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FLAXSEED AS A NUTRACEUTICAL: A REVIEW

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Abstract:

Flax seed (Linum usitatissimum) is a key source of phytochemicals in the functional food area. Flax seed oilseed crop which has gained importance due to its unique nutrient profile. Flax seed comprises high amount of fiber and is a significant source of a-linolenic acid in the diet of vegetarian people. It is evident from several studies conducted that flaxseed carries functional ingredients and provide health benefits. Omega-3 fatty acid, lignan and dietary fiber are major bioactive components of flaxseed which can be delivered through value added products. Commercially, all parts of flaxseed plant are exploited directly or after processing. Flaxseed consumption in the diet prevents serious diseases like coronary diseases, cardiovascular diseases, cancer, diabetes, obesity, gastrointestinal, post-menopausal, renal and bone disorders. Few review are available for commercial utilization of flaxseed in preparation of various value-added products (bakery, dairy, extruded, snack, fermented and other traditional).

Keywords: Flaxseed, Nutritional Components, Value-Added Components, Health Benefits.

Introduction:

The term “nutraceutical” combines two words- “nutrient” (a nourishing food component) and “pharmaceutical” (a medical drug). The name was coined in 1989 by Stephen DeFelice. According to DeFelice, nutraceutical can be defined as, "a food (or part of a food) that provides medical or health benefits, including the prevention and/or treatment of a disease. When food is being cooked or prepared using "scientific intelligence" with or without knowledge of how or why it is being used, the food is called "functional food." Thus, functional food provides the body with the required number of vitamins, fats, proteins, carbohydrates, etc. needed for its healthy survival. When functional food aids in the prevention and/or treatment of disease(s) and/or disorder(s) other than anemia, it is called a nutraceutical [1].

Classification

A] Nutraceuticals or functional foods can be classified on the basis of their natural sources, pharmacological conditions, or as per chemical constitution of the products.

1. Animals, minerals, or microbial sources.
2. Nutraceuticals as per the chemical groupings.

B] Nutraceuticals are categorized on the basis of foods available in the market.

1. Traditional nutraceuticals
2. Non-traditional nutraceuticals

Flax *(Linum usitatissimum*) is a blue flowering crop that produces small, flat seeds ranging in color from golden yellow to reddish brown which belongs to the family of linaceae commonly known as flaxseed or linseed [1]. The seeds are commonly consumed in one of three ways: whole seed, ground seed, or flaxseed oil. Flax is an oldest agronomic crop having more than 300 species and which are cultivated for food and fiber. Flax seed is recognized either by variety or by color (brown and yellow). Brown coloured flaxseed is the most common and high in alpha-linolenic acid, while there are two types of yellow coloured flaxseed: Omega and Linola [2] Golden flaxseed has a nutty-buttery flavour. Top most

producer of flaxseed in the world is Canada with 0.81 million tons in 2014–2015 [3] Most of the benefits reported from flaxseed consumption are believed to be due to the following three important components found in flaxseeds, α-linolenic acid (ALA), lignans, and fiber. Flaxseed contains protein (23.4%), lipids (45.2%) and mineral (3.5%) which are nutritionally very important (Mueller et al, 2010). Flax protein is relatively rich in arginine, aspartic acid and glutamic acid, and the limiting amino acids are lysine, methionine and cysteine [4] .Flaxseed contains highest amounts of lignans and secoisolariciresinol diglucoside (SDG) which also provides additional health benefits [5] .Flaxseed contain total fibre - around 25 to 28% and major fibre fractions are cellulose, mucilage gums, and lignin [6]. Based on a proximate analysis conducted by the Canadian Grain Commission flax is rich in fat, protein and dietary fiber. An analysis of brown Canadian flax averaged 41% fat, 20% protein, 28% total dietary fiber, 7.7% moisture and 3.4% ash. Cellulose, hemicellulose and lignin are insoluble fiber constituents abundantly found in flaxseed while mucilage gums form the soluble fiber fraction [7]. Major lignan present in flaxseed is secoisolariciresinol diglycoside (SDG). Flax seed is an equally good source of minerals, particularly, phosphorus, magnesium, calcium, iron, zinc and very little amount of sodium. Flaxseed is also a good source of B-vitamins [8].

