

***Linum usitatissimum* L. (Flaxseed)–A Multifarious Functional Food**

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Abstract

Flaxseed (*Linum usitatissimum* L.) is one of the world's oldest cultivated crops with evidence dating back thousands of years. Flaxseed is a premium food delivering high performance and is one of the richest sources of ω -3 fatty acids (α -linolenic acid) known to man. Whole flaxseed, flaxseed oil, lignan precursors, and its mucilage have many potential uses in the prevention or treatment of various diseases. Flaxseeds have been classified as functional food because it provides numerous health benefits in addition to serving as a source of nutrients. No doubt flaxseeds are beneficial in several ways but their consumption in excess amounts may result in some side effects such as allergies, oxidation/rancidity, increase in bleeding and bleeding time, elevation of blood sugar levels, deficiency of ω -6 fatty acids and psychological problems. They have also been considered as a good mood food.

KEYWORDS: Flaxseed, ω -3, ω -6 fatty acids, alpha linolenic acid, dietary fiber, lignans

1. Introduction

Flaxseeds are scientifically known as *Linum usitatissimum* L and in *Latinusitatissimum* means 'most useful'. It is a multi-farious crop (El-Beltagi, Salama, & El-Hariri, 2007) and is grown either for the production of oil or fiber (Diederichsen & Richards, 2003; Vaisey-Genser & Morris, 2003; Touré & Xueming, 2010). Flaxseed is also known as linseed and is thought to be one of the oldest cultivated crops with evidence of cultivation dating back thousands of years (Newkirk, 2008). Consumers are returning back to its use due to its multifarious health benefits. Flax is nature's miraculous plant and cures our heart, blood, joints, colon, ageing, brain and even peace of mind.

2. Biology

Flax plant has small, narrow leaves that are less than an inch long. Stems are branched near the base of plant (Figure 1A). The height of plant varies from 30 to 36 inches (Myers, 2002). Flowers are blue colored (Rubilar, Gutiérrez, Verdugu, Shene, & Sineiro, 2010). Flax seeds are flat and oval with pointed tip and their color varies from dark brown to yellow (Freeman, 1995) (Figure 1B). Flax seeds are of two basic varieties – yellow and golden-brown with almost similar nutritional values and equal amount of short chain Omega (ω) - 3 fatty acids.

In the World's food supply, flax is making its mark as a functional food(Tour'e & Xueming, 2010; Singh & Jain, 2011). Flax confers its health benefits due to the presence of α -linolenic acid (ALA), the essential ω -3 fatty acid, and phytochemicals such as lignans(Morris, 2003).

3. Nutritional composition



A

B

Figure 1: (A) Flax plant (B) Flaxseeds

The composition of flax varies with variety, environmental factors and method of analysis (Daun, Barthet, Chornick, & Duguid, 2003). The major nutritional components of flaxseed include oil, viscous lignan-rich fibres (mucilage), protein and minerals. A 100g portion of flaxseed provides 534 Kcal energy and contains approximately 7% carbohydrates, 10% protein, 53% total fat and 21% dietary fat. The nutritional information of flaxseed is given in Figures2, 3, 4 & 5. Flaxseed is high in most of the B vitamins, magnesium (Mg) and manganese (Mn) (Dolson, 2010) and is low in saturated fatty acids, for example cholesterol. About 73% of the fatty acids present in flaxseeds are polyunsaturated fatty acids(Madhusudhan, 2009). Muir, Westcott, & Aubin (1996) and Muir & Westcott (2003) reported that flaxseed contains 40- 50% oil and meal, comprised of 23- 34% protein, 4% ash, 5% viscous fiber (mucilage) and lignan precursors (9 - 30 mg/g of defatted meal).

Flaxseed is a source of good-quality protein and albumins and globulins are the storage proteins of flaxseed with globulins forming the highest portion (58-66% of the total seed protein)(Chung, Lei, & Li-Chan, 2005).

