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# Functional and nutraceutical scenario of flaxseed and sesame: A review

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## Abstract

Flaxseed or linseed (*Linum usitatissimum* L.) comes from the flax plant, an annual herb. Sesame (*Sesamum indicum*) belongs to family *Pedaliaceae*. The main importance of flaxseed and sesame is in the human nutrition sector because it is emerging as an important functional food ingredient thanks to the content of active compounds, pointed to provide health benefits. There are several ways to eat flaxseed and sesame in the form of oil or added to the bakery product. Scientific evidence support consumption of flaxseed for the high content in omega-3, omega-6 rich oil, α-linolenic acid, lignans, high-quality proteins and fibers, compounds which are biologically active in the prevention of some chronic diseases such as many types of cancer, diabetes, cardiovascular diseases and cerebrovascular stroke. Along with being a good source of plant protein these both have great ability to lower blood pressure. They are also a rich source of many vitamins and minerals.

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## Introduction

Globally, since the past few years, man has been trying to explore the mysteries of nature and he has discovered many components of human interest and has used them against various ailments to increase the standards of health. Since ancient times, researches have been using medicinal plants to treat and cure human health disorders and thus have an important part in human history. These plants are proved to be therapeutic agents against many life-threatening sicknesses. Trending dietary habits, comprised of simplified and refined are the main cause of obesity-associated ailments. Consumption of diets low in nutrients and functional components leads to metabolic disorders increasing the chance of disorders. The flaxseed can be used as a whole or it can be incorporated in different other foods including bakery products. The bioactive component of flaxseed, lignan has health-promoting and disease preventive potential that makes flaxseed to be used in different products (Singha *et al.,* 2011). The present research project was designed to explore the role of flaxseed as a functional food. Utilization of *Sesamum indicum* L as a valuable food is attaining more popularity in the present years. From the prehistoric times, it is cultivated for cooking and other purposes. Many useful nutrients such as protein, soluble and insoluble dietary fiber as well as omega-3 fatty acids are present in sesame. It can be used as a whole or it can be merged in different other food products including bakery foodstuff (Saleem *et al*., 2008).

### *Flaxseed; an overview*

The flax (*Linum usitatissimum*) is a blue flowering rabi crop and is a member of family linaceae, commonly known as "Alsi". The flaxseed and linseed are the other names that are often used interchangeably. The flax in North America when eaten by humans is named "flaxseed" and named as "linseed" when it used for linoleum flooring. However, Europeans use the term flaxseed to explain the varieties grown for the manufacturing of linen (Singha *et al.,* 2011). The history of flaxseed cultivation has been found as early as 3,000 B.C. The flaxseed grain is oval and flat, slightly larger than a sesame seed possessing about 2.5x5.0x1.5 mm size.

Flaxseed is available in two colors i.e. brown and yellow. In Canada, the common flaxseed being grown is brown seeded and it is high in alpha-linolenic acid (ALA) that is an omega 3 fatty acid. On the other hand, there are two types of yellow seeded flaxseed. The first type known as Omega is developed by the U.S. and it has high ALA content like brown variety. Solin is the name given to other types of yellow seeded variety and it has low ALA content. It was made to be utilized in foods and is used in margarine. In some supermarkets and stores, both Omega and brown flaxseed are being sold. In commercial whole-grain bread being sold in the United Kingdom and Australia, whole seed as an ingredient is offered to consumers but the varieties of solin are not available to purchase directly. There must be a yellow seed coat of solin in Canada so that handlers and growers can easily maintain it separately from brown flaxseed during all the handling steps. Nulin TM is a novel type of flaxseed having more amount of ALA as compared to normal flaxseed.

High-fat contents along with a good quantity of dietary fiber, protein and potassium are associated with flaxseed. According to an analysis, it contains 38.76% crude fat, 23.99% NFE, 21.23% protein, 8.02% crude fiber, 4.53% moisture and 3.47% ash depending upon the cropping location, cropping year, environmental conditions and seed variety. The mineral assay revealed that flaxseed has 826.32, 430.54, 240.80, 32.43 and 6.10 mg/100g of potassium, magnesium, calcium, sodium and iron, respectively (Hussain *et al.,* 2008).

Flaxseed contains about 40% fat. The amount of saturated fat was low and there was a reasonable amount of monounsaturated fat while the quantity of polyunsaturated fat was prosperous (Pradhan *et al.,* 2010). Flaxseed is the major source of omega-3 fatty acids and alpha-linolenic acid that is an essential fatty acid accounts for more than 50% of total fatty acids. Linoleic acid is another polyunsaturated fatty acid present in flaxseed that accounts for 15% of total fatty acids. Two metabolites are formed by the conversion of alpha-linolenic acid after elongation and denaturation called docosahexaenoic acid andeico sapentaenoic acid (Barcelo Coblijn and Murphy, 2009).

The building blocks of protein are amino acids flaxseed protein has a pattern of amino acids that is quite similar to the pattern of soya bean protein. It is considered as most nutritive protein among plants. Essential amino acids are those which our body cannot synthesize and have to be taken through diet. Flaxseed is blessed with some essential amino acids like lysine, histidine, methionine, phenylalanine, threonine, tryptophan and valine (Connon, 1999).