Form of flaxseed	Wt. (g)	Energy (Kcal)	ALA (g)	Total dietary fibre (g)	Soluble fibre
Whole seed	11	50	2.5	3.0	8.8
Ground seed	8	36	1.8	2.2	6.4
Flaxseed oil	14	124	8.0	0.0	0.0

Figure 1. Composition of Flaxseed (based on one tablespoon)

Flaxseed contains saturated, monosaturated, polyunsaturated fatty acids; globulin & glutelin proteins; dietary fibers like mucilage, cellulose, hemicellulose and lignin; vitamins such as A, C, E, thiamine, riboflavin, niacin and vitamin B6; Energy, Carbohydrates, Lipids and minerals like calcium, iron, phosphorus, magnesium, sodium, zinc as shown in Figure 2.

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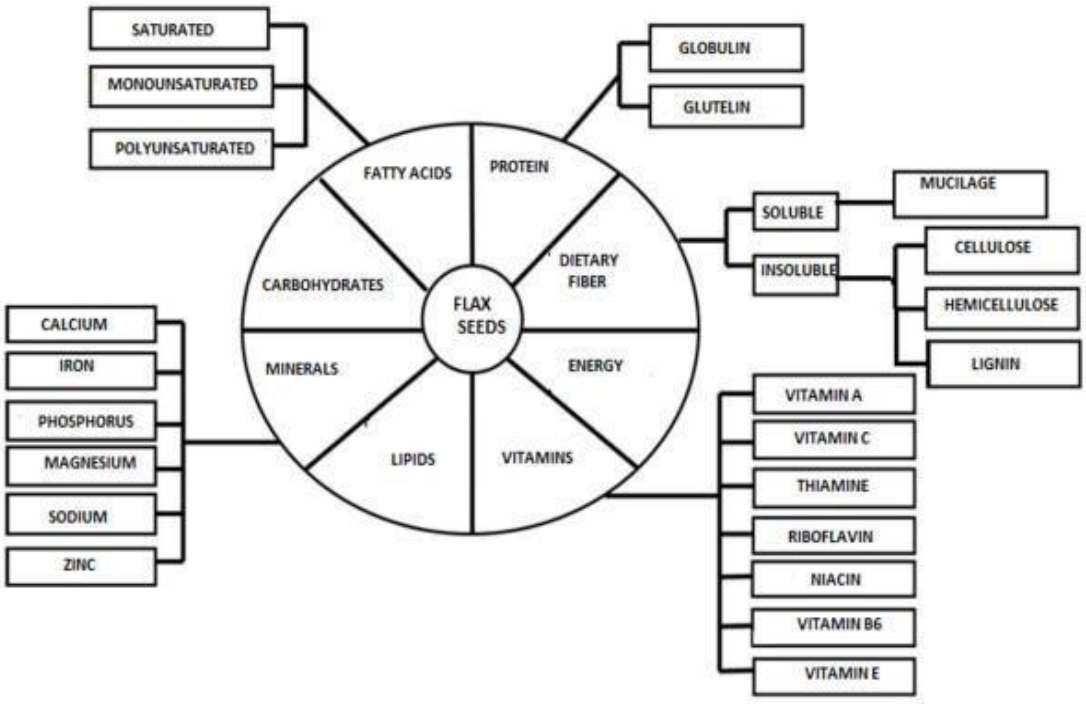

Figure 2. Flaxseed Nutritional/phytoconstituents

Health Benefits & Uses of Flax

The consumption of flaxseed in diet has many health benefits which are discussed below:

Cardiovascular Benefits: As the building block for other messaging molecules that help in prevention of excessive inflammation, ALA can help protect the blood vessels from inflammatory damage. Numerous studies have shown the ability of dietary flaxseeds to increase blood levels of ALA, even when those flaxseeds have been ground and incorporated into baked goods like breads or muffins [9]. A number of mechanisms have been proposed by which flax may exert its beneficial effects on the cardiovascular system: Reducing serum cholesterol, reducing platelet aggregation, reducing inflammatory markers, Improving glucose tolerance.

Anti-inflammatory Benefits: When flaxseeds are consumed, two other ω-3 fatty acids have also been shown to increase in the bloodstream, namely, eicosapentaenoic acid (EPA) and docosapentaenoic acid (DPA). Increase in EPA and DPA also helps in the inflammatory protection [9]. Protection of our blood vessels from inflammatory damage is also provided by the lignans in flaxseeds [10].

