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REVIEW ARTICLE

Bioactive Constituents as a Potential Agent in Sesame for Functional and Nutritional Application

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Abstract

Sesame seeds have been grown since ages in tropical regions in almost all parts of the world. Sesame is a flowering plant which is cultivated throughout the countries. Sesame is and foremost important and one of the oldest oilseed known to man. This wonder oilseed is a baggage of nutritive value as well medicinal properties. In ancient India, sesame oil was frequently used as a chief ingredient in various ayurvedic preparations and remedies. In countries like Japan and China sesame oil was also used for providing energy, soothing mind, preventing aging and for good health. Sesame contains approximately 50% of oil which is highly resistant to oxidative stability. Along with oil sesame is an affluent source of nutritious protein, carbohydrate, dietary fibre, zinc, magnesium and many other minerals. Sesame seeds both directly and in roasted in various traditional confections in India in the form of *laddus, chikki, tilgulpoli* etc. Sesame seed is also used as a major ingredient in many international cuisines like *Tahini, Daqqa, Gyintholik* etc. Sesame is a good source of bioactive constituents. These bioactive constituents include lignans, tocopherol and phytosterols. Lignans are the oxidative coupling products of β-hydroxyphenylpropane. Sesame contains both oil- dispersed lignans and glycosylated lignans. Many of these glycosylated lignans are interconvertible and have tremendous medicinal properties. Sesame seeds majorly contain sesamin, sesamolin, sesaminol, sesamol and many other lignans. These lignans have many pharmacological properties e.g. antioxidant activity, antiproliferative activity, enhancing antioxidant act of Vitamin–E in lipid peroxidation systems, lowering cholesterol, neuroprotective effects, reducing the incidences of breast and prostate cancer etc. The tocopherols, the major vitamin E play a crucial role in prevention of human. Tocopherol vitamers are free radical scavengers that work as lipid soluble antioxidants. Sesame contains both α and γ tocopherols. The collaborative synergy of γ tocopherol with sesaminol or sesamin of sesame seeds makes it to comparable to that of α tocopherol. Sesame seeds contain nearly 400-413 mg/100g of the phytosterols. These phytosterols reduces blood cholesterol levels by resembling to cholesterol in humans. They are also capable in anti- cancer, anti- atherosclerotic, anti-inflammatory and anti- oxidative effects.

Keywords: Sesame, Bioactive constituents (lignans, tocopherols, phytosterols), Health benefits.

1. Introduction

Sesame, *Sesamum indicum L.*, is commonly known as Sesamum or benniseed. It belongs from the Pedaliaceae family. Sesame is majorly cultivated in India, Sudan, China and Burma. These major countries produce approximately 60% of total world production (El Khier *et al.*, 2008). It is well thought-out to be one of the first plants for its seed value. It has been originated in Africa (Ram *et al*., 1990) or Syria and nearly in the civilization of Babylonia about 3000 BC (Johnson *et al*., 1979). It is also believed that sesame may have originated in the savanna grasslands of central Africa scattering later to countries like Egypt, India and China.

According to ancient Chinese civilization sesame was described as a food having various physiological effects, especially useful for providing energy, a soothing frame of mind, and preventing aging when eaten over a long period. In traditional Indian medicine, i.e. Ayurveda, sesame oil has been used as the basal oil for human body massage (Weiss, 1983; Joshi *et al*., 1961). In Japan also people have believed traditionally that sesame is very good for healthy lifestyle (Namiki, 1995). Therefore, sesame has been used extensively for thousands of years as a seed of worldwide significance in various forms like edible oil, paste, cake, confectionary purposes, and flour. Sesame seed and oil have been evaluated as a representative health food and widely used for their good flavour and taste (Namiki and Kobayashi, 1989).

Sesame seeds are the affluent source of nutritious fat, protein, carbohydrates, dietary fibre, zinc, magnesium and many other minerals. Sesame oil is distinguished oil as it is highly defiant to oxidative rancidity even during prolonged exposure of air, light and water (Global Agri-Systems, 2010). This outstanding stability of the oil is attributed due to the presence of potential antioxidants namely lignans, tocopherols and phytosterols (Elleuch *et al*., 2007; Lee *et al*., 2010).