It was stated that there is no gluten in flaxseed. Normally, it is a protein that is present in cereal grains like rye, barley, oats and wheat (Murphy and Hendrich, 2002). Celiac disease is caused by a component in gluten called gliadin and it has high contents of amino acids glutamine and praline. These cereals are noxious for peoples having celiac disease. Now, celiac disease is known as a chronic inflammatory disorder but the system of how mucosal lining of the gastrointestinal tract is irritated by gluten is not well clarified. Flaxseed is beneficial in this respect that people with celiac disease can consume it in their diets (Vijaimohana *et al.,* 2006).

Flaxseed is rich in fiber content and it has cellulose, mucilage gums and lignans as chief fractions. Plants' cell walls are composed of key structural material called cellulose. The second fraction of fiber is mucilage gum that is a form of polysaccharide and it tends to become gelatinous on mixing with fluids. There are three different types of arabinoxylans in flaxseed mucilage. These add to gel qualities by forming large aggregates in solution. The third fraction of fiber is highly branched called lignin and it is present in cell walls of woody plants. Lignans are sometimes confused with another compound lignan while in reality, both are different. Lignans are bioactive components of plants that mainly impart health benefits to humans and these are being studied in cancer prevention (Riaz *et al.,* 2020). A bulking agent, dietary fiber is present in a considerable amount in flaxseed as soluble and insoluble fractions. The viscosity and weight of the ingested stuff are raised along with a decrease in passing time in the gastrointestinal tract. Dietary fiber aids in controlling blood glucose and appetite as well as promoting laxation. The peril of obesity, diabetes, heart diseases and cancer might be lessened by consuming diets having wealthy dietary fiber (Daun and Przybylski, 2000; Tufail *et al.*, 2020).

*Utilization of flaxseed in different foods*

Specialty grains (wheat, barley, flaxseed, sprouted grains and rice extract) are used in breakfast cereals to add novel textures, flavors and colors in these products. The chapatti prepared from the composite flours containing 15 g roasted flaxseed powder, 0.05 g oil and 80 g of whole wheat flour was evaluated for its chemical composition. That single serving of chapatti contained 29.9 grams carbohydrates, 6.3 grams protein, 5.9 grams fat and 198 calories. Similarly, chapattis containing 20% or lower levels of the full-fat flaxseed flour were found acceptable by the panelists concerning their sensory attributes. The mineral contents of the chapattis increased significantly as the level of the replacement of the full-fat flaxseed flour was increased in the wheat flour (Hussain, 2004).

The bread containing 10 and 13% levels of flaxseed were characterized by higher amounts of protein, fat, dietary fiber, macro and microelements in comparison to standard bread. There was a significant increase in Fe, Zn and Mg contents of the bread with the increasing level of flaxseed flour in the wheat flour (Gambus *et al.*, 2004). The ground flaxseed used 30% to 50% is acceptable in muffins and quick bread (Alpers and Morse, 1996). The cookies prepared from wheat flour containing 20% whole flax grains, partially defatted flaxseed flour and full-fat flaxseed flour were found acceptable for their sensory attributes (Hussain, 2006).

Another study investigated the quality of 2 bakery products (cookies and muffins) containing brown and yellow linseeds (flaxseed) flour at 11 and 9%, respectively. These levels of replacement did not affect the sensory properties of flaxseed cookies and flax muffins. The increased linseed content improved the dietary and nutritional values of both types of bakery products due to the increased total protein and dietary fiber contents (Gambus *et al.,* 2003). The study conducted and showed that protein content of biscuits made from composite flour containing 15% ground flaxseed increased from 6.50% to 8.52%, fat content increased from 26.13% to 31.45%, fiber content increased from 0.15% to 3.78% and ash content increased from 0.26% to 1.00%. The supplementation of flaxseed flour up to 15% showed no deleterious effect on the sensory attributes of biscuits (Zaib un Nisa, 2000). The minerals like Fe, Zn contents increased significantly with 15% supplementation of flaxseed flour.

According to study, a 3% increase in linseed in the recipe for flax hermit cookies and 5% rise of linseed in flax muffins increased the amounts of proteins, dietary fiber, micro and macro minerals (Gambus *et al.*, 2004). The effect of combining flaxseed meal (15%) and soy flour (5% and 10%) on the product quality in the production of yeast bread. The addition of flax and soy flour resulted in the reduction of bread volume. The sensory attributes like crust and crumb color were also affected due to the addition of soy/flaxseed flours and the darker color was observed in both products. No significant differences in moisture in the flax and soy/flax bread were recorded as compared to control bread prepared form wheat flour alone (Frank and Sarah, 2006). The study conducted the addition of flaxseed in wheat flour at 15 and 20% levels resulted in a decrease of dough stability, lower crust and crumb scores as compared to the control bread prepared form 100% wheat flour (Koca and Anil, 2007). Another study conducted by the effect of the addition of flaxseed in bread rolls and cinnamon rolls on their sensory profile and chemical composition was studied. At 0 and 6 days of storage, no significant changes were observed in their sensory attributes. The higher contents of saturated fatty acids were observed in a cinnamon roll. Both the bakery products were found saturated fatty acids were observed in cinnamon rolls. Both the bakery products were found to be higher in alpha-linolenic acid contents. The fiber contents of bread rolls were also increased (Pohjanheimo *et al.,* 2006).

