IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

A REVIEW ON FLAXSEED FOR THE HEALTH AND DISEASE PREVENTION PERSPECTIVES

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ABSTRACT

Flax seed (Linum usitatissimum) is an essential oilseed crop that has grown in popularity in recent decades due to its unique nutritional profile. Flaxseed is high in α-Linolenic Acid (ALA), an omega- 3 fatty acid, protein, dietary fibre, and lignan, especially Secoisolariciresinol diglucoside (SDG). Several studies have shown that these components are beneficial to human nutrition. Flaxseed has a major impact on human nutrition because it contains active compounds that have been associated with positive health outcomes, making it a crucial functional dietary item. Scientific data supports flaxseed use; nonetheless, a considerable portion of the population is still uninformed of the advantages connected with its consumption and its potential usage as a functional food element in cuisines. Flaxseed is well recognised for its high alpha-linolenic acid content, but it also contains lignans, soluble fibre, and protein, all of which are physiologically active in the prevention of some non-communicable chronic illnesses. Flaxseed dietary fibre has been shown to help relieve constipation, maintain regular bowel movements, and act as a hypocholestermic agent. SDGs contain antioxidant and free oxygen radical scavenging properties. As a result, it may possess anticancer properties. Flaxseed contains anti-nutrients such as cyanogenic glycosides and linatine. Flaxseed has a far lower anti-nutrient effect on human health than soyabean and canola. Accordingto the researchers, flaxseed-infused food items can have excellent customer appeal as well asnutritional advantages.

Key Words- α-Linolenic Acid, Secoisolariciresinol diglucoside, hypocholestermic agent, cyanogenic glycosides

INTRODUCTION

In recent decades, the possible health advantages of particular foods and food additives haveincreased consumer interest in healthy eating. In actuality, food isn't just meant to state hunger. And to meet consumers' basic nutritional needs, as well as to prevent diseases associated with poor nutrition and improve their physical and mental health [1].

Functional foods have a significant impact on the relationship between diet, health, and well-being. There are numerous definitions of "functional foods" throughout the world, but none are official or widely acknowledged. The term "functional food" refers to a food or a dietary element that mayhave physiological advantages and aid in the treatment or prevention of disease [2].

Flaxseed is establishing importance in the world's food chain as a functional food. Flaxseed is a high-potential functional food with the availability of essential nutrients such as alpha-linolenic acid,lignans, high-quality protein, soluble fibre, and phenolic compounds. Because of its very high level of alpha-linolenic acid (ALA), dietary fibre, high-quality protein, and phytoestrogens, it has developed as an attractive nutritious meal [3]. Flaxseed is consumed in whole grain, oil, milled, or ground form. And it provides around 55% ALA, 28- 30% protein, and 35%fibre. Flaxseed has new prospects as a functional food right now, thanks to consumer demand for foods with superior health advantages. Because of its good nutritional profile and promised health benefits, it has become a popular element in diets designed specifically for certain health benefits [4]. Flaxseed is becoming more and more popular as a functional dietary component in recent years, due to advancements in scientific study.

Figure 1: (A) Flaxseed plant
(B) Flax seed

Flaxseed, often known as linseed or Linum usitatissimum, is a member of the Linaceae family and belongs to the genus Linum. In Indian languages, it is commonly known as Alsi, Jawas, and Akse bija. Linum is derived from the Latin word lin, which means "thread," and the species name"usitatissimum". Linum angustifolium, assumed to be the progenitor of flax/linseed, is supposed to have originated in the Mediterranean region, which may have been the source of origin [5

LITERATURE REVIEW

Hair gel is a hairstyling product that is used to harden hair into a particular hair style. Herbal hair gels are primarily products aimed at cleansing the hair, promoting the hair growth and preventing hair loss. In the modern scenario, marketed goods contain silicon and chloride, which cause hair damage, hence herbal hair gels are recommended. Herbal hair gels help to retain moisture and nourish the hair, resulting in healthier hair development. It also helps to overcome the various damages caused by chemical agents in various marketed products. The present paper emphasizes on composition, types, methods of evaluation, also a brief review on herbal hair gel formulations.

- **Ramakrishna S. et al. (2022),** formulated a herbal hair gel using Guar gum and Jatamansi. The gel was formulated in two processes. First, the powdered rhizome of Nardostachys jatamansi
was extracted with alcohol using reflux condensation. Second, guar gum powder was triturated with water until a gel consistency is formed. The formulation was evaluated for varies physical parameters like pH, viscosity, spreadability, homogeneity, stability studies, skin irritation and washability [6].