Antioxidant Benefits: Risk of oxidative stress in the blood vessels can also be lowered by flaxseed intake. In addition to being a very good source of the mineral antioxidant manganese, polyphenols in flaxseed including flaxseed lignans provide measurable antioxidant benefits.

Antidiabetic Benefits: Low glycaemic index foods containing soluble fibre not only prevents certain metabolic ramifications of insulin resistance, but also reduces insulin resistance [11]. Soluble fibre and other components of flaxseed fractions potentially affect insulin secretion and its mechanisms of action in maintaining plasma glucose homeostasis. Flaxseed was shown to reduce the postprandial blood glucose response in humans. Oxidative stress plays a significant role in the etiology of type-1 and type- 2 diabetes. It results in reduced insulin production.

Post-menopausal Benefits: Flax is currently being researched as a supplement for women entering into menopause [9]. The high fibre of flax coupled with the health benefits of the essential fatty acids have shown to have a positive impact on hormonal modulation in clinical trials of women over the age of fifty. Women who enjoy high fibre diets experience fewer problems and side effects due to menopause [10]. The ease with which flax can be added to home cooked foods makes it an excellent supplement and easily implemented healthy diet change. Flaxseed is also used during menopause for hot flashes and breast pain.

Anticancer Benefits (Breast): Flaxseed helps in reduction in tumour cell proliferation, reduction in mammalian tumour size and number and having a positive effect in controlling the initiation and promotional stages of mammalian cancers. Studies indicated a 46% reduction in the number of tumours per rat fed a diet that contained purified SDG at 1.5 mg/day (equivalent to a 5% flaxseed/day intake) [12]. In a study addition of 10% percent flaxseed oil in diet reduced tumour growth and metastasis incidents [13]. Both flaxseed and flaxseed oil have been used for high cholesterol levels and in the prevention of cancer. Lignans have a very similar chemical structure to some of the therapies available for breast cancer, and recent research has focused on using lignans for cancer treatment and their role in cancer prevention. Flaxseed supplementation has shown beneficial effects on breast cancer in laboratory animals. In a study, mice were injected with human cancer cells and

then fed a typical lab chow diet for 8 weeks. At 8 weeks, rats were randomly assigned into a group that continued with the chow diet or to a 10% flaxseed diet. At the end of the study, flax seed supplementation was shown to reduce the tumour growth rate and reduce metastasis by 45%. In another study, feeding nursing mice with a 10% flax seed diet protected the offspring from mammary gland tumours. When challenged with a carcinogen to induce mammary gland tumours, they had significantly lower incidence of tumours, tumour load, mean tumour size, and tumour number compared to those whose mothers had not received flaxseed supplementation.

Anticancer Benefits (Prostate): Flaxseed supplementation (ground flaxseed) has shown to be beneficial for prostate cancer in both animal and human studies. The beneficial factor may be the lignans found in flaxseed.

Flaxseed is most commonly used as an anti-laxative and also used as an anti-arthritis.

Flaxseed as nutritional component

The major anti nutritional factors which limit the use of flaxseed are:

Cyanogenic Glucosides: Flaxseed contains cyanogenic glycosides, such as linamarin, linustatin, lotasutralin, and neolinustatin, which release toxic hydrogen cyanide upon hydrolysis [12]. Cyanogenic glycosides content differs depending in small amounts. Hydrogen cyanide is a powerful respiratory inhibitor if absorbed in sufficient quantities. The primary cyanogenic glycoside in flaxseed is linamarin and it ranges from 0 to 300mg/kg (Flax Feed Industry Guide, 2008).

Linatine: Flax contains a vitamin B6 (pyridoxine) antagonist called linatine. The concentration typically ranges from 20-100 mg/kg. Occasionally symptoms of vitamin B6 deficiency can be observed in broiler chickens fed flax and, therefore, it is recommended that diets containing flaxseed or meal be supplemented with additional pyridoxine to offset the potential negative effects of linatine on this vitamin [13].

Mucilage Gum: Mucilage are water soluble, indigestible, mucilaginous carbohydrates composed of galactose, xylose, arabinose, rhamnose and galacturonic acid sub-units that absorb water and increase intestinal viscosity. These mucins are likely responsible for the therapeutic effects of feeding flaxseed. Mucilage is found in the outer hull of the seed and accounts for approximately 8 percent of the weight of the seed [13].