The study conducted the storage stability of 2 samples of milled flaxseed kept at 23°C (73°F) for a period of 128 days. Samples were placed in paper bags with plastic lining (Malcolmson *et al.*, 2000). The samples were checked after each 33 days for their chemical composition, sensory attributes and volatile indicators of quantity. Both of these samples showed a minute increase in peroxide values. Another worked on the quality of spaghetti having flaxseed in ground form. They showed that spaghetti having a fine particle size of ground flax was of better quality as compare to coarser size particles (Manthey *et al.*, 2002).

The study conducted replaced wheat flour with oat bran and flaxseed powder used for cake preparation. They observed the rheological and Physical aspects of that product. That modification in formulation showed a significant change in the color of crust and crumb. Substitution of more than 40% made the cake harder. While springiness increases as substitution increases (Lee *et al.*, 2004).

*Flaxseed lignans*

Phytochemicals are endemic in the human diet from the ancient times to fight against diseases as most of the medicines were derived from plants. In the recent era, diet-based therapy has been revitalized globally and people are adopting the approach of using natural materials as an intervention against various ailments. Herbal medicines are becoming popular not only in developed but also in developing countries for health care because of their extensive biological activities and safe status (Potawale *et al.*, 2008).

Ever since humans have consumed plant material in their diet, they have unknowingly consumed plants containing lignans. Compared to the hundreds of millennia that lignans have been part of the diet, it is only since the midpoint of the last century that have we been aware of the chemical nature of the majority of these compounds. Furthermore, it is only in the last few decades that we have started to establish a connection between lignans and biological effects. In the Textbook of Natural Medicine, indexed lignan entries can be found on only 4 pages out of a total of 1620 pages in this two-volume set (Westcott and Muir, 2003).

Flaxseed's fiber and Omega 3 fatty content are well studied and investigated but there is one more worthy component is lignan. These are the phenolic compounds and associated with many health benefits that include cancer prevention (Crosby, 2005). The joining of two coniferyl alcohol residues present in the cell wall of plants gives rise to these diphenolic compounds (Westcott and Muir, 2003). Fiber-rich plants are important source of lignans that includes grains like oats, barley and wheat. These are also present in some vegetables like broccoli, carrots and garlic.

Flaxseed contains the highest amount of lignan as compared to any other food source (Murphy and Hendrich, 2002). In flaxseed, the major lignan is secoisolariciresinol (SECO) that is present in the form of glucoside called secoisolariciresinoldiglucoside (SDG). It is attached to other SDG molecules through hydroxyl methyl glutaric acid (HMGA) to make lignan macromolecule (Eliasson *et al.*, 2003).

It is worthwhile to review some of the historical backgrounds on the connection of secoisolariciresinoldiglucoside (SDG) and its bioactivity. In a publication of limited distribution, the first isolation of bioactive component SDG from flaxseed (*Linum usitatissimum*) was reported in 1956. Some chemical characterization was reported that established the basic structure but, as was typical of the day, there was no mention of biological activity (Westcott and Muir, 2003).

According to investigation SDG content vary between 0.7 to 1.9% in whole and ground flaxseed that accounts for 78 to 208 mg SDG per tablespoon of whole flaxseed or 57 to 151 mg SDG per tablespoon of ground flaxseed. Flaxseed oil also contains some lignan and the amount of SDG is about 0.1% or 14 mg per tablespoon of flaxseed oil (Morris, 2004). Once ingested, lignans are deglycosylated and converted by bacteria in the large intestine to produce enterolactone (ENL) and enterodiol (END), the mammalian forms of plant lignans. SECO, in the form of SDG, is the most prevalent mammalian lignan precursor in flaxseed, and thus attracts the most attention, although flaxseed also contains several other lignans, including matairesinol and lariciresinol (Thompson, 2003; Struijs *et al.,* 2007). SECO is also the lignan converted most efficiently into mammalian lignan forms. Once absorbed in the intestine, lignans, both SECO and its metabolites enter the circulation system and begin to exhibit their numerous physiological effects (Crosby, 2005).

Clinical trials on animals and humans have been conducted to see the levels of enterodiol (END) and enterolactone (ENL) by feeding on flaxseed. It was found that the levels of END and ENL were considerably increased in urine. Flaxseed intake increased the levels of END and ENL in urinary excretion of healthy young women and postmenopausal women up to 280 times after 6 weeks. These levels were also increased in healthy young men (Hutchins and Slavin, 2003).

The identification of mammalian lignan, END and ENL in humans and animals took place in 1980. In the gastrointestinal (GI) tract of the human body, GI bacteria from mammalian lignans by hydrolyzing the sugar part of SDG and liberate SECO (Ford *et al.*, 2001). The next step is the dehydroxylation of SECO followed by demethylation that is done by colonic microflora and it yields END. The other mammalian lignan ENL is formed by oxidation of END by GI microflora. Matairesinol can also be used for the formation of ENL directly but this pathway is insignificant if the diet contains other lignans (Westcott and Muir, 1998). There is a difference in mammalian lignans and plant lignans and this is due to the position of different groups at 3' position. A hydroxyl group is present at 3' position in mammalian lignan and there are oxygenated substituents at 3' and 4' positions in plant lignans. Mammalian lignans are higher in concentration in urine as compare to concentration in plasma (Muir and Westcott, 2003).