- **R. Abiyarasu et al. (2022),** formulated a polyherbal hair gel using extract of gauva leaves, amla and aloe, which is effective in treating Candidiasis. By using maceration extraction method,
phytochemical extract of Psidium guajava was obtained. Gauva leaves extract was evaluated by Cup and plate method against the fungus C. albicans and bacteria S. aureus. Evaluation of organoleptic properties and physicochemical tests were performed and compared with herbal marketed product and considered as safe [7].

- **Poonam Madan et al. (2021),** developed a hair pack using selected drugs such as Amalki, Bibhitaki, Haritaki, Japa, Yashtimadhu, Musta, and Brahmi and converted it into a gel form to provide significant result in controlling dandruff and its associated symptoms and modified

dosage. The prepared formulations were evaluated for organoleptic properties, physicochemical parameters such as pH, Viscosity, Homogeneity, Spreadability Test, Skin Irritation Test, TLC, Microbiological Test and clinical study which was compared with the marketed products [8].

- **Arunadevi Birajdar et al. (2021),** formulated safe medicinal formulations from herb Abrusprecatorius for the purpose of treatment of alopecia and antimicrobial activity, prepared by soxhlet extraction method. The current investigation was carried out to evaluate the hair growth enhancing potentiality of aqueous extract of Abrusprecatorius leaf. The prepared herbal hair gel was evaluated for organoleptic properties, physicochemical parameters, anti-microbial and anti- lice activity, which was compared with the marketed products [9].

- **Tamsheel Fatima Roohi et al. (2021),** formulated a polyherbal hair gel and evaluated for standardization of polyherbal extract obtained from berries and flaxseed by qualitative phytochemical analysis, physicochemical analysis, Fourier transform infrared spectroscopy, UV analysis, thin layer chromatography. The maceration method is used for performing the extraction and plant-based edible polymer Acrypol 934 P for the preparation of the polyherbal ethyl acetate extract and its gel-based formulation. Different phytochemical tests andphysicochemical evaluation procedures were followed for standardization of extract and afterwards gel formulation [10].

- **Megha Jain et al. (2020),** formulated a polyherbal hair gel using hydro-alcoholic extract of Triticum aestivum Linn. (Wheat grass leaves), Mentha piperita Linn. (Leaves), Moringa oleifera Lam. (Leaves), Punica granatum Linn. (Fruits), Eclipta alba Linn. (Leaves) and Murraya koenigii (L.) Spr. (Leaves), prepared by hydro-alcoholic extraction method. The extract of these herbs were taken for formulation of polyherbal hair gel using Carbopol 934, which was further evaluated for its efficacy. The formulation was evaluated for varies physical parameters like clarity, viscosity, extrudability, pH, etc. PHGG-3 formulation was found to be suitable as compared to other tested PHHG [11].

- **Mr. Maharu Shamrao Bhil et al. (2020),** formulated a hair setting gel by using Onion oil and Beheda extract, which was prepared by using the distillation process using alcohol as a solvent.
The formulations were evaluated for organoleptic properties, physiochemical parameters such as pH, viscosity, spreadability, washability, homogeneity, skin irritation test and consistency which was compared with the marketed products [12].

- **Goswami Anindya et al. (2019),** developed a hair gel formulation with Black pepper (Piper nigrum), Hibiscus leaves extract and Ziziphus jujuba leaves extract for its antibacterial activity which makes it beneficial against dandruff and scalp infection, prepared by soxhlet extraction method using ethanol as a solvent. The formulations were evaluated for physicochemical parameters such as pH, spreadability, homogeneity, viscosity, and skin irritation [13].

- **Sarukh Vikram S. et al. (2019),** formulated a herbal hair gel containing Allium cepa extract, prepared by microwave assisted extraction method. The prepared herbal gel was further evaluated for pH, Homogeneity, Appearance, Spreadability, Viscosity, In-vitro diffusion study.
The gel formulation F3 was found to have good all above desirable properties. It was concluded that Allium cepa

herbal gels can be successfully prepared by using a polymer which made thegel and prepared gel shows better application property [14].