2. Indian Scenario

A new innovative technology for increasing the production of the oilseeds was launched as Technology Mission on Oilseeds in the year 1986. The mission was introduced with the aim to create and manage conditions that would harness the best of production, processing and storage technologies to attain self-reliance in edible oils (www.pnbkrishi.com/sesame.htm).

Within a period of ten years the Mission was able to achieve substantial progress in oil seed production. This transformation was termed as the Yellow Revolution. The oilseed production in India is since then estimated to be 25.5 million tonnes. India is noticeably included in the top five countries of the world in oilseed production. India cultivates around nine edible oilseeds in which sesame ranks fifth in production, followed by groundnut, rape seed, soya bean and sunflower in the series. India produced 0.62 million ton of sesame (FAO, 2012).

2.1 Area of cultivation

Beside India, China, Sudan, Mexico, Turkey, Burma and Pakistan are also prominent sesame producing countries on the world map. In India, the major two sesame producing states are West Bengal (843 Kg/ha) and Karnataka (845 Kg/ha) respectively. The other states with corresponding area of cultivation for sesame are jotted down in Fig 1.

2.2 Season

Sesame in India is grown in *Kharif*, semi-arid, *rabi* and summer season or even more than one season in some states in crop rotation. In state like Gujarat, Maharashtra, Madhya Pradesh, Chhattisgarh and Orissa sesame is grown in of *Kharif* and *Rabi* season both, whereas as a summer crop after late potato crop in Orissa and in almost round the year in parts of Southern India. It can withstand a temperature range of 25-27°C which encourages rapid germination, initial growth and flower formation. Low temperatures at flowering stage can result in the production of sterile pollen, or pre-mature flower drop. Sesame is extremely susceptible to water logging and heavy continuous rains. Sesame is predisposed to hail damage at all stages of growth. It cannot withstand frost, continued heavy rain or prolonged drought. The proper time for planting of sesame under northern Indian conditions is last week of June to first week of July. A range of 25-27°C temperature is suitable for its proper germination. In South India sowing time during *Kharif* season may vary from May to July and for *Rabi* season from October to November.

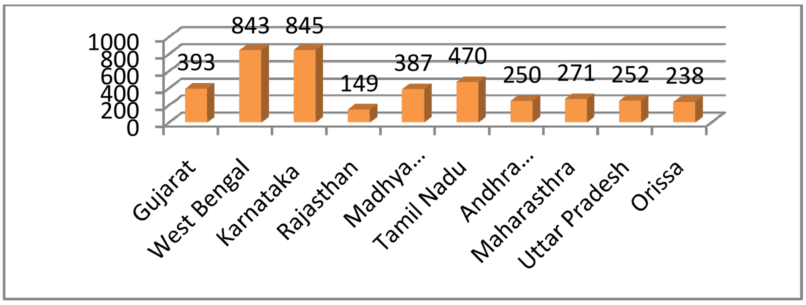


Fig 1: State-wise area of cultivation of sesame seeds in India

2.3 Soil

Sesame thrives best on sandy loam soil with adequate soil moisture. Though sesame can be grown widely on array of soils provided they are needed to be well drained. Its cultivation is vulnerable in highly alkaline, acidic and sandy soils. Neutral soils have shown best results and therefore ideal for its growth, but considerable results have also been obtained on both slightly acidic and alkaline soils. Soil pH ranging 5.5 to 8.0 is considered best for the growth of the sesame crop. Well–drained loams and heavy clay loam can also be used for the growth of the crop.

2.4 Oil Content

Sesame is a rich source of oil (50%) and protein (18-20%). Approximately 75% of oil which is produced in India is undergoes for oil extraction, 2.5% for planting purposes and remaining is used in confectionary items and in religious Hindu ceremonies. Major chunk of the oil i.e. 73% is used for edible purposes, 8.3% goes in hydrogenation and 4.2% is used in industrial purposes for the manufacturing of paints, pharmaceuticals and insecticides. In south India sesame oil is used as an important medium for cooking. Low grade of sesame oil is utilized for soap making, perfumed oils, anointing the body and for various medicinal purposes.