Flaxseed supplementation has shown to impart positive effects in breast cancer, skin cancer and colon cancer when studies conducted on rats and mice (Clark *et al.*, 2003). The effect of flaxseed flour supplemented in a high-fat diet was studied to check the reduction of tumors in mice. Inbred mice at the promotional stage of tumor genesis were fed on a diet supplemented with 5% flaxseed flour and it resulted in a reduction of tumor size up to 66%. There was a significant decrease in the size and number of mammary tumors as compared to control groups (Li *et al.*, 2006). The peril of breast cancer associated with plasma insulin-like growth factor I (IGF-I) was reduced significantly in a rat breast cancer model with dietary supplementation of SDG or flaxseed (Rickard *et al.*, 2008).

Animal studies had shown the inhibitory result of SDG on mammary tumor development at early stages while mammary tumors at the late stage were affected by flaxseed oil and ground flaxseed. In a study conducted on Sprague Dawley rats to check the reduction in colon cancer, treatment with flaxseed resulted in a reduction of tumor number up to half and there was an increase in cecal β-glucuronidase activity and urinary lignan excretion (Thompson *et al.*, 2011).

Flaxseed and SDG have been shown to inhibit lung metastasis of a mouse melanoma cell line. In this study, the melanoma cells were injected directly into the bloodstream and this study may not be representative of the normal metastasis process. Flaxseed and mammalian lignans inhibited metastasis and growth of established human breast cancer in a nude mice model (Dabrosin *et al.*, 2002; Chen and Thompson, 2003).

*Antioxidant potential of flaxseed*

Flaxseed and its derivatives like flaxseed oil, lignan extracts and flaxseed fiber have gained much interest to be used as ingredients in functional and nutraceutical foods due to various health benefits associated with them. The interest is increasing due to evidence provided by investigations and research on flaxseed over the past 20 years that proved its shielding effects against several chronic diseases like insulin-dependent diabetes mellitus, atherosclerosis and various forms of cancers (Tufail *et al.,* 2018).

There are two classes of natural antioxidant i.e. primary and secondary antioxidants. Primary antioxidants also called chain-breaking antioxidants attack directly on lipid radicals and transform them into a stable form. The secondary antioxidant also is known as preventive antioxidants use a different mechanism to slow down the rate of oxidation (Decker *et al.*, 2005). The mode of action of primary antioxidants is the donation of a hydrogen atom. On the other hand, secondary antioxidants employ different modes of action that include binding metal ions, absorption of ultra-violet radiation, decomposition of hydroperoxides and scavenging oxygen (Schwarz *et al.*, 2001). Natural phenolic compounds found in plants can act as primary as well as secondary antioxidants through various mechanisms and their activity can be accessed by monitoring the drop off radical (Decker *et al.*, 2005).

The antioxidant potential of flaxseed major lignan and its mammalian lignan has been reported. In *vivo* and in *vitro* studies have been conducted to check the antioxidant effects of flaxseed and it was found effective against some chronic diseases by employing various modes of action (Yuan *et al.*, 1999). Evaluated the antioxidant prospective major flaxseed lignans SDG and SECO and mammalian lignans enterodiol (END) and enterolactone (ENL) against DPPH, AAPH initiated peroxyl radical plasmid DNA damage and phosphatidylcholine liposome lipid peroxidation. The antioxidant potential of SDG and SECO was significant against DPPH as compared to their mammalian counterparts which were inactive. In the case of AAPH peroxyl radical-induced DNA damage, SDG was more effective followed by SECO, END and ENL (Hu *et al.,* 2007). The order of antioxidant potential was the same against liposome lipid peroxidation. The agent responsible for the antioxidant activity of plant lignan was 3-methoxy-4-hydoxyl in SDG and SECO as compared to Meta monophenol structures of mammalian lignan. The antioxidant activity of mammalian lignans was attributed to the abstraction of benzylic hydrogen and resonance stabilization of phenoxyl radicals. The results showed that the antioxidant activities of flaxseed lignans can be achieved in *vivo*.

*Health claims of flaxseed*

Flaxseed is a complex plant material in which several components including dietary fiber, flaxseed oil, protein and phenolic compounds are mainly responsible for some health benefits. Some of the studies showing the health benefits of whole flaxseed, defatted flaxseed meal, flaxseed oil and individual flaxseed components are reviewed under this section.

There are two groups of omega fats; omega-3 and omega-6 fatty acids. Linolenic acid, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) are the three types of omega-3 fatty acids and are nutritionally important. All three fatty acids have been shown to reduce the risk of cardiovascular disease. Linolenic acid is naturally present in canola, flaxseed, and walnuts whereas the other two types of omega fats are mainly present in fish like salmon, mackerel and herring (Hurteau, 2004). Ground flaxseed is high in omega–3-fatty acids, which have been shown to reduce hypertension, cholesterol and triglyceride level (Oomah and Mazza, 1998). Flaxseed acts as a good source for lowering cholesterol and improving heart functions due to the eicosanoides derived from omega-3-fatty acids (Simopoulos, 2012). It is revealed in many studies that monounsaturated and polyunsaturated fatty acids are responsible for lowering the total cholesterol in the diet (Zambon *et al.*, 2006). The studies on lipid profile of male Wister rats fed high-fat diets like flaxseed and trout (sources of polyunsaturated fatty acids), peanut (source of monounsaturated fatty acids) and chicken skin (source of saturated fatty acids) indicated that total cholesterol levels in rats fed flaxseed diet were lower than in rats fed on the other fats (Cintra *et al.,* 2006).