- **D. Manjula et al. (2018),** formulated a herbal gel of flaxseed for the purpose of moisturizingand nourishing the hair. Four different types of gel formulations containing carbopol 934 in varying concentrations ranging from 0.5 to 2% were prepared and evaluated. The evaluation of all the formulations (F1 to F4) were done on various parameters like physical appearance, pH, viscosity, spreadibilty, extrudability, homogenity, grittiness and stability. Among the four formulation, F4 showed good spreadabilty, consistency, homogeneity, appearance, optimumviscosity, pH and was stable for long period of time [15].

- **Arpan Chakraborty et al. (2016),** formulated a hair growth gel formulation containing extractsof Hibiscus rosa sinensis flower 1%, Eclipta alba whole plant 1% and Solanum nigrum plant berries 0.5% which was preferably used in the case of Alopecia. Shade-dried powdered berriesof Hibiscus rosa-sinensis and Solanum nigrum were extracted with methanol by cold maceration,while Eclipta alba was extracted with petroleum ether extract by cold maceration. The formulated gel was evaluated for parameters such as pH which was found to be 6.68, viscosity of4731 cps, and spreadability of 11.05 (g-cm/sec) whereas consistent homogeneity was found with no skin irritation [16].

History of flaxseed

Flax is the oldest agronomic crop, with over 300 kinds that have been farmed for food and fibre since ancient times. Studies reveal that it is not only a portion of nutritious food, but that it also has therapeutic benefits, both preventative and curative. It has been growing since the dawn of civilization, according to records, and people all around the world have praised its utility over the ages [17]. Flaxseed, which originated in Mesopotamia, has been grown since 5000 BC and was primarily utilized for the fabrication of cloths (linen) and paper until the 1990s [1]. History claims that the Babylonians first grew flax seed about 3000 B.C., and artefacts from their tombs show them growing flax and making garments from its fibres. Ancient Egyptian tombs have been discovered to contain linen made of flaxseed. In ancient Egypt, linen was used to wrap the royal mummies and linseed oil preserved the dead Pharaohs' corpses. Meanwhile, flax was used to make the clothing of the Jewish high priests in the Old Testament [17,18]. Hippocrates (650 B.C.) spoke about using flaxseed to relieve digestive discomfort, while Theophrastus advised flaxseed mucilage as a cough treatment (in the same era). Tacitus praised the advantages of flax around the beginning of the first century (A.D). It has been documented that flaxseed was so important for the health of Charlemagne's (the 8th-century king's) subjects that he created laws and regulations governing its use. Later in the 15th century (A.D), Hildegard Von Bingen utilized flaxseed meals in hot compresses to treat diseases. It has been long used in many aspects of Greek, Roman, and Egyptian daily life [19]. Furthermore, it is now primitive to a broad area that extends from the Mediterranean region to India. Flax is primarily grown for fibre in western Eurasia, while it is primarily grown for oil in eastern Eurasia [17].

Flaxseed oil and its derivatives are utilised in animal feed. The use of flaxseed in human diets has expanded globally over the last two decades. The terms flaxseed and linseed differ slightly. Flaxseedis a term used to describe flax when it is consumed as food by people, whereas linseed is a term usedto describe flax when it is used in

industry and as feed [20]. Flaxseed has received considerable attention in the field of food and disease research during the last two decades due to the potential health advantages linked with certain of its biologically active component. Its growing popularity is due to its health benefits, which include lower risk of cardiovascular disease, lower risk of cancer, notably of the breast and prostate glands, anti-inflammatory action, laxative impact, and relief of menopausal symptoms and osteoporosis [21].

It has grown in several regions of the world, including Canada (35%), Argentina (21.8%), China (18.9%), India (13.8%), and the United States (11.3%). The world's top flax grower and source of approximately 80% of the world's flaxseed commerce are Canada, which produced 614,000 metric tonnes of flaxseed in 2013–2014 [1]. Flax seeds have been used as food for almost 6,000 years, and they may have been the first superfood to be farmed on earth. Flax seed is grown all over the world for fibre, oil, medical purposes, and as a nutritional commodity [22,23].