2.5 Colour Variations of Sesame across India

Location	Variety
Gujarat	White
	Brown
	Black
West Bengal	White
	Dehusked
Andhra Pradesh	Black
	White
Assam	Black
	White
Orissa	White

Source: Nagendra Prasad *et al.* (2012).

2.6 Rotations

In North India, sesame is commonly grown in mixed rotation with *arhar*, *jowar*, cotton, maize, groundnut and *bajra* crops. In *rabi* season, sesame is grown as a pure crop subsequent to linseed, barley and gram, lentil etc. In *Kharif* season sesame is grown both as pure and mixed crop.

2.7 Cultivation

Sesame seeds are very small in size therefore field must be prepared for good germination. Seedbed should be prepared keeping into consideration that the bed should be fine, firm and compact. Generally, one ploughing session is followed by two to three harrowing followed by planking leads to good condition of field for planting.

2.8 Sowing

The sesame crop should be sown in lines. Between the rows a space of around 45 cm and between the plants a distance of 15 cm should be maintained. In one hectare area, for uniform distribution seeds should be mixed prior with dry soil or powdered farm yard manure or sand. Seed should not be sowed beyond 2-3 cm and enough soil moisture should be maintained at the time of sowing. Agrosan G.N. or Ceresan is used as a pre treatment of the seed before sowing at the rate of 2 g per kg of seed.

2.9 Fertilizer Management

Sesame is usually grown by the small and marginal farmers on comparatively poor nutritional soils which results in poor average yields. Moreover as sesame is not considered as a main crop hence crop is put on enduring fertility of the foregoing crop and spared fertilizers are applied. For obtaining high yields and good crop, fields should be applied with 30 kg of nitrogen and 60 kg P_2O_5 and 30 kg K_2O per hectare along with organic manure. Application of nitrogen and phosphorus is necessary for increasing the number of capsules per plant as well as number of seeds per capsules. In sandy soil submission of nitrogen in three splits which includes one- third 30 days at the time of sowing, one–third 30 days after sowing and remaining one third 50 days after sowing. Whereas in heavy soils application of nitrogen in two which involves both splits two- third at sowing and one–third at flowering stage.

2.10 Water Management

Sesame crop do not require water for irrigation, but this crop is at risk to drought in various physiological growth stages. The crop requires in totality about 50 cm of water for its entire growth period. First phase of irrigation is required after 24-40 days of sowing. Second phase and third phase irrigation should be given at flowering i.e. 45-50 days and pod development i.e. 65-70 days after sowing. Irrigation at, or just after or at the maximum flowering stage is mandatorily essential so that the capsule should develop fully.

2.11 Harvesting

Sesame crop are advisable to harvest, when the yellow colour is developed on the leaves and capsules, along with it defoliation starts. The capsule starts maturing from the base first and then starts maturing at the top. As soon as the plant turns yellowish- brown the plant is harvested. The crop should not be stand dead ripe in the field, which may lead to substantial loss of the crop due to shattering. Bundles of harvested crops are stocked erect for six to eight days for drying on the threshing floor and later on it is threshed (www.mssrf.org).