Incorporating full-fat flaxseed meal into the diet eliminated the adverse effect of hydrogenated soybean oil on serum cholesterol levels in hypercholestrolemic rats. Full fat flaxseed meal enhanced the cholesterol-lowering effect of diets containing flaxseed oil. The flaxseed protein was also found to be effective in lowering plasma cholesterol and triacylglycerides (Bhathena *et al.,* 2002).

The flaxseed fiber is also considered to reduce the blood glucose and cholesterol levels by delaying and reducing their absorption in the body (Shen *et al.*, 2009). Increasing the level of soluble fiber of guar gum, chickpea, and lentil in wheat flour contributed towards the reduction of blood glucose, total cholesterol and increase in the HDL cholesterol of Sprague Dawley rats fed on these fibers. The studies showed 5 and 8% reduction, respectively, in serum total and LDL cholesterol levels in subjects fed partially defatted flaxseed (Jenkins *et al.,* 1999). These researchers attributed the LDL reduction to the soluble fiber component of the flaxseed. Cunnane *et al.* (2005) reported that blood glucose level reduced by about 27% when bread containing flaxseed was consumed, while Bhathena *et al.* (2003) observed 26% and 41% reductions in the plasma total cholesterol of leans and obese rats, respectively due to the effect of inclusion of flaxseed meal in their diets.

Gambus *et al.* (2001) conducted an experiment on Wister rats which were fed standard bread or bread containing 10 or 13% milled flaxseeds for 19 days and observed 47.0 and 48.5% reduction in average blood cholesterol concentration and low-density lipoprotein fraction, respectively as compared with the group of rats fed on standard bread with no added flaxseed. In a similar study done by Kritchevsky (2012), it was observed that rats fed a 20% flaxseed diet showed a 25% additional reduction in serum and liver cholesterol than rats fed a diet containing 10% flaxseed. Cunnane *et al.* (2005) stated that 8% reduction in LDL protein and a 30% increase in bowel movement observed in adults consuming 50g flaxseed per day for 4 weeks. An experiment on rats fed flaxseed bread achieved impressive hypocholesteric effects. Hasler *et al.* (2004) observed a 6.9% reduction in total cholesterol of women fed on bread and muffins supplemented with 38 g of flaxseed for six weeks. Lemay *et al.* (2002) noticed small changes in cholesterol levels of 25 hypercholestrolemic women fed on a diet containing 40 g flaxseed/day.

The total cholesterol, LDL cholesterol and lipoprotein concentration reduced significantly, possibly due to the activity of linolenic or linoleic acids, fiber and non-protein constituents present in this seed. In a clinical study by Lucas *et al.* (2012), 40 g of either ground flaxseed or a wheat-based comparative control regimen was fed to postmenopausal women daily for three months. The flaxseed supplementation resulted in a 6% reduction in both serum total and HDL cholesterol, whereas no effect was observed due to the use of a control regimen. The flaxseed regimen reduced the serum levels of both LDL and HDL cholesterol by 4.7% and triglyceride by 12.8% (Prasad, 2014). Another studied the effect of secoisolariciresin diglucoside (SDG) isolated from flaxseed in rabbits and concluded that SDG helped to decrease hypercholestrolemic atherosclerosis due to reduction in serum total and LDL cholesterol. An increase in HDL-cholesterol and antioxidant reserves was also observed. Dodin *et al.* (2005) reported that the intake of flaxseed reduced serum total (-0.20±0.51) mmol/liter and high- density lipoprotein (-0.08±0.24) mmol/liter cholesterol concentrations of menopausal women who consumed 40g flaxseed/day (Arjmandi *et al.*, 2013).

Flaxseed's lignans have shown antineoplastic effects based on *in vitro* and animal research. Regular consumption may reduce the risk of certain cancers. The antitumoral effect is attributed to the lignans (lignans are antimycotic, anti-oxidative and anti-estrogenic). Dietary supplementation of flaxseed reduced mammary tumor size and number in rats. Several studies have shown an inhibitory effect of dietary ALA on tumor growth and incidence in rodent mammary-tumor models, although one study showed no effect and not all evidence is free of inconsistency (Sonn *et al.*, 2005).

Evidence of the effects of flaxseed, SDG, mammalian lignans and their precursors, and phytoestrogens in general on carcinogenesis are available (Adlecreutz, 2002). Animal model studies have been conducted at the initiation (before carcinogen), promotion (after carcinogen) and progression (visible tumors) stages of carcinogenesis. It was found that 1.5 mg per day of SDG administered at the initiation stage resulted in 46% fewer tumors per group and 37% less tumor multiplicity (Thompson *et al.*, 2011). A second study at the late promotion early progression stage, use of 1.5 mg SDG per day resulted in a reduction in established tumor volume by 54% and new tumor volume by 75%, the average new tumor number per group by 50%, and new tumor incidence by 27% (Thompson *et al.*, 2011). Administration of either flaxseed or flaxseed oil reduced the established tumor volume but did not affect new tumor size or established or new tumor number. It was concluded that SDG had a greater inhibitory effect on tumor number than either the flaxseed or flax oil (Thompson, 2003). Flaxseed and SDG have been shown to inhibit lung metastasis of a mouse melanoma cell line. In this study, the melanoma cells were injected directly into the bloodstream. Flaxseed and mammalian lignans inhibited metastasis and growth of established human breast cancer in a nude mice model (Chen *et al.*, 2003).