India is the largest flaxseed-producing country in terms of acreage, accounting for 23.8% of the total, and third in production, accounting for 10.2% of global production. It's fascinating to learn thatflaxseed originated in India and was a staple food crop. Flaxseed is still eaten as a meal in India, as well as for medicinal purposes. It is mostly grown in Madhya Pradesh, Maharashtra, Chhattisgarh, and Bihar in India [24]. Although it is predominantly produced for oil in India, a limited amount of flax is also farmed for fibre in temperate highland regions like Himachal Pradesh. Several cultivars such as Sheela, Sweta, Garima, Sharda, Rashmi, Shikha, Padmini, Shekhar, Neelam, LC-2063, and LC-2023 have been produced for oilseed and fibre flax in India [25].

Botanical description of flaxseed

Flaxseed is a diverse crop. Flaxseed is viewed as a potential functional food component since it offers several health benefits in addition to its nutritional value. Flaxseed are derived from a blue- blooming annual plant of the Linaceae family. The leaves of the flax plant are short, thin, and less than an inch long. Near the plant's base, the stems are branched. From 12 to 40 inches in height, flax plants can grow. The plant has a thin, fibrous stem, and its vivid blue blossoms can reach a diameter of 3 cm. The five-petalled blooms are arranged into a five-celled ball that may hold up to 10 seeds. Till the plant's growth finishes, it will continue to bloom. The spherical fruit capsules carry twoseeds in each of their five compartments [26]. Flaxseeds are flat and rounded. Their form is oval witha pointed tip, and inside are two embryos and an embryo axis, as well as a seed coat (also known asa testa). It has a shiny, smooth surface. Additionally, their colours range from dark brown to yellow. Flaxseed has a crisp and chewy texture with a lovely nutty flavour. Flaxseed is distinguished by its variety or by its colour (brown and yellow). Brown flaxseed is the most common and contains the most alpha-linolenic acid, while yellow flaxseed comes in two varieties: Omega and Linola [27]. The nutritional value of brown and yellow or golden kinds of flaxseed is essentially the same. The amount of pigment present controls the colour of the seed coat, which can be altered through standard plant breeding procedures [26].

Figure 2: Brown flaxseed, Yellow or Golden flaxseed.

There are some distinctions between the brown and gold varieties of flaxseed. The golden kind of flaxseed has more soluble carbohydrates than the brown version, but less fibre. Omega-3 andomega-6 content in golden flaxseed are higher, but antioxidant activity in brown flaxseed is higher. Flax has healing properties because it contains alpha-linolenic acid (ALA), an essential omega-3 fatty acid, as well as phytochemicals such as lignans [28].

Chemical composition of flaxseed

About 40% of the seed is made up of lipids, 30% is dietary fibre, and 20% is protein. The elemental composition varies greatly between types and is also influenced by the environment in which the plant is cultivated. In a study, brown Canadian flaxseed had average values of 41 per cent fat, 20 per cent protein, 28 per cent dietary fibre overall, 7.7 per cent moisture, and 3.4% ash. The protein content of the seed decreases as the oil content increases [29]. According to its physicochemical constitution, flaxseed is a multi-component system that contains bioactive plant materials such asoil, protein, dietary fibre, soluble polysaccharides, lignans, phenolic compounds, vitamins (A, C, F, and E), and minerals (P, Mg, K, Na, Fe, Cu, Mn and Zn). Table 1 illustrates the composition of flaxseed [28].

Table 1 Chemical composition of nutrient and phytochemicals in flaxseed.

S.No.	Nutrients/bioactive compounds	Quantity/10 0g of seed	S.NO.	Nutrients/bioactive compounds	Quantity/10 0g of seed
1.	Energy	450 Kcal	15.	Biotin	6 mg
2.	Protein	20.0 g	16.	Carotenes**	Not detected
3.	Carbohydrates*	29.0 g	17.	α-Tocopherol **	7 mg
4.	Total fats	41.0 g	18.	δ-Tocopherol**	10 mg
5.	Linolenic acid	23.0 g	19.	γ-Tocopherol**	552 mg

6.	Dietary fiber	28.0 g	20.	Calcium	236 mg
7.	Lignans	10-2600 mg	21.	Copper	1 mg
8.	Ascorbic acid	0.50 mg	22.	Magnesium	431 mg
9.	Tiamin	0.53 mg	23.	Manganese	3 mg
10.	Riboflavin	0.23 mg	24.	Phosphorous	622 mg
11.	Niacin	3.21 mg	25.	Potassium	831 mg
12.	Pyridoxin	0.61 mg	26.	Sodium	27 mg
13.	Pantothenic acid	0.57 mg	27.	Zinc	4 mg
14.	Folic acid	112 mg			

Table adapted from reference [28].