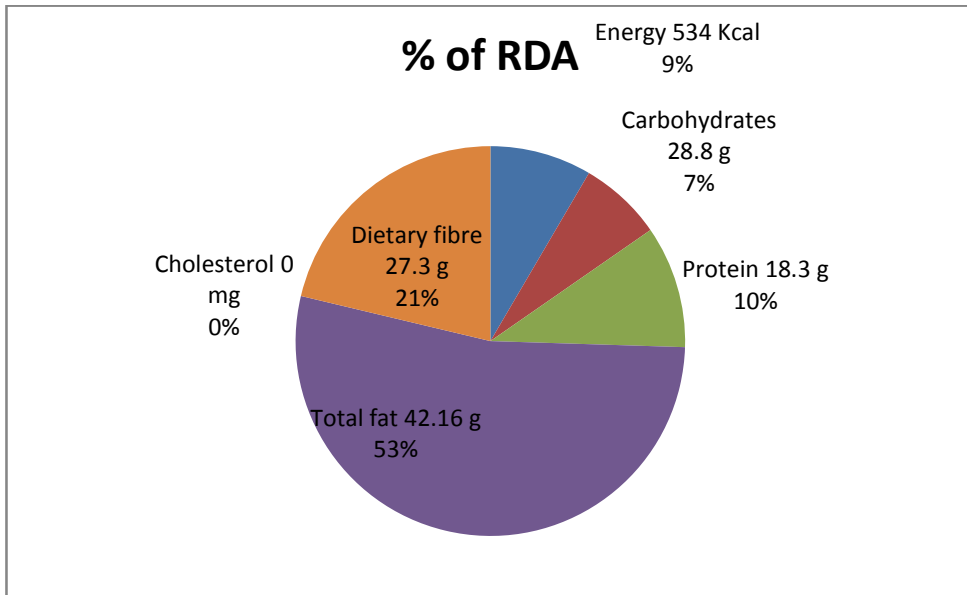


Figure 2: Nutritive value of Flaxseed(USDA, National Nutrient Data Base, 2012)

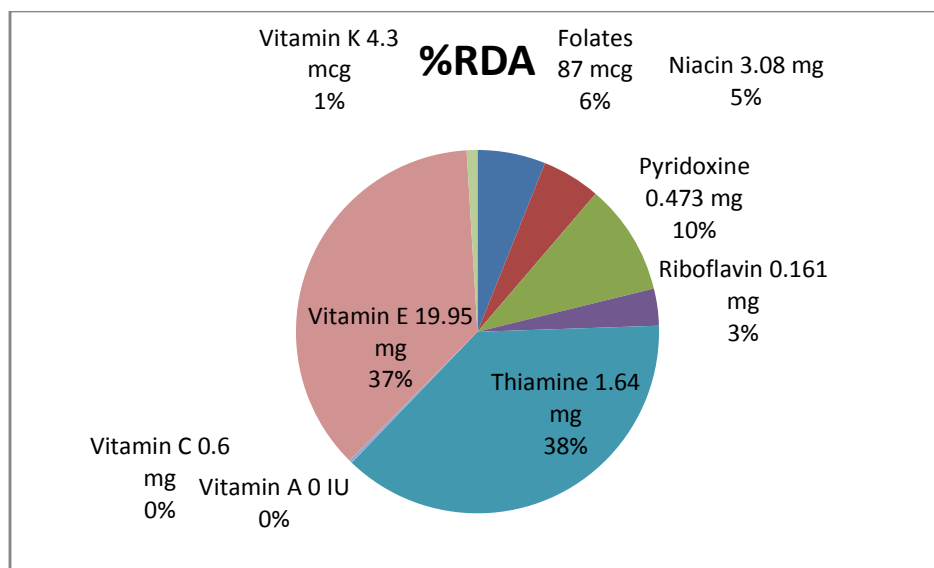


Figure 3: Vitamins in flaxseed(USDA, National Nutrient Data Base, 2012)

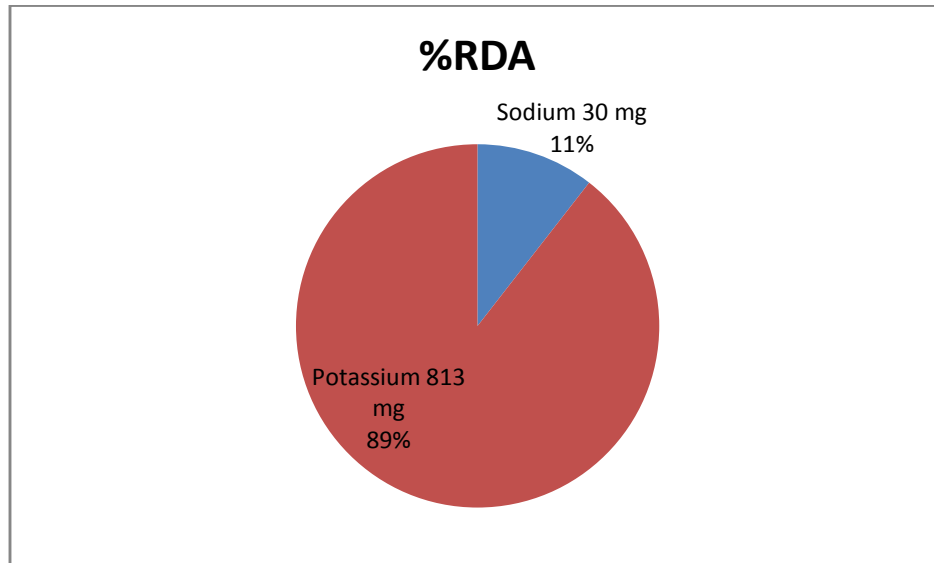


Figure 4: Electrolytes in Flaxseed(USDA, National Nutrient Data Base)