Hormone replacement therapy has often been prescribed to counter the effects of bone loss and menopausal symptoms. The possibility of using flaxseed or SDG to ameliorate these effects has been reviewed (Ward, 2011). Female rats exhibit some improved bone strength in early life but this does not persist into adulthood when lignans are provided during suckling to adult life stages (Ward *et al.*, 2015). SDG does not have adverse effects on bone strength. In males receiving a 10% flaxseed diet from birth to postnatal day 50, there was a decrease in bone strength but this difference disappeared by postnatal day 132 (Zebib *et al.*, 2013). The effect may not have been related to the lignan, as a diet with SDG did not reduce bone strength during the same period. Bone strength did not differ among groups at postnatal day 132.

Ischemic heart disease, stroke, peripheral vascular disease, collectively known as cardiovascular heart disease (CHD) is the major cause of mortality in industrialized countries. Hypercholesterolemia is an established risk factor in atherosclerosis. Oxygen-free radicals (OFR) have been implicated in several diseases including hypercholesterolemic atherosclerosis, resulting in oxidative stress. Flaxseed has several components that might have a pharmacological activity that could reduce oxidative stress. Typically flaxseed contains about 35–45% oil with alpha-linolenic acid (ALA) accounting for about one half or more of the total fatty acids present. The second component that is of interest is the gum or soluble fiber fraction. A third seed component that is attracting significant medical investigation is the lignan secoisolariciresinoldiglucoside (Westcott and Muir, 2003).

Prasad and his associates examined traditional high ALA flaxseed, low ALA flaxseed and purified SDG. In the initial study, rabbits were separated into 4 groups: One group was fed on the control diet and the other was wed on control plus 7.5 g/kg body weight flaxseed diet. The other two groups were fed on the same diet but with a 1% addition of cholesterol. The rabbits were maintained on their respective diets for 8 weeks. The aorta was removed and examined for the extent of atherosclerosis. Hypercholesterolemia atherosclerosis was reduced by 46% in Group 4 compared to Group 3. The reduction in atherosclerosis was associated with a reduction in levels of OFR production. Serum triglycerides remained unchanged and there was a slight elevation in serum total cholesterol. From these results, it was not possible to determine what flaxseed component, lignan, or $\alpha$-linolenic acid, was responsible for the reduction in atherosclerosis (Prasad, 2014).

Prasad (2014) used purified SDG in their investigation and flaxseed was replaced with 15 mg of SDG per kg body weight of rabbits. Examination of the aorta revealed that SDG reduced the development of hypercholesterolemia atherosclerosis by 73%. The development of streptozoticin (STZ) induced diabetes mellitus, a model for type 1 diabetes, is associated with reactive oxygen species. A 75% reduction in diabetes was observed with SDG treatment in this model. This was associated with a decrease in the serum and pancreatic lipid peroxidation product, malondialdehyde, a decrease in oxygen-free radical producing activity of white blood cells and an increase in pancreatic antioxidant reserve (Prasad, 2010). An animal model for type 2 diabetes is the Zucker diabetic fatty (ZDF) rat. SDG added to the drinking water reduced the incidence of diabetes from 100% in the untreated group to 20% in the SDG treated group of ZDF rats in a 10-week study (Prasad, 2014).

*Sesame; an overview*

Sesame (*Sesamum indicum* L.) is an ancient herbaceous oilseed crop. It is broadly cultured in many areas of the world mainly in tropical and subtropical parts of the world such as China, Indonesia, Pakistan, Mexico, Bangladesh, Burma, Thailand, Turkey, Afghanistan, Egypt, Sudan, El Salvador, Tunisia, Saudi Arabia, Guatemala, Sri Lanka and semi-arid are states also adapted it. Economically it is a very vital crop. It is also comprised of many bioactive compounds such as phytosterols, flavonoids and tocopherols. Due to its better quality and yield, it is also called queen from other oilseed crops. Production of sesame in all over the world is 7554200 hector areas (Namiki, 2007).

In Pakistan, the total production of sesame is 29.100 and the total production area of sesame is 70.900 respectively. Its yield is 410 kg/ha. Sesame is rich in oil, antioxidant and protein contents it is used in pharmaceutical, nutraceutical and food industries in various countries. In many countries like China, Turkey, Germany many and India it is used to cure health disorders e.g. colic acid and cancer. Roasted sesame used to make and it improves sensory and functional properties by enhancing color and flavor (Moazzami *et al.*, 2007). In tahini products, it is milled to get oil to make and oily paste (Bedigian, 2004).

It is also used as an anti-aging agent, rich in vitamin B complex, A and E and also contains minerals like phosphorus, zinc, magnesium, calcium, copper, iron and potassium. Sesame comprises two types of lignans these are sesamolin and sesamin (Murial and Arauz, 2010). Sesame acts as a photo antioxidant because of the scavenging In its molecular composition sesame contains benzodioxole and phenolic groups. The sephenolic contents have a role to perform antioxidant activity. While benzodioxole groups are commonly present in nature and act as antioxidants, anti-tumor and for various other biological purposes (Bedigian, 2004).