Flax seed is cultivated in many parts of world for fiber, oil as well as for medicinal purposes and also as a nutritional product [14]. Demand for flaxseed has been increased because of consumer awareness about the relationship between diet and health. Flaxseed is considered as a potential functional food ingredient as it provides various health benefits along with nutritional value [15]. Flax seed is an important source of a-linolenic acid in the diet of vegetarian people. Therefore, it may serve as an alternate for supplying fatty acid to populations which do not have large access to seafoods [16]. The total protein content in flaxseed ranges between 20 to 30% composed of mainly 80% globulins and 20% glutelin [17]. 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 [7]. Flax seeds also contain anti-nutrients which may pose adverse health effects and may influence the well-being of human population. Major anti- nutrients in whole flaxseed are cyanogenic glycosides (250– 550 mg/100 g) [18], while the phytic acid content of flaxseed meal is 2.3–3.3% which result in decreased absorption of nutrients. Hydrogen cyanide released from flaxseed is minimal and lower than the toxic or lethal dose. The release of hydrogen cyanide is approximately 5–10 mg from 1– 2 tablespoons recommended daily intake of flaxseed. This value is much lower than the acute toxic dose which is estimated to be 50–60 mg. Also, human beings can detoxify cyanide levels below 30– 100 mg/day [19].

Balanced diet is vital for good health and well-being. The food delivers energy, protein, fat, vitamins and minerals for living, growth and to work properly. Wide variety of different foods is required to provide precise amounts of nutrients for good health. Unhealthy eating habits are the leading cause of death and increased risk of numerous diseases. Diet and nutrition play an important role in critical ailments such as coronary heart diseases, obesity, cancer, type-2 diabetes, bone disorders, dental caries, gall bladder disease, dementia and nutritional anaemia. Flaxseed flour greatly enhanced nutritional qualities without affecting the overall acceptability of products. Ash, protein, fat and crude fiber contents of flaxseed cookies and biscuits were more than control which could be accounted by the fact that flaxseed is far higher in mineral, fat, protein and fiber content than wheat flour [20] . Fortification of biscuits with flaxseed flour resulted in decreased carbohydrate content as compared to control [21] . Results indicated that flaxseed flour incorporation considerably enhanced nutritional quality, particularly protein, fat, crude fiber, iron, calories and omega-3 content of cereal and energy bars without affecting their sensory and quality properties [22]. The major benefit of flax seed enrichment is generally an increase in omega-3 fatty acid content of products. Flax seed oil enriched biscuits were particularly rich in alpha linolenic acid and they contained a less amount of linoleic acid [23] . Cakes and breads prepared with 30% flaxseed flour received claims of good and excellent source of dietary fiber and

linolenic acid [24]. As a baking ingredient, ground flaxseed does not lose significant amounts of ALA during baking [25]. Also, extruding, drying and cooking had little or no effect on stability of lipids in macaroni containing flaxseed [26] .This might be due to the high natural level of antioxidant active lignans, which contribute to the oxidative stability of flaxseed oil and products with incorporated flax seed. Levels of soluble, insoluble and total dietary fiber and essential amino acids were higher in unleavened flat bread with added flaxseed when compared with control [27].

Applications of Flaxseed

Consumer demand is increasing day by day for nutritious and health promoting products. With its nutritional and health benefits, flaxseed has immense potential for use in various food formulations.

Considering the nutritional benefits; flaxseed whole as well as meal has been used in the development of various food products which are discussed below:

ω-3 rich energy bar with flaxseed: A nutritious energy bar utilising flaxseed in the formulation along with cereal (white oats), pulses (roasted bengal gram) and legumes (soy protein) with varying levels of sweeteners to deliver a nutritious health product was developed

[28] (Figure 3). Significant increase in total calories was found with increasing levels of flaxseed; the maximum (397.95 kcal) for bars with 20% flaxseed and 45% sweeteners. This energy bar sample also showed the maximum protein (12.41%), crude fat (11.86%), ash (1.65%), iron (3.77 mg/100 g), crude fibre (2.18%) and ω-3 as α-linolenic acid (22.50%, fatty acid basis) content. Also, 15% flaxseed and 45% sweeteners along with other ingredients may be considered for production of acceptable quality omega-3 fatty acid rich energy bar at commercial scale, which also stored well under refrigerated condition.