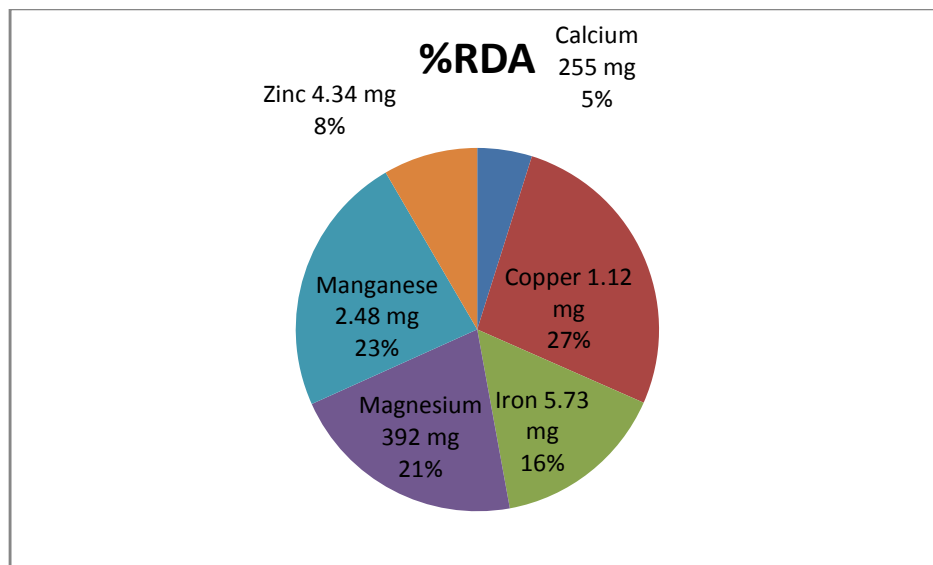


Figure 5: Mineral composition of Flaxseed(USDA, National Nutrient Data Base, 2012)

4. Flaxseeds: a multifarious plant

- **High in ω -3 fatty acids:**Flaxseed is the seed with highest ω -3 fatty acid (α -linoleic acid) content. It contains about 48% of all the lipids and is advisable to be included in a normal diet (Coskuner & Karababa, 2007). Wilkes (2007) stated that as people are becoming aware of the health benefits of ω -3 fatty acids, their demand for ω -3fatty acid rich foods, e.g. flaxseed is increasing day by day.Stahl (2007)demonstrated the potential health benefits as lowering risk of cardiovascular diseases,beneficial for arthritis, eczema and brain development etc.

- **High in dietary fiber:** Flax contains both insoluble and soluble fiber (Morris, 2003). These dietary fibers help to improve laxation and prevent constipation by increasing fecal bulk and reducing bowel transit time (Greenwald, 2001). Water soluble fiber fraction of flax makes about one-third of total dietary fiber and help to maintain blood glucose levels and lower blood cholesterol levels. The main soluble fiber in flax is mucilage gum (Canada, 2003). Stahl (2007) demonstrated the use of flaxseeds in digestion as its intake improves the function of liver and lowers cholesterol level. Incorporation of flax mucilage and α -linolenic acid into the diet reduces cholesterol level of body and regulates blood sugar levels (Lucas et al., 2004; Stahl, 2007) and help to prevent or reduce diabetes (Rubilar et al., 2010). Polysaccharides in flaxseed reduce the risk of various diseases such as lupus, nephritis, arteriosclerosis and hormone-dependent types of cancer (Williams et al., 2007; Bilek, 2009; Rubilar et al., 2010).
- **High in plant lignans:** Lignans are both antioxidants and phytoestrogens. Secoisolariciresinol (SDG) is the main lignan and other lignans including isolariciresinol, pinorexinol, mataresinol and other derivatives of ferulic acid are also present (Daun et al., 2003). *Linum usitatissimum* L. is the richest source of lignin, which contains tens to hundreds times more than most other edible plants. After consuming flax seeds, plant based lignans are converted into mammalian lignans—enterodiols and enterolactone (Morris, 2003). Lignans prevent the development of cancer by blocking certain enzymes involved in hormonal metabolism and interfering with growth and spread (metastasis) of tumour cells (Brooks & Thompson, 2005). In flax, SDG are present at levels 750–800 times greater than any other known crops and vegetables (Westcott & Muir, 1996). Stahl (2007) demonstrated the potential health benefits as lowering heart disease risk, risk of breast, endometrium and prostate cancer, inhibits the development of some types of diabetes (Mueller, Eisner, Yohie-Starck, Nakada, & Kirchoff, 2010).
- **High in phytochemicals:** Flaxseed contains many phytochemicals such as phenolic acids, cinnamic acids, flavonoids and lignins, which are antioxidants and affect the cell growth and viability. These agents protect against cancer and heart diseases (Arts & Hollman, 2005).