*Values include dietary fiber.

**Values in mg/kg of flaxseed lipids.

Omega-3 Fatty acids

The best plant source of omega-3 fatty acid, or α-linolenic acid, is flaxseed (ALA). The amount of saturated fatty acids in flaxseed oil is low (9%), the amount of monounsaturated fatty acids is moderate (18%), and the amount of polyunsaturated fatty acids is high (73%). A good n-6: n-3 fatty acid ratio of around 0:3:1 is delivered by the 30% of lipids in flaxseed that are composed of α- linolenic acids (ALAs), 17% linoleic acids (LAs), 19% oleic acids, 3% stearic acids, and 5% palmitic acids [30]. The seed may therefore be a substitute for providing this fatty acid to people concentrated in regions of the world where marine foods, which are the best sources of n-3 fatty acids, are hardly available. The two categories of omega fats are omega-3 and omega-6 fatty acids. There are three forms of omega-3 fatty acids (α-linolenic acid), eicosapentaenoic acid (EPA), and docosahexaenoic acid that are crucial for nutrition. It has been demonstrated that all three fatty acids lower the risk of cardiovascular disease [5].

Table 2 Fatty acids content of flaxseed oil.

S.NO.	**Parameters**	**Percentage (%)**
1.	Saturated fat	9.0
2.	Monounsaturated fat	18.0
3.	α-linolenic acid (omega-6-fatty acid)	16.0
4.	α-linolenic acid (omega-3-fatty acid)	57.0

Table adapted from reference [28].

Due to their biological actions, omega-3 fatty acids help prevent and treat chronic illnesses suchas type 2 diabetes, renal disease, rheumatoid arthritis, high blood pressure, coronary heart disease, stroke, Alzheimer's disease, alcoholism, and some kinds of cancer. Additionally, it may aid in preventing some infections and treating conditions such as emphysema, psoriasis, preterm labour, glaucoma, Lyme's disease, lupus, ulcers, migraine headaches, eating disorders, attention- deficit/hyperactivity disorders, and panic attacks [31].

Protein

Flaxseed contains 20 to 30% protein, which is made up of 80% globulins (linin and Conlin in) and 20% glutelin. Globulins, which make up 58–66% of the total protein in flaxseed, are the mainstorage proteins. The amino acid composition of flaxseed is similar to that of soybean. Gluten is not present in flax. Gliadin, a substance high in the amino acids proline and glutamine, is the particular component of gluten that causes the illness known as "celiac disease" [32]. Whole flaxseed, flaxseed meals, and separated proteins are excellent sources of glutamic acid/glutamine, arginine, branched- chain amino acids (leucine and valine), and aromatic amino acids (tyrosine and phenylalanine). Arginine, aspartic acid, and glutamic acid are very rich in flaxseed proteins, but lysine is limited. High quantities of cysteine and methionine increase antioxidant levels, which lowers the risk of cancer [22]. Flaxseed's high plant protein concentration is important, especially in light of recent claims that plant proteins may lower blood cholesterol levels. It is yet unknown how flaxseed protein works. Flaxseed protein is regarded as a minor quality characteristic [33].

Dietary fibres

Compared to many legumes (5-10% of cooked food), flaxseed has more dietary fibre (18%), whichis made up of both soluble (25%) and insoluble fibre (75%). Due to the presence of mucilage in the outer layers of the seed, flaxseed occupies a special position among oilseeds. Flaxseed mucilage has gained popularity as a result of its numerous health advantages and potential functional qualities. Flax mucilage and α -linolenic acid is nutrients that can help to prevent or manage diabetes by lowering blood sugar levels [34,35], lowering cholesterol levels, and regulating blood pressure. It contains 35–45% fibre, of which 2/3 is insoluble and 1/3 is soluble. Lignin, cellulose, and hemicellulose make up insoluble fibre. The mucilage of the seed coat appears to make up the majority of the soluble fibre in flaxseed. It makes up approximately 7–10% of the weight of seeds. Mucilage gums, which make up the majority of soluble dietary fibre, are crucial in reducing blood cholesterol levels and improving insulin sensitivity, among other things [36].

Table 3 Dietary fiber content of flaxseed.

S.NO.	Dietary fiber component	Gram per 100gm of flaxseed
1.	Total dietary fiber	40
2.	Soluble fiber	10
3.	Insoluble fiber	30

Table adapted from reference [3].

