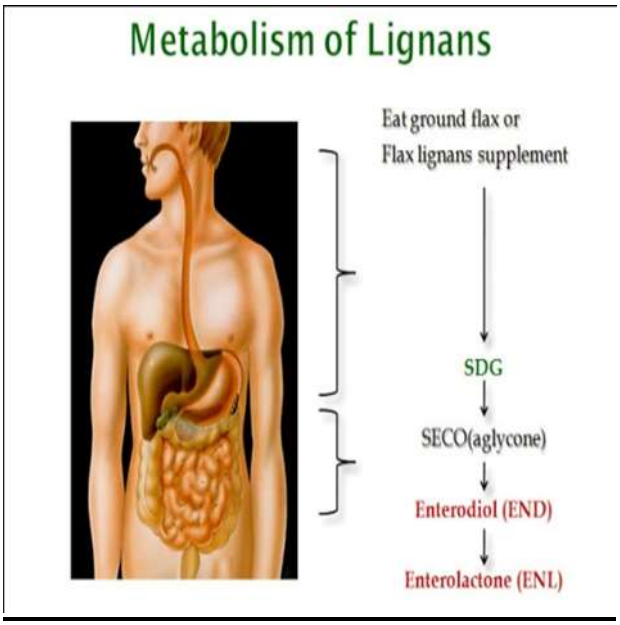
Whole flaxseed contains 250–550 mg/100 g cyanogenic glycoside (Singh et al. 2011a, b) [17]. In the intestine, cyanogenic glycosides release hydrogen cyanide, a potent respiratory inhibitor, by intestinal β-glycosidase that produces thiocyanates. Thiocyanates interfere with iodine uptake by thyroid gland and long term exposure aggravates iodine-deficiency disorders, goiter and cretinism. Phytic acid, another anti-nutrient present in flaxseed, 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 (Erdman 1979; Akande et al. 2010)[18]. Phytic acid interferes with the absorption of calcium, zinc, magnesium, copper and iron. It is a strong chelators, forming protein and mineral-phytic acid complexes and thus reducing their bioavailability (Erdman 1979; Akande et al. 2010)[18]. Trypsin inhibitors are also reported in flaxseed, though activity is insignificant as compared to soybean and canola seeds (Bhatty 1993)[19].

Alpha-Linolenic Acid

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 (Riediger et al. 2009). Flaxseed oil is rich in polyunsaturated fatty acid (73 % of total fatty acid), moderate in monounsaturated fat (18 %) and low amount of saturated fat (9 %) (Cunnane et al. 1993; Dubois et al. 2007). It is rich in both the essential fatty acids—alpha-linolenic acid (ALA), and linolenic acid (LA).

Metabolism

Omega-3 fatty acid is known as essential fatty acid because humans cannot introduce a double bond beyond the ninth carbon from carboxyl end of fatty acid. ALA serves as the precursor for the synthesis of polyunsaturated fatty acids—EPA (Eicosapentaenoic acid) and DHA (Docosahexanoic acid). During the transformation of ALA into EPA and DHA, a series of fatty acids belonging to n-3 PUFA family are also synthesized via desaturation and elongation reactions in the presence of specific desaturase and elongases. Similarly, linolenic acid is also synthesized using similar enzymatic reactions. It has been reported that the conversion of ALA to EPA and DHA is not very efficient in humans and animals and there exist competition between both the fatty acids for the same enzymes. Long chain PUFAs, EPA and DHA are further metabolized by the enzymes cyclooxygenase and lipoxygenase to eicosanoids, prostaglandins, leukotrienes. Among these eicosanoids, E_2 series prostaglandins, leukotrienes B_4 derived from linoleic acid are the key metabolites which are responsible for many inflammatory diseases like cardiovascular diseases and arthritis, while eicosanoids and E3 series prostaglandins derived from linolenic acid have anti-inflammatory responses (James et al. 2000). Therefore, it is advised that human beings should consume a diet that contains a balanced ratio of omega-3 and omega-6 essential fatty acids. The two groups of essential fatty acids compete with each other for placement within cell membranes. If the intercellular environment has a higher proportion of one type of fatty acid as compared to the other, it is likely that the predominant fatty acid will be incorporated into cell membrane, resulting in adverse effects in the fluidity of the cell membrane affecting cellular functions and overall health of the cell. If there is an equal proportion of both the essential fatty acid in the intercellular environment, there is selective preference for omega-3 fatty acid. Both these fatty acids have opposing, yet necessary, influences over physiological functions (Lunn and Theobald 2006; Kaur et al. 2012)[20]. EPA and DHA can be converted endogenously into different metabolites known as resolvins, neuroprotectins and protectins. The resolvins act as potent anti-inflammatory mediator. In particular, they function to limit the extent of inflammation by blocking the actions of prostanoids, and also by helping to clear site of inflammation from breakdown products of inflammatory process. Resolvins and protectins promote resolution in oral, lung, kidney, skin, gastrointestinal and various other inflammations to maintain homeostasis by activating specific mechanisms. DHA is converted into neuroprotectins which exhibit neuroprotective effects (Simpolous 2011; [21]



Benefits for The Body

A large number of clinical studies have recognized the tremendous potential of n-3 polyunsaturated fatty acids against inflammatory mediators like prostaglandins E_2, leukotriene B_4, TNF-α, interleukin, and cytokines. These clinical studies revealed that n-3 polyunsaturated fatty acids are helpful in prevention of coronary heart diseases, atherosclerosis, rheumatoid arthritis and asthma (Arend and Dayer 1995; Kremer 2000). 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 (Kremer 2000). It has also been reported that the consumption of omega-3 dietary supplements lead to significant reduction of nonsteroidal anti-inflammatory drugs (Arend and Dayer 1995). Flaxseed possesses antioxidant and hepatoprotective properties. Several studies advocated the cholesterol lowering benefits of flaxseed meal (Cunnane et al. 1993; Ridges et al. 2001; Bhathena et al. 2003)[22]. Commercial processing of flaxseeds is carried out to obtain oil and various by-products. Compositional changes during processing are of prime importance to food, feed and nutraceuticals industry. Processing of flaxseeds at commercial level involves multiple steps.