Flaxseed Chutney Powder: In India, a variety of chutneys and pickles in large volumes based on vegetables, pulses and spices are consumed along with rice and breakfast items like chapatti, idli, dosa, and vada. Flaxseed chutney powder, a palatable functional food adjunct was prepared by mixing roasted and powdered flaxseeds with other selected spice ingredients. The protein content of the powder was 24.2% and 23.4% in flaxseed powder and flaxseed chutney powder respectively. This flaxseed chutney powder is non-hygroscopic in nature and can be served with cooked rice and fermented food such as dhokla, dosa and idli (Figure 4).

Other Applications: Flaxseed is utilised as a main food ingredient in order to enhance functional foods. Whole or ground flaxseed can be used in various food products, such as bread, pasta, candy, chocolate bar, chocolate muffin, bun, cereals, salad toppings, corn snack, cake, tortilla, ice cream, yogurt, or can be consumed as a roasted snack [29] . Flaxseed is also processed for oil, which is a major product for the organic food industry. Roasted flaxseed can be used in bread and confectionery products [30]. Addition of flaxseed and flaxseed oil in bread making has more effectively retained moisture and softness than in control during six days storage at room temperature [31]. Flaxseed at 30–50 percent substitution for flour greatly enhanced the nutritional qualities of some nutrients without affecting the overall acceptability of bakery products [32]. An extruded food product was prepared by using linseed, wherein grains are ground, impregnated with water by steaming, made into paste form, and extruded. Flaxseed flour can also be used in extruded products. Addition of flaxseed flour significantly reduced the expansion ratio and increased bulk density and breaking strength results, indicating a denser product [12]. Flaxseed contains important quantities of compounds with functional and bioactive properties, such as α-linolenic acid, lignans; soluble fibre and proteins, whose effects on the prevention of diseases such as diabetes, cardiovascular, colon cancer and inflammation have been tested. These characteristics make flaxseed an attractive source of functional ingredients for the preparation of foodstuffs.

Figure 3. ω-3 rich energy Flaxseed Bar

Figure 4. Flaxseed Chutney Powder

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Value-added products prepared by flax seed

Value added products are prepared for enhancing the value of food items through the addition of ingredient, processing or packaging. Some examples of value-added products are breakfast cereals, skim milk, ice cream, yogurt, cheeses, extruded snacks, etc.

1. Bakery products: The baking industry is one of the leading systematized processed food industries. Bakery products are popular due to their convenience, low price and ready-to-eat nature, easy transportation, availability in numerous tastes and textural profiles. The foremost benefit of bakery products is docility for fortification with cereals, millets or other ingredients [33]. Therefore, these products are an effective medium for delivering functional ingredients to consumers. Commercially available cookies are mostly deficient in ALA and dietary fiber [34]. Refined ingredient usage makes biscuits deprive of grain components that are protective of health [35]. Flax seed can be incorporated into baked good as whole, milled, ground, roasted and in the form of oil. Flaxseed addition in bakery products has been a challenge for various researches due to oxidative instability of flaxseed at high temperatures and during storage. Recent studies have suggested that flaxseed has been used in various bakery products like bagels, breads, biscuits, cookies, muffins, pizza, buns and patties in Figure 5. Addition of flax seeds into various bakeries and other cereal products gave positive results for enhancing overall nutritional quality. Tafton bread with 5 and 15% coated ground flaxseed with arabic gum or hydrogenated fat had acceptable rheological and organoleptic characteristics [36]. Flaxseed muffins (7.3%, 11.6% and 15.5%) were less acceptable than control muffins on the basis of sensory parameters, but they provide 16% of the dietary fiber requirement [37]. Flaxseed cookies (6 and 12%) were accepted by the consumer without adversely affecting physical and sensory quality [38]. Shortening can be replaced with flaxseed oil up to 30% in cookies and it enhances v-3 fatty acid by 14.14% in flaxseed oil cookies [39]. Chemical evaluation of some products (pan bread-pizzaTahina) showed that protein content, fat, fiber, and ash content increased with addition of flaxseed to wheat flour by 15% while carbohydrate decreased in bread and pizza [40].