Phenolic compounds

In general, phenolic acids, flavonoids, and lignans are the three types of phenolic chemicals found inflaxseeds. Ferulic acid (10.9 mg/g), chlorogenic acid (7.5 mg/g), and gallic acid (2.8 mg/g) are the main phenolic acids found in defatted flaxseed. Other phenolic acids that are found in small amountsinclude 4-hydroxybenzoic acid, p-

coumaric acid glucosides, and hydroxycinnamic acid glucosides. The primary flavonoids present in flaxseeds are flavone C- and flavone O-glycosides [37]. The highest source of phytoestrogens is flaxseed (lignans).

Lignans

Lignans are phytoestrogens that are widely distributed in plants that are high in fibre, as well as in cereals (wheat, barley, and oats), legumes (bean, lentil, and soybean), vegetables (broccoli, garlic, asparagus, and carrots), fruits, berries, tea, and alcoholic drinks. Flaxseed contains about 75–800 times more lignans than cereal grains, legumes, fruits and vegetables [38]. The highest dietary source of lignan precursors is flaxseeds. The bacteria that ordinarily occupy the human intestines transform the lignan precursors, enterodiol and enterolactone, when they are consumed. Secoisolariciresinol diglucoside, which is mostly present in flaxseed, is a precursor of lignans [39]. The main lignan in flaxseed is Secoisolariciresinol diglucoside (SDG), which accounts for between 294 and 700 mg per
100grammes. Matairesinol (0.55 mg/100 grammes), pinoresinol (3.32 mg/100 grammes), lariciresinol (3.04 mg/100 grammes), and isolariciresinol (0.55 mg/100 grammes) are minor components [40]. Lignan-rich foods are part of a healthy diet; lignans have a significant role in the prevention of hormone-related malignancies, osteoporosis, and cardiovascular disease [1].

Micronutrients

Flaxseed include a variety of vitamins and minerals, including calcium, magnesium, and phosphorus. It is critical since a 30g chunk of the seed contains 7% to 30% of the Recommended Dietary Allowance (RDAs) for various nutrients [41]. Tocopherols are the most prevalent vitamins, with α-, β-, and γ- forms, although natural tocopherols come in four varieties which are α, β, γ and δ-tocopherols. Alpha-tocopherol is a fat-soluble vitamin isomer of γ -tocopherol and a type of vitamin E. It has a greater amount of β -tocopherols (200 ppm) than α-tocopherols (15-20 ppm) and γ- tocopherols (15-20 ppm) (5-7 ppm) [42].

Table 4 Minerals content of flax.

S.NO.	Minerals	mg/100gm of flaxseed	mg/tbsp milled flax
1.	Calcium	236	19.0
2.	Copper	1	0.1
3.	Iron	5	0.4
4.	Magnesium	431	34.0
5.	Manganese	3	0.2
6.	Phosphorous	622	50.0
7.	Potassium	831	66.0
8.	Sodium	27	2.0
9.	Zinc	4	0.3

Vitamin E is an example of an antioxidant that shields cell components from the damaging effects of free radicals, which, if unchecked, can result in the development of cancer [43]. Several water- and fat-soluble vitamins are present in flaxseed. As listed in Table 4 [5]. Vitamin E may help to prevent cancer by enhancing immune function and lowering the generation of carcinogenic nitrosamines in the stomach from nitrites in food [43].

Carbohydrates

Flax has just 1 gramme (g) of carbs (sugars and starches) per 100 g. As a result, flax adds little to total carbohydrate consumption; it is advised for persons suffering from certain disorders. Flaxseed polysaccharide is made up of two primary components: neutral arabinoxylan (75%), and acidic rhamnogalacturonan (25%). The arabinoxylan is mostly constituted of xylose, arabinose, and galactose, whereas the rhamnogalacturonan is formed of L-rhamnose, D-galactose, D-galacturonic acid, and L-fucose acid. Among accessions from the global collection of flaxseed, there are considerable and noticeable differences in the quality, yield, and content of monosaccharides [42].

Anti-nutritional compounds of flaxseed

Anti-nutrients are chemical compounds found in food that do not provide nourishment to the body. Flax includes beneficial components, but it also contains anti-nutritional compounds such as cyanogenic glycosides(CGs), phytic acid, linatine and trypsin inhibitors etc. The health and wellnessof humans may be negatively impacted by these antinutrients. The kind and concentration of these anti-nutrients in the dietary material determine how they affect the body [44]. According to Ganorkar and Jain (2013), flaxseed antinutrients have a lesser impact on human health than soybean and canola [5].