*Sesame Oil*

Vegetable oils comprise many antioxidants like p-carotenes, vitamin A and phenolic groups during cooking. These antioxidants considered as free radical scavengers, which are used to stop the development of cancer. Sesame oil has many health effects because it affect serum lipid amounts and for the enhancement of anti-mutagenic anti-inflammatory activities. Total fatty acid profile of sesame is 96% with the participation of 35% linoleic acid, 7% stearic acid, 43% oleic acid and 1% palmitic acid (Saydut *et al.*, 2008).

From chemical compounds of sesame like lignans play a vital role to improve health e.g. they act as neuroprotective ant proliferative, enzyme food products as a seasoning ingredient, cooking oil, salad oil, in margarine and shortening. It is also used in other industries like in soaps, cosmetics, pharmaceuticals, insecticides, perfumery and paints. It can be used the extraction of oil is pressing for this purpose pressers are used as extraction (Namiki, 2007). In the conventional method, during extraction, severe heat treatment is used which denature proteins and affect oil quality anti-oxidant and antihypertensive. It also enhances hepatic fatty acid oxidation and decreases blood cholesterol levels (Uzun *et al.,* 2007). It is used in various without winterization after the refining process. The most common method for according to previous studies 25%, 50%, 75% and 100% sesame oil used to replace fat with various emulsifiers and hydrocolloids and check their effect on the microstructural properties, fatty acid composition, rheological properties and quality of the cake. Results showed that by increase single concentration of sesame oil batter characteristics, cake volume and viscosity decrease. Disordered gluten matrix has been showing in microstructural studies. While at 50% sesame oil concentrations cake quality improved with continuous protein network and smooth structure of the cake.

It also enhances unsaturated fatty acid profile like linoleic acid by lowering saturated fatty acids. While in another study milk proteins were used to check its effect on rheological properties of oil-in-water emulsion at ambient temperature (Martinchik *et al.*, 2011). The changes in their properties under cold storage were observed in a month. For this purpose, 0.3-0.5% xanthan gum was used with 2% whey concentrate and sodium caseinate. Results showed that rheological properties with xanthan gum improved and have a dominant effect on emulsion rheology than milk proteins. It also increases the flow behavior and consistency rate of emulsion (Saydut *et al.*, 2008).

*Production*

According to the worldwide production of sesame seed 15 estimated to be 3.15 (MT) per 4 (MT) in the early 1960s. The leading producers are China and India, each with an annual yield of about 750,000 tons followed by Myanmar (425,000 tons) and Sudan year having risen from (300,000 tons). These numbers are only rough estimates of the condition without a record of the internal trade and domestic processing, as sesame is a smallholder crop and most of the yield consumed locally. International exports of sesame seeds are expected to have reached 657,000 tons having increased from 427,000 tons in 1988. India exports of sonic 100,000 tons and is now the single biggest exporter of sesame seeds, while Sudan is on the second position, exporting over 138,000 tons per year. China was the principal exporter in 1988 in the world (FAO, 2005).

**Nutritional scenario**

Sesame oil is very stable and hardly turns in hot weather. Sesame oil is rich in unsaturated fatty acids where the fatty acids composition showed there is 14% saturated 39% monounsaturated and 46% poly-unsaturated fatty acids (Roy *et al.*, 2009). Ranges of the percentage of carbohydrates present in sesame seed suggested that it has 3.2 % glucose, 2.6 % fructose and 0.2 % sucrose while the leftover quantity is dietary fibers. Also, they have necessary physiological effects including antioxidant activity, blood pressure and serum lipid-lowering potential as verified by several studies conducted on animals and humans (Uzun *et al.,* 2007).

The main protein fraction (globulin) in sesame covers about 95% of 13S globulin and seems to be a simple, salt soluble, very vulnerable to heat denaturation and parallel in subunit structure to soybean 11S globulin with more hydrophobic characteristics (Kappor, 2001).

The latter characteristic restricts the utilization of sesame proteins in certain food formulations, especially in drinks and beverages, which demonstrates the need to alter the functionality of sesame proteins before it can be utilized in the processing of limited dairy items (Padua, 2005). Functional properties mirror the intrinsic physical characteristics of the protein as impacted by high in sulfur collaborations with food components and the processing heals it (Kato *et al.,* 2005).

Ainated red naphtha-quinone color having antifungal activity, known as chloro sesamone (2-chloro-5, 8-dihydroxy-3-3methy1-2-butenyl- 1, 4-naphthoquinone), has been accounted to come from sesame root. In another examination three anthraquinones, Authrasesamones A, B and C, were segregated from the roots of sesame Anthrasesamone C is an uncommon chlorinated anthraquinone in higher plants (Hahm *et al.*, 2015). The aggregate phytosterol content in sesame seeds is -400 mg/100 g, which is higher when compared with English walnuts and Brazil nuts (113mg/100g and 95 mg/100 g, respectively). Only a quarter cup of sesame seeds provides 74.0 % of the Daily Value (DV) for copper, 35.1% of the DV for calcium and 31.6% of the DV for magnesium (Uzun *et al.,* 2007).