2. Dairy products: Dairy-based products are a major part of functional foods. Functionality of dairy products can be developed and designed simply by modifying and enriching healthy nature of the original base. Type of milk and culture, the amount of milk fat and non-fat milk solids, fermentation and temperature used affect aroma, body and flavour of cultured dairy products. Figure 7 showed Milk and milk products have been proven to be a successful medium for delivering bioactive ingredients [41]. Value-added dairy products include low-lactose or lactose-free products, hypoallergenic formulations with hydrolysed protein for milk- hypersensitive infants, milk enriched with calcium, vitamins, etc. [42] . Flaxseed oil and flaxseed lignan have also been supplemented into milk and various dairy products such as ice cream, cheese, yogurt, whey drinks and butter. 2% w/w flaxseed oil in a 12% w/w ice cream mix can be incorporated without significantly affecting the overall functionality of ice cream. SDG added to milk, yogurt, and cheese were found to withstand hightemperature pasteurization, fermentation, and milk renneting

processes well [43]. Microencapsulated flaxseed oil powder was fortified in dahi (Indian yoghurt) at three different formulations as 1, 2 and 3%, which could serve as a potential delivery system of omega-3 fatty acids [44].

3. Extruded products: Extrusion cooking technology plays a key role in many food processing industries as a continuous cooking, mixing, shearing and forming process [45]. It can be used to produce a number of foods and feed applications such as snacks, ready to eat cereals, confectionery products and crisp breads. Convenience, value, attractive appearance and particular texture of extruded foods are the main reason of consumer acceptance of these foods [46]. An extruded flaxseed-containing product that can be consumed as a breakfast cereal or snack may encourage consumption of flaxseed and provide health benefits for consumers [47]. Manthey et al. (2008), Sinha and Manthey (2008), Gupta (2012) have developed flaxseed- based pasta which ensures functional properties of flaxseed. Under conditions of 10% flaxseed flour, 230 rpm screw speed, temperature of 90°C and moisture of 12% an expanded snack product with good physical properties can be obtained [48]. Vadukapuram et al. (2014) [49] reported that in extruded bean snack, omega-3 fatty acids and bulk density, improved with increasing concentration of flaxseed (5–20%). With incorporation of 10% flaxseed flour for the preparation of extruded noodles indicated improvement in protein content, but as the level of flaxseed flour increased it shows the negative effect on sensory, color and cooking characteristics of noodles [50].

4. Snack products: A snack is part of the food typically eaten in between meals, but not as a substitute for a meal. Snacks provide considerably less calories than would be consumed in a typical meal. Conventionally, snacks are prepared from ingredients such as cold cuts, fruit, leftovers, nuts and sandwiches, etc. Processed snack foods are convenience food and less perishable than prepared foods. They often contain sweeteners, preservatives, and appealing ingredients such as chocolate, peanuts, and specially-designed flavours (for e.g. flavoured potato chips), flaxseed laddoo [51] (Figure 6). Addition of flaxseed (10%) resulted in an increase of omega-3 fatty acids and protein of wheat chips samples and overall acceptability of chips increased with increase of frying temperature [52]. Addition of reddish-brown flax seeds into snacks enhances texture and gives a superior taste along with a pleasant nutty flavour [53]. Moreover, flaxseeds have a healthy lipid profile which alters the lipid content of snack products and modify omega-3 polyunsaturated fatty acid profile. Thus, it improves the nutritional quality of these snacks and reduces risk of chronic maladies in the community [54]. A snack made with flaxseed and corn showed a sevenfold increase in dietary fiber, 100% increase in protein content and was as acceptable as commercial corn snacks [55].

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Figure 5. Flaxseed Bread

Figure 6. Flaxseed Snack (Laddoo)

Figure 6. Flaxseed Milk

Conclusion:

The presence of several functional and value-added components such as α-linolenic acid, lignans; soluble fibre and proteins, whose effects on the prevention of diseases such as cardiovascular, diabetes, cancer, obesity, gastrointestinal, post-menopausal, renal, colon cancer, inflammation and bone disorders. This review shows that the flaxseed has immense potential for use in various food formulations and flaxseed is utilised as a main food ingredient in order to enhance functional foods. Considering the nutritional benefits flaxseed whole, flaxseed powder, flaxseed oil as well as meal has been used in the development of various food products. Also, the review is available for commercial utilization of flaxseed in preparation of various value-added products (bakery, dairy, extruded, snack, fermented and other traditional).

Future scope:

In future flaxseed gives more benefits like to combat Post-Menopause symptoms in women's. From flaxseed with its nutritional and health benefits, we can formulate more pharmaceutical formulations to treat diseases such as cardiovascular, diabetes, cancer, obesity, gastrointestinal, post-menopausal, renal, colon cancer, inflammation and bone disorders.

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