5. Flax as a complete functional food

From the past few years, people are becoming more health conscious demanding the food having high nutritional value and the same time conferring health benefits. In this regard, the demand for flax in food and beverages, functional foods and dietary supplements has risen dramatically (Newkirk, 2008). Flaxseed is considered to be a complete functional food due to the presence of α -linolenic acid (Bozan & Temelli, 2008)

6. Health benefits

People have been consuming flaxseed from centuries due to its good flavor and nutritional properties (Newkirk, 2008). The various health benefits associated with the consumption of flaxseeds are given as below:

- **Maintains the health of heart:** Flaxseed confers its health benefits on heart due to the presence of α -linolenic acid (ALA) and ω -3 fatty acid (Bloedon & Szapary, 2004; Madhusudhan, 2009). According to Chen, Power, Mann, Cheng, & Thompson (2007), Waldschläger et al. (2005) and Dupasquier et al. (2007), ω -3

fatty acids regulate gene transcription and expression, thereby altering enzyme synthesis and modify several risk factors for coronary heart diseases, including reducing serum triglycerides and blood pressure.

Due to its nutritional attributes, flaxseed and its components improve cardiovascular health. Flaxseed contains about 35% oil out of which 55% is α -linolenic acid (ALA). Flaxseed with very low ALA, flaxseed oil, flax lignan complex (FLC), and secoisolariciresinoldiglucoside (SDG) reduced the development of hypercholesteromic atherosclerosis by 46%, 69%, 0%, 73%, and 34% respectively, in the rabbit model (Prasad, 2009). He also reported that FLC and SDG slowed the progression of atherosclerosis but does not affect the regression of atherosclerosis. In general, lignan reduces serum total cholesterol, low density lipoprotein (LDL) cholesterol and raises serum high-density lipoprotein (HDL) cholesterol. As flaxseeds are a rich source of lignans, they may prove to be beneficial for reducing the cardiovascular diseases (CVDs). It has been reported by many researchers that dietary flaxseed supplementation prevent hypercholesterolemia-related heart attack and strokes (Prasad, 1997).

- **Reduction of inflammation:** Both the flaxseeds and flaxseed oil possess anti-inflammatory activity (Fitzpatrick, 2008; Mhamunkar, 2009). Atherosclerosis has been identified as an inflammatory disorder and ω -3 fatty acids may be beneficial in preventing inflammatory disorder. Lignans and ALA in flax help to prevent inflammation that affects the body's immune system. A study was carried out by Roy (2007), in which middle aged men were supplemented with ALA and after supplementation, inflammation markers got significantly reduced. Since, flaxseeds are a rich source of ω -3 fatty acids and ALA, these seeds possess anti-inflammatory activity. Dietary fatty acids present in flaxseed gets converted into prostaglandins (a hormone like substance) which are also important for regulating inflammation.
- **Reduction in blood pressure:** ω -3 fatty acids present in flaxseed have been found to regulate transcription and expression of genes, thereby altering enzyme synthesis and modifying several risk factors for coronary heart diseases, including reducing serum triglycerides and blood pressure (Waldschläger et al., 2005; Chen et al., 2007; Dupasquier et al., 2007).
- **Decrease in blood triglyceride:** High triglyceride level in blood is often caused by consuming unhealthy foods. Some of the research studies showed that flaxseed oil has been beneficial for reducing triglyceride levels (Singleton, 2011). Some of the recent studies indicate that ω -3 fatty acids present in flaxseed reduce serum triglycerides and blood pressure. Flaxseed oil is a rich source of ω -3 and ω -6 fatty acids which in appropriate proportions work together to keep inflammation levels at bay in our body. It is also due to the presence of lignans which makes flaxseed useful for preventing and treating various diseases. Prasad (2009) reported that flaxseed oil does not affect serum lipids, except for a slight reduction in serum triglycerides. Some recent studies have shown that ALA lowers C-reactive protein (CRP) – an inflammatory biomarker. (Wilkes, 2007).
- **Induction of blood clotting.** Flaxseed seems to make platelets which improve blood clotting (Flaxseed, 2011). It has also been reported by Jirage (2011) that flaxseed oil reduces the risk of blood clot formation.