*Cholesterol-lowering effect*

A review of literature has suggested that there is strong evidence for sesame oil on cancer prevention, regulation of blood glucose level and lipid peroxidation in both streptozotocin as well as normal rats having diabetes. Similarly, in a research study, diabetic and ordinary rats were administered commercially synthesized with 6% sesame oil for about 42 days. At the point when diabetic rats that were fed with sesame oil were compared with other diabetic rats and results showed that whom they administered sesame oil illustrated an adequate reduction in lipid hydroperoxides. The people were requested to proceed with their general eating routine before taking an altered eating regimen for around fourteen days (Quasem *et al.,* 2009). The modified regime for the study with the addition of 40 g of baked sesame seeds was planned to be included an eating regimen for twenty-eight days going before to an additional four weeks of normal eating regimen. Fasting blood glucose level was measured for all the patients as well as body weight was measured at different intervals like on zero-day and after twenty-eight (four weeks) and fifty-six days (Bamigboye *et al.*, 2010).

Keeping back on everyday routine after the treatment including sesame seeds in diet can provide beneficial outcomes due to their utilization during treatment only while got vanished after stopping its utilization. Thus, valuable impacts on lipid profile and for cancer prevention by sesame seeds were demonstrated by the following conducted investigation. (Cooney *et al.*, 2005). As the previous studies have been carried out to bring down the cholesterol level, the major lignan of the sesame seeds have been turned out to be helpful with lipid profile however, these outcomes have been displaying differential conclusion because of the way of considered models, two elements and preparation techniques utilized for sesamin extraction.

A project was designed to check the possible link between sesamin levels in animal models that eventually lacks hypercholesterolemia LDL receptors. For this purpose, rats were assembled into sesamin, stanol ester, Atherogenic with stanol ester (4 classes) given weight control plans that were either diet or controlled diet. Results showed that serum cholesterol level was significantly raised in the group that was provided with the atherogenic diet but no reaction was found to be observed for their triglycerides level (Penalvo *et al.*, 2012).

Moreover, it has also been observed in various studies that intake of sesame seeds has demonstrated to depict a positive effect on human's lipid profile as well as positively fluencies the anti-oxidant capacity of animal models (Hsu *et al.,* 2002). In the respective study, 24 subjects could properly finish the following research. The research was designed to assess the impact on LDL oxidation; lipid, blood sex hormones and tocopherol in post-menopausal ladies of sesamin that is a noteworthy lignan present in sesame seed, half of these subjects were fed sesame seeds three weeks. To HDL fraction as well as total cholesterol was measured essentially and results declared it to be useful for post-menopausal ladies (Juan *et al.*, 2005). As half of these subjects were given 50g of sesame seed powder every day for approximately five weeks, proceeded to a washout for three weeks, however, at that point when taking 50g/day of rice powder and was sustained for a particular time to subjects for i.e. five weeks. Other groups of the study including subjects took both of the powders backward. Ingestion of high amount of cholesterol is the significant reason that plays an essential part in causing genuine cardiovascular illness risk factors. Despite sesame seed oil, many other valuable oils have not provided any such role. Worldwide, few countries especially Iran and its surroundings these seeds are used and its special dish is also made of crushed sesame named "Ardeh". The effect of 35 grams of sesame seeds oil after regular consumption of 45 days by replacing with other oils of daily usage has been found a significant reduction in hypertension in women, as well as decreased levels of serum triglycerides, were observed. Moreover, thiobarbituric acid reactive substances-TBARS was also reduced as well as a beneficial effect on body weight (BMI) and blood pressure. Moreover, the control group did not show any such effect on all of these parameters. In another research study, diabetic patients having type 2 diabetes consumed 35grams of sesame seed oil daily. The results showed that triglycerides level. The lignin content of sesame seeds has displayed important functions linked with human physiology with antioxidant activity in various research studies. In this study when lignans from sesame seeds were provided to artificially induce diabetic rats showed a beneficial effect on lipid peroxidation as well as its serum blood level (Hsu *et al.*, 2004). Diabetes Mellitus was induced using alloxan in rats thereby control group (diabetic and non-diabetic), as well as three groups receiving the treatment, became diabetic. While non-diabetic rats received sunflower oil and remaining diabetic trial groups were fed with 0.5 % lignans of sesame seed for 4 weeks, 0.25 % u-tochopherol in oil mixed with sunflower and the third group received 0.25% alpha-tocopherol + 0.25% sesame lignans mixed with sunflower oil. The study was conducted to analyze the effect of sesame seeds on liver tissues, RBC layer, lipid peroxidation and lipid profile. All the groups were provided with sesame oil except the control group and the result demonstrated that total cholesterol was reduced in those groups receiving treatment. Moreover, non HDL cholesterol was increased and lipid peroxidation, as well as triacylglycerol level, was reduced in the sesame lignin group and tocopherols sesame containing diet as compared to tocopherol group. Biochemical content of the whole untreated form of sesame seeds along with a physiochemical profile and two different varieties of sesame seeds SI and S2 produced as a result of hulling and burning at high temperatures were selected to prepare Tehineh which is referred as sesame glue arranged that was a sweetened tahineh. The findings of this study illustrated that both S1 and S2 possess a high content of all the components including cinder, dietary fiber and polyphenols along a lower amount of proteins and oil (Cooney *et al.*, 2005).

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