Cyanogenic glycosides

Cyanogenic glycosides are nitrogenous secondary plant metabolites made from amino acids. People who regularly consume meals high in cyanates may experience long-lasting consequences, which first manifest in the nervous system. These three primary anti-nutrients—Linustatin (213–352 mg/100 g), Neolinustatin (91-203 mg/100 g), and Linmarin (32 mg/100 g)—are the most common. Linamarin, which varies from 0 to 300 mg/kg, is the most prevalent of these cyanogenic glycosides (Linustatin, Neolinustatin, and linamarin). Linustatin and Neolinustatin are the main components of the cyanogenic glycoside found in whole flaxseed, which comprises 250–550 mg/100 g [45].

Among the alkanols are methanol, ethanol, and isopropanol. More than 90% of the cyanogenetic glycosides, Linustatin and Neolinustatin, were eliminated using methanol solutions. Because cyanogenic glycosides are heat labile, they are easily destroyed by processing techniques including autoclaving, microwave roasting, pelleting, and some detoxifying enzymes like glycosidases. This results in the release of hydrogen cyanide, which may be evaporated using steam [46]. When a seed isdamaged, β-glucosidases are activated and help to release the toxic hydrogen cyanide (HCN).However, proper preparation of foods containing CG contributes to lowering the dangers

of poisoning. For example, when flaxseed was cooked for more than 2 hours at 200 °C, more than 85%of Linustatin and Neolinustatin were eliminated [47].

Phytic acid

Another anti-nutrient in flaxseed is phytic acid, which has a concentration of 23 to 33 g/kg of the flaxseed meal [48]. Despite being known for reducing the bioavailability of micronutrients, recent research has shown that phytic acid also has antioxidant, anticancer, hypocholesterolemic, andhypolipidemic characteristics. Phytic acid inhibits the absorption of calcium, zinc, magnesium,copper, and iron. It also reduces calcium, magnesium, zinc, and iron usage due to its capacity to create insoluble salts with these ions [48]. The presence of phytic acid in flaxseed leads to the formation of protein mineral-phytic acid complexes that are not digestible, resulting in poor nutrient absorption and weight gain. It is a strong chelator that, by forming compounds with phytic acid, lowers the bioavailability of proteins and minerals [49].

Linatine

Flax also includes linatine, a pyridoxine (vitamin B6) antagonist. Linatine (Gamma glutamyl- 1- amino-D-proline), which causes a vitamin B6 deficit, is also present in flaxseed meals at a concentration of 10 mg/100 g. In the case of chicks, Linatine (Antipyrodoxidine factor) is a vitamin B6 antagonist. While flaxseeds have not been related to vitamin B6 insufficiency in people, researchers Ratnayake et al. (1992) and Dieken (1992) observed that the Linatine (a vitamin B6 antagonist) in flaxseed had no influence on vitamin B6 levels or metabolism in subjects fed up to 50 g of ground flaxseed daily. Symptoms of vitamin B6 deficiency might be seen in certain people. To counter balance the potentially deleterious effects of Linatine on vitamin B6, meals including flax orseed meal should be supplemented with extra pyridoxine [50].

Trypsin inhibitors

Trypsin inhibitors are found in a lot of plant seeds. The particularly leguminous seed has large TI levels. The TI is categorised into two categories: Kunitz trypsin inhibitors and Bowman-Birk trypsin/chymotrypsin inhibitors. The most frequent TI discovered in soybeans are Kunitz trypsin inhibitors, while the most frequent TI found in grain legumes like field peas and lentils are Bowman-Birk trypsin/chymotrypsin inhibitors [51]. Since they reduce protein digestion and subsequent absorption by inhibiting proteases, trypsin inhibitors present in the diet are known to harm animal development for decades. In the gastrointestinal system, dietary TI binds to pancreatic digesting enzymes trypsin and chymotrypsin to create inactive complexes, resulting in abnormal AA digestibility [51]. Through a negative feedback mechanism, the inactivation of trypsin and chymotrypsin enhances the secretion of these enzymes into the gastrointestinal system [52].