- **Control of reproductive function:** Flaxseed oil can contribute to a healthy reproductive system (Ninomiya). Ingestion of about 40 g to 50 g of ground flaxseeds (flaxseed powder) helps in supporting the health of female reproductive organs as well as male prostate gland. A study by Tou, Chen, & Thompson (1998) indicated that 5 or 10% flaxseed or SDG at levels found in 5% flaxseed had no apparent effect on rat dam's pregnancy but exerted reproductive changes in an offspring. Supplementation of 10% flaxseed to pregnant rat dams resulted in an estrogenization as indicated by greater maternal uterine and ovarian relative weights, but it was insufficient to cause impairment in pregnancy.
- **Regulation of sleep/wake cycle:** Insomnia is a common problem in most of the people and mainly its major causes are the conditions such as anxiety, stress and depression. People suffering from insomnia due to stress can sleep well by having flaxseeds. It is the high level of ω -3 fatty acids and tryptophan in flaxseeds which helps in boosting serotonin (sleep regulating compound) levels in blood. Magnesium also helps in overcoming anxiety, stress and depression, thus enhancing sleep. Magnesium exerts its effect by relaxing the nervous system and muscles and overcoming the night terrors (Jyotsna, 2012).
- **Anti-cancerous properties:** After consuming flaxseeds, secoisolariciresinol (SDG) present gets converted into active mammalian lignans - enterodiola and enterolactone, which have the potential to reduce the growth of cancerous tumors, especially hormone-sensitive ones such as those of the cancers of breast (Brzezinski & Debi, 1998; Bruno, 2009), endometrium and prostate (Touré & Xueming, 2010). Lignans have an antioxidant activity and contributed to the anti-cancerous activity of flaxseed (Prasad, 1997; Kitts, Yuan, Wijewickrame, & Thompson, 1999; Yuan, Richard, & Thompson, 1999; Kangas, Saarinen, & Mutanen, 2002). Lignan, enterodiol and enterolactone are believed to be responsible for inhibiting the growth of human prostate cancerous cells (Lin, Awitser, & Demark-Wahnefried, 2001). A study conducted by Morton et al. (1997) indicated that the higher enterolactone levels in prostatic fluid of the populations with a lower risk of prostate cancer. A small clinical study carried out by Demark-Wahnefried et al. (2001) showed that supplementation of 30g of flaxseed per day in men decreased proliferation of cancer cells and increased apoptosis. Craig (1999) reported that flaxseed and flaxseed meal (FLM) decrease the risk of cancer, particularly of mammary and prostate gland. SDG exerts its beneficial effects due to its ability to scavenge \cdot OH radicals (Prasad, 1997). Flaxseeds have been reported to inhibit colon and skin cancers in cell cultures in animal studies (Thompson, 2003; Morris, 2003). A study was carried out by Danbara et al. (2005) in which a dose of 10 mg/kg of enterolactone was injected by subcutaneous injection 3 times per week. The results showed this treatment reduced the expression of colon 201 human colon cancer cells in athymic mice. Using various testing protocols, they concluded that tumor suppression was due to apoptosis and decreased cell proliferation.
- **Fighting menopausal symptoms:** Phytoestrogens present in flaxseed help to reduce menopausal symptoms such as hot flashes (Edwards, 2003). They exert hormonal effects (Hutchins, Maartini, Olson, Thomas, & Slavin, 2001; Rodriguez-Leyva, Bassett, McCullough, & Pierce, 2010). Supplementation of dietary

flaxseed (40 g/day of crushed flaxseed) exert effects similar to that produced by hormone replacement therapy for decreasing menopausal symptoms(Lemay et al., 2002) as well as hot flashes in post-menopausal women not taking estrogen therapy(Pruthi et al., 2007). SDG may alleviate menopausal symptoms(Ruyter, 2012).