Lignans

Lignans are phytoestrogens, which are abundantly available in fiber rich plants, cereals (wheat, barley, and oats), legumes (bean, lentil, and soybean), vegetables (broccoli, garlic, asparagus, carrots) fruits, berries, tea and alcoholic beverages. flaxseed contains about 75–800 times more lignans than cereal grains, legumes, fruits and vegetables (mazur et al. 2000; meagher and beecher 2000; murphy and hendrich 2002; hosseinian and beta 2009)[23]. secoisolariciresinol diglycoside (sdg) is the major lignan of flaxseed, alongwith minor contents of matairesinol, pinoresinol, lariciresinol and isolariciresinol (meagher et al. 1999; sicilia et al. 2003; krajcova et al. 2009)[24]. sdg ranges from 11.7 to 24.1 mg/g in defatted flour

and 6.1 to 13.3 mg/g in whole flaxseed flour (johnsson et al. 2000). sdg is metabolized by bacteria in the colon of humans to synthesize mammalian lignans known as enterodiol (end) and enterolactone (enl) (chen et al. 2007)[12]. in human body, the lignans are acted upon by the gastrointestinal microflora to release seco, non-sugar moiety of sdg. further hydroxylation and demethylation by the microflora, lead to the production of mammalian lignan-enterodiol (end), which is then oxidized to give enterolactone . Flaxseeds serve as a good source of both soluble and insoluble dietary fiber. Flaxseed holds a unique place among the oilseeds due to presence of mucilage located in outer layers of the seed (singh et al. 2011a, b) [21]. Flaxseed mucilage has gained momentum due to its superb health benefits and potential functional properties. Dietary fiber of flaxseed reaches the large intestine and is fermented by colonic microflora with production of short chain fatty acids (SCFA), hydrogen, carbon dioxide, methane and biomass and exhibit laxative effects (Kritchevsky 1979)[12]. In the large intestine, both soluble and insoluble fibers have their bulking effect resulting in increasing both dry and wet weight of the colon contents and feces. Soluble fiber increases water binding, initially by the binding capacity of its macromolecules, later by increasing the mass of microbial cells. The contribution of soluble fiber to faecal weight was insignificant compared to insoluble fiber. Recent studies, however, have shown that it is of the same magnitude (Malkki 2004)[3].

AS Ingredient

In functional foods arena, flaxseed has resurged as a new potential functional ingredient with a vast array of medical benefits. Flaxseed supplemented food products are gaining popularity because of its high content of polyunsaturated fatty acids, protein, soluble fiber and

phytochemicals. It is utilized as a versatile ingredient in various types of food products. It is convenient to use flax seeds as whole or milled in batters, dough and various baked products. Flaxseed-water mixture serve as egg substitute in the diet of vegetarians especially in baked products pancakes, muffins and cookies. These baked goods are slightly gummier and chewier, and have low loaf volume than normal. One tablespoon of milled flaxseed (approx. 15 g) along with three tablespoon of water (approx. 45 mL) substitute for one egg. Flaxseed gum (0.45 % w/w) can be utilized for stabilization of emulsion in case of salad dressings (Stewart and Mazza 2000)[4]. Functional properties of flaxseed constituents are presented in Table 4. Flaxseed products are quiet stable for a longer period at ambient temperature despite of generous amount of alpha-linolenic acid. Several studies justify the above statement that storing the milled flaxseed for about 4 months did not result in deterioration of quality (Singh et al. 2011a, b)[7.] Similarly, bread prepared with the flaxseed oil cake at the rate of 10 and 15 % had peroxide levels well below the threshold limits after the 6 months of storage (Ogunronbi et al. 2011)[9]. Flaxseed is also being incorporated in the feed of animals to improve the nutritional quality of the meat and fat obtained from them. Omega-3 enriched eggs, pork products are now-a-days available commercially (Kassis et al. 2011). Recently there has been resurgence in the use of flaxseed oil for edible purposes because of its nutraceuticals values. Fresh flaxseed is golden yellow in color, has neutral taste and is very sensitive to heat, light, oxygen; therefore it is usually extracted by cold pressing when it is meant for edible purposes (Choo et al. 2007a, b)[9]. Since, flaxseed oil has very high amount of alpha-linolenic acid, it is highly susceptible to oxidation, rancidity and poor sensory quality (Hosseinian et al. 2004; Wiesenborn et al. 2005)[17.] The oxidation products serve as a causative agent for chronic diseases.

CONCLUSION

Various clinical trials revealed that the flaxseed constituents provide disease preventive and therapeutic benefits. This encourages development of new branded healthy and functional foods using flaxseeds, oil and cakes. More in vivo studies are required to ascertain the health benefits of flaxseed constituents and to know the minimum amount of flaxseed required to explore its therapeutic potential for all population groups including pregnant and lactating women and to know possible problems posed by its overdose. There is need for the development of rapid, reproducible and economic techniques for the analysis of nutraceuticals from flaxseed.

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