Cadmium

Cadmium has the potential to be hazardous to the human body. When this metal accumulates in the kidney, it can induce renal dysfunction, pulmonary emphysema, aminoaciduria, glycosuria, phosphaturia, and even impair mineral reabsorption, leaving organisms vulnerable to osteomalacia [1].

Nutrition in action:- Health benefits of flaxseed

The various health benefits associated with the consumption of flaxseed are given as below:

Anti–diabetic functions

Flaxseed fibre consumption improved blood glucose levels. In type 2 diabetics, daily lignan administration resulted in considerable improvements in glycemic control. Flaxseed lignin, SDG lowered high-fat diet. They improved hyper-lipidaemia, hypercholesterolaemia, hyper- insulinaemia,and hyper-leptinaemia. These effects may help to prevent obesity and minimise the cardiovascular risk associated with lifestyle disorders such diabetes, atherosclerosis, and hypertension. Dietary fibreis a potential diet for lowering the risk of lifestyle-related disorders such as diabetes. Researchers from the World Health Organization released an open-label study on the efficacy of flax seed powder intake on diabetes control [53].

Anti-inflammatory functions

Flaxseed and flaxseed oil both have anti-inflammatory properties. Atherosclerosis has been identified as an inflammatory condition, and omega-3 fatty acids may help to prevent it. Flax contains lignans and ALA, which aid to prevent inflammation, which impacts the immune system. Roy (2007) conducted a research in which middle-aged males were treated with ALA and inflammatory indicators were dramatically decreased following supplementation. Flaxseed haveanti-inflammatory properties because they are high in omega-3 fatty acids and ALA. Flaxseed contains dietary fatty acids that are turned into prostaglandins (a hormone-like substance) that are also helpful for controlling inflammation [54].

Anti-cancerous properties

Flaxseed contains secoisolariciresinol (SDG). This is transformed into active mammalian lignans, such as enterodiolandentero-lactone, which has the ability to inhibit the formation of malignant tumours. Lignans contain antioxidant properties and have contributed to flaxseed's anti-cancer potential. Lignan, enterodiol, and enterolactone are thought to suppress the proliferation of human prostate malignant cells. Flaxseed and flaxseed meal (FLM) lower cancer risk [53].

Flaxseed have been shown in animal experiments to suppress colon and skin malignancies in cell cultures. Danbara et al. (2005) conducted a trial in which a dosage of 10 mg/kg enterolactone was given subcutaneously three times per week. In athymic mice, this therapy decreased the expressionof colon 201 human colon carcinoma cells. They determined that tumour suppression was caused by apoptosis and reduced cell proliferation using multiple testing techniques [54].

Maintains the health of heart

Flaxseed has heart-health advantages since it contains -linolenic acid and omega-3 fatty acids. Fatty acids control gene transcription and expression. Then, regulating enzyme production and modifying many risk factors for coronary heart disease. Treatment for heart disease includes lowering serum lipids and blood pressure. Flaxseed and its components boost cardiovascular health. Flaxseed are high in lignans, which may help to prevent cardiovascular disease (CVDs). Dietary flaxseed supplementation reduces the risk of hypercholesterolemia-related heart attacks and strokes [55].

Flaxseeds provide the highest concentration of lignans, which are transformed to enterolactone by intestinal microflora. Enterolactone has been proposed as the primary active molecule mediating atherosclerosis protection [56].

Reduction of menopausal symptoms

Flaxseed contains phytoestrogens, which assist to alleviate menopausal symptoms such as hotflashes. They have a hormonal impact. In postmenopausal women who are not receiving estrogen therapy, dietary flaxseed supplementation (40 g/day of crushed flaxseed) has benefits similar to hormone replacement therapy in terms of reducing menopausal symptoms and hot flashes. Menopausal symptoms may be alleviated by SDG [54].

CONCLUSION

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. Presently, flaxseed has new prospects as functional food because of consumers growing interest for food with superb health benefits. Owing to its excellent nutritional profile and potential health benefits, it has become an attractive ingredients in the diets specially designed for specific health benefits. ALA is one of the essential poly unsaturated fatty acid and reported to exhibit anti-inflammatory, anti-thrombotic and anti-arrhythmic properties. Nutritionists all over the world suggest incorporation of omega 3 fatty acid source in the diet. Flaxseed has healthy properties that prevent from cardiovascular disease, problems related to menopausal and many more disease.

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