- **Regulating menstrual cycle.** Consuming flaxseeds is one of the food choices that help to regulate menstrual cycle due to the presence of lignans (phytoestrogens). These phytoestrogens have weak estrogenic and anti-estrogenic properties which help balance the menstrual cycle (Garvin, 2011).
- **Relieving stress.** Psychological factors have been found to contribute to coronary artery diseases (CAD)(Williams, 2006). ω -3 fatty acids in serum have been associated with variations in mood, personality and behavior in hypocholesterolemic subjects(Conklin et al., 2007). Spence, Thornton, Muir, & Westcott (2003) indicated that flaxseed can ameliorate the rise in blood pressure during mental stress. It was also contented from the results that cortisol levels in plasma were decreased in groups treated with flaxseed.
- **Acne and skin complexion.**Acne is a common problem particularly with the teen agers. Inflammation is considered to be one of the causes of acne formation. As flaxseed, due to the presence of ω -3 fatty acids, are beneficial for reducing inflammation; therefore, they may also help to reduce acne formation by acting as an anti-inflammatory agent. Flaxseeds also help to restore the healthy balance in body and may improve acne(Stephanie, 2009; Uzoma, 2011). Lignans in flaxseeds inhibit 5- alpha-reductase, an enzyme involved in the conversion of testosterone to DHT (its more active form). In other words, it can be said that it helps to balance the androgens production, which if released in excess, can cause acne. Essential fatty acids also strengthens the skin's cell membranes, thereby hydrating the innermost layers of skin which makes skin less susceptible to hormonal fluctuations and more resilient to infection(Stephanie, 2009).
- **Alleviation of pre-menstrual symptoms (PMS):**The presence of α -linolenic acid makes flaxseed useful in alleviating the PMS. Phytoestrogens present in flaxseed helps in regulating the heavy periods by balancing estrogen levels in body. Flaxseeds also reduce the breast pain associated with menstruation but not sufficient scientific evidence is there to support (Kent, 2011), but Burns (2011) reported that lignans in flaxseeds may be responsible for reducing breast pain.However, flaxseed oil is not effective because lignan are only present in hull of flaxseed. Mood swings are frequent problems associated with PMS which can be averted by eating flaxseeds.
- **Constipation, diverticulitis and irritable bowel syndrome (IBS):**Flaxseeds being a rich source of dietary fiber soften the stool and increase the weight and size of stool, which is easier to pass. As a result less pressure is placed on existing haemorrhoids and decreasing constipation and developing haemorrhoids. Also, soluble fiber improves symptoms of IBS such as constipation, abdominal pain and diarrhoea.
- **Anti-lupus properties.** According to Bruno (2010), flaxseeds may inhibit inflammatory mechanisms and modulate blood fats in autoimmune diseases, lupus

nephritis. Clark et al. (1995) carried out a trial in which they fed nine people with kidney damage due to systematic lupus erythematosus (SLE) with increasing amounts of flaxseed for a total of 12 weeks. It was contended from the results that 30 g per day was the optimal intake for improving kidney function, reducing atherosclerosis development and decreasing inflammation. Antioxidants present in flaxseeds potentially help with SLE(Prasad, 1997).

7. Flaxseeds as good mood food

Good mood foods are considered as a panacea for life as they are key for stress management of life. They help us to feel happier and more energetic which may be helpful to overcome the stress, depression and anxiety. Certain neurotransmitters like serotonin, dopamine level enhancing foods; ω -3 fatty acids, niacin, folic acid, magnesium, selenium, phenylalanine and tyrosine, tryptophan containing foods can help us in stress condition and make mood happy. Flaxseeds are one of the best examples of good mood foods that can be very easily incorporated into daily diets to fight against the stress as they have abundance of ω -3 fatty acids, ALA, Mg and vitamin B complex. Flax seeds are the richest source of ω -3 fatty acids in the plant kingdom and are good brain foods (Carter, 2010). Therefore, it can be a better choice for vegans to use flax seed oil as replacer/substitute or equivalent fat of fish oil(Thakur, Pandey, & Jain, 2012).

8. Toxicity

Flaxseed is undoubtedly a highly nutritious whole grain and is believed to confer several health benefits to humans after consumption. But, toxicity may occur if consumed in excess amounts (Kelley, 1999). Presence of cyanogenic compounds and cadmium in flaxseed is a concern. Heating destroys these cyanides but the healthy fats in flaxseeds are also destroyed (Novick, 2009). If the flaxseeds are consumed raw, it may raise the level of a toxic chemical, cyanide in blood. However, toxicity has not been reported if flaxseed is prepared properly and used at the recommended dose (Wolf, 2010).

9. Safety and side effects of flaxseed

For most of the people, flaxseeds are safe. However, there are side effects associated with its consumption which include gastrointestinal side effects such as bloating, gas, constipation, abdominal pain, diarrhea, stomachache and nausea. Even more side effects are likely to occur, if flaxseeds are consumed in higher doses. There are reports that people who consumed flaxseeds in high doses developed minor but annoying side effects such as stomachache, flatulence and diarrhea(Aguecheek). These side effects are due to laxative effects of flaxseeds(Wolf, 2010). The four major potential issues associated with flaxseed consumption are:

- i. Allergies.** Hypersensitivity reactions to flaxseed following occupational exposure have been reported(Collaboration, 2012). Allergic reactions such as any signs of bleeding and severe constipation or an intestinal blockage may result by consuming flaxseeds(Monson, 2008).
- ii. High fiber load.** Since the fiber content of flaxseeds is quite high, it is, therefore, advisable, first start with a small amount and then the quantity to be increased slowly, otherwise, cramping and laxative effect can result. People suffering from irritable bowel syndrome (IBS) should be careful as they may suffer from strong reactions due to consumption of flaxseeds (Dolson, 2010).
- iii. Oxidation/Rancidity.** Flaxseeds being high in unsaturated fatty acids are susceptible to oxidation and thus rancidity. Flaxseed oil is more susceptible to

oxidation than whole flaxseeds because later is protected by a natural storage system. Flaxseed oil must be stored in a dark bottle under refrigeration system for keeping it from rancidity. No doubt flaxseeds are high in unsaturated fatty acids but they do not undergo rancidity as quickly as we would think. This is because flaxseeds also contain high amount of antioxidants(Dolson, 2010).

- iv. **Cyanide.** Flaxseeds contain very small amount of cyanide, especially when consumed raw. When flaxseeds are heated, cyanide compounds are broken down. Human body is, however able to neutralize certain amount of these compounds. According to U.S government agencies, 2 tablespoons of flaxseed is certainly safe and is probably an “effective dose” for conferring health benefits (Dolson, 2010).
- v. **Increasing bleeding and bleeding time.** ω -fatty acids may slow the formation of blood clots and increase bleeding. Therefore, those who are taking blood thinning medications like Coumadin or aspirin, or similar other herbal remedies like *Ginkgo biloba* and saw palmetto, should consult their doctor before adding flaxseeds to their diet(Aguecheek). People having bleeding disorders are advised to be cautious or refrain from using flaxseed products(Wolf, 2010).
- vi. **Deficiency of ω -6 fatty acids.** Consuming flaxseeds in high doses, in the absence of other fat sources, can lead to an ω -6 fatty acid deficiency, which might cause some health problems.
- vii. **Elevation of blood sugar levels.** It is advisable to people suffering from diabetes to consult their doctor before consuming flaxseed products, because ω -3 fatty acids in flaxseed oil may elevate blood sugar levels(Wolf, 2010).
- viii. **Psychological problem.** Taking flaxseeds or flaxseed oil orally may cause a person with bipolar disorder to experience mania or hypomania (Wolf, 2010).

10. Anti-nutritional factors in flaxseed

Despite several health benefits and a good source of nutrients, flaxseed has been questioned as a food due to the presence of number of factors that interfere with the normal development of humans and animals (Dan, 2010). Flaxseed contains toxic cyanoglycosides (limarin), vitamin B6 antagonist factors and other anti-nutritional factors including cyanogenic glycosides (Bhatty, 1995; Hall, 2006; Udenigwe & Aluko, 2011), trypsin inhibitors, phytic acid, allergens and goitrogens which limit its use as a human food.

11. Consumption of Flax

Flaxseed can be incorporated into diet through oil, milled or ground flaxseeds or through eggs, meat produced by animals fed flax meal (Vaisey-Genser & Morris, 2003). The seeds are now widely used as bakery ingredient and have gained popularity in many countries (Fitzpatrick, 2007). The ground flaxseeds should be stored in an airtight opaque container and refrigerated or frozen. The refrigerated ground flaxseed should be used within 30 days. One table spoon of ground flax per serving can be incorporated into morning hot cereal after cooking. We can also sprinkle ground flax over a salad, cooked vegetables or cold breakfast cereals (Singh & Jain, 2011).

12. Recommended dose

Flaxseeds are approved on 12% ‘no objection basis’ by Food and Drug Administration (FDA) for inclusion in foods (Plumb, 1983). Flaxseed should be ground prior to use and

even the roasted flaxseeds can be enjoyed directly or sprinkled over cereal, yoghurt and other foods or can be even used in baking. If a person decided to start intake, it is important to note that one should eat it into the diet slowly. It is recommended to take 1-2 tablespoons ground flaxseed or 1 tablespoon of flaxseed oil daily (Fayed, 2008). In studies where the product was used in baked goods for treating high-cholesterol or menopause symptoms, doses of 40 - 50g were used daily (Monson, 2008). National Academy of Sciences has established daily requirement of 1600 mg of ALA for men and 1100 mg for women older than 19, though no such requirement has been established for eicosapentenoic acid (EPA) and docosahexanoic acid (DHA) (Wertheim, 2011).

13. Applications of flaxseeds in food industry

Food and Drug Administration (FDA) has approved flaxseed on a “no objection basis” to be included in food (Carter, 1993; Plumb, 1983). Based on an evaluation of the situation by FASEB, “no objection” status of flaxseed is adequate for now regardless of the fat that flaxseed and cold pressed flaxseed oil do not have Generally Recognized as Safe (GRAS) status (Carter, 1992). With increasing consumer consciousness, the demand for nutritious and health promoting foods is increasing at a faster pace. Flaxseed being a rich source of nutrients and possessing numerous health benefits, it finds its use in various food product formulations (Mantri, Sonavane, & Arya, 2012). Considering their nutritional benefits; flaxseeds whole as well as an ingredient has been used in the development of various food products discussed as:

- **Flaxseed chutney powder (FCSP).** Flaxseed is used for the preparation of flaxseed chutney powder (FCSP), a palatable functional food adjunct. FCSP is prepared by mixing roasted and powdered flaxseeds with other selected spice ingredients. The composition of flaxseed powder (FSP) and flaxseed chutney powder (FCSP) is given in table 1.

Table 1 Composition of flaxseed powder (FSP) and Flaxseed Chutney Powder (FCSP)

S. No.	Parameter	Amount	
		FSP	FCSP
1.	Protein	24.2%	23.4%
2.	Total polyphenol	439 mg/100g	522 mg/100g

Source: Mantri et al., 2012

- **ω -3 rich energy bar with flaxseed.** A nutritious energy bar utilizing flaxseed in its formulation has been developed. It contains cereal (white oats), pulses (roasted Bengal gram) and legumes (soy protein) with varying levels of sweeteners (45%, 50 and 55%) to deliver a nutritious health product (Mantri et al., 2012).

The composition of energy bar with flaxseed is given in table 2.

Table 2 Composition of energy bar with flaxseed

S. No.	Parameter	Amount
1.	Protein	12.41%
2.	Crude fat	11.86%
3.	Ash	1.65%
4.	Iron	3.77 mg/100g
5.	Crude fibre	2.18%

6.	Omega-3 as α -linolenic acid	22.50%
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Source: Mantri et al., 2012

- **Flaxseed gums.** Carter (1993) reported that flaxseed gum has been used for the following purposes:
 - to enhance viscosity (best at pH 6-8)
 - to aid in foam stability at 1% (w/v), comparing favorably with ovalbumin
 - to increase absorption in bread while improving loaf volume, oven spring and keeping quality
 - to significantly improve objective and subjective bread characteristics
 - to affect shear rate as gum arabic does
 - show promise as “food thickener” and “improving agent” in baked goods
- **Baked goods.** Ground or whole flaxseed can be added to almost each baked product and add a nutty flavor to bread, waffles, pancakes, and other products if it composes 6-8% of dry components of the recipe or formula (Carter, 1993). Flaxseed flour is used in breads and are also used commercially in muffin, cookie, and other mixes. Addition of ground flaxseed and ground whole wheat may improve the neutral flavor of pancake and waffle mixes (Carter, 1993).

14. Future aspects and conclusion

Consumer demand is increasing day by day for nutritious and health promoting foods. Flaxseed has an immense potential for use direct or in various food formulations as a complete functional food. Flaxseeds are not only the source of carbohydrates and oil but are also a key factor in one’s diet due to the presence of many protective factors such as ω -3 fatty acids, dietary fibers, lignans and phytochemicals in the whole seed. Despite being a better source of nutrients and demonstrated health benefits, flaxseeds are not being consumed by many people. Recently there has been resurgence in the use of flaxseeds. People should be encouraged to consume flaxseed as it confers numerous health benefits besides being nutritionally sound. Flaxseeds if consumed in excess amounts may result in several side effects. Many options exist to including flaxseed into the diet such as adding ground flaxseed cereal, yogurt or sprinkling it on salads, as well as baking with it. Therefore, flaxseeds are a promising nutraceutical and a repository of medicinal benefits.

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