3. Nutritional Profile of Sesame

Sesame is an amazingly healthful food utilized for over 5,000 years, it is a most potent, nutrient-dense medicinal foods still used from ancient times. Sesame seeds are not only praised for their nutritional content in seed form, but are also highly valued for their rancid-resistant oil. Sesame seed majorly constitutes of oil, protein, carbohydrate and many minor minerals and vitamins. The chemical composition of sesame oilseed is about 50-52% oil, 17-19% protein and around 16-18% carbohydrate (Tunde-Akintunde and Akintunde, 2004). Sesame seed oil content depends upon the species and conditions in which seed is grown. The sesame hull also comprises of oxalic acid, crude fibre, calcium, zinc, magnesium and other minerals. As oxalic acid is considered as an anti-nutritional factor which interferes with the bioavailability and absorption of calcium. A study by Akinoso *et al.* (2011) found that dehulling of sesame seed reduces the oxalic acid content from 3% to 0.25% by the seed weight. Sesame seed oil is a rich source of unsaturated fatty acids where the fatty acids composition of the oil mainly includes oleic (18:1=39.1%) and linoleic (18:2=40.0%) acids, with palmitic (16:0=9.4%) and stearic (18:0=4.76%) acids in smaller amounts, and linolenic (18:3=0.46%) acid in trace amount. Sesame oil contains essential fatty acids in considerable amount which includes n-3 (linolenic acid) and n-6 (linoleic acid).

The protein content of sesame seed comprises of about 95% of 13S globulin and seems to be a simple, salt soluble, very susceptible to heat de-naturation. This subunit is identical to the 11S globulin subunit in soybean which has more hydrophobic properties. This property confines the usage of sesame proteins in fluids and beverages formulations, which requires modifications in the functional and structural structures of sesame proteins to be applied for value addition of dairy products (Kapadia *et al.,* 2002). Sesame seed protein enclosed of appreciable amounts of Arginine (140 mg), Leucine (75 mg), Methionine (36 mg), Lysine (31 mg), Cystine (25 mg).

The carbohydrate content of sesame is poised of 13.5% which includes 3.2% glucose, 2.6% fructose and 0.2% sucrose and remaining is dietary fibre. It also contains an oligo-sugar planteose [O-α-D-galactopyranosyl-(1,6)-β-D-fructofuranosyl-α-D-glucopyranoside] without starch content. The major carbohydrates content of sesame seed is present as dietary fibers and its content has been reported to be 10.8% (Namiki, 2007; Anilakumar *et al.,* 2010).

Sesame seed contains a significant amount of vitamin B. Since, the vitamin B is present in the seed coat or the hull of the seed, therefore hulled sesame seed contains no vitamin B, sesame seed flour or whole sesame seed should be consumed for complete intake of vitamin B. Among the other vitamins in sesame seed, the existence of vitamin E is very interesting in relation to its effectiveness as a health food. Though, tocopherol content in sesame oil is less than soybean and corn oil. Moreover, the tocopherols present in sesame seed are mostly as in γ-tocopherol form, and the content of α-tocopherol is very low. It is well known fact that vitamin E activity of γ-tocopherol is less than 10% that of α-tocopherol. But synergistic effect of γ-tocopherol with sesame lignans makes its equivalent to that of α- tocopherol due to which sesame shows better effects on anti-aging and antioxidant activity. Besides lignans and tocopherol sesame is also enriched with another bioactive constituents i.e. phytosterols. The total phytosterols content in sesame seeds is nearly about 400-413 mg/100 g, which is higher as compared to English walnuts and Brazil nuts (113 mg/100g and 95 mg/100 g, respectively) (Phillips *et al.,* 2005).

Sesame seeds are a significant source of important minerals which comprises Potassium, Phosphorus, Magnesium, Calcium and Sodium (Loumouamou *et al.,* 2010). Potassium has the highest concentration, which also plays a vital role in the synthesis of amino acids and proteins. Calcium and Magnesium together are required for the major functions like photosynthesis, nucleic acids and carbohydrate. Individually Calcium helps in teeth development whereas for enzyme activity magnesium plays a crucial role. For the better and healthy bone development, kidney function and cell growth phosphorus is needed. The bulk of these minerals in the sesame oil make its highly nutritionally acceptable among the customers. The detailed of nutritional profile of sesame is presented in Table 1.

4. Utilization of Sesame Seed

One of the obvious reasons for using sesame seed being it contains 50% of oil, its stability against oxidative degradation and superior nutritional profile which majorly contains about 20% protein plus various minor nutrients.

Sesame is highly preferred as a traditional food in various parts of the world especially in the eastern part of the world. Sesame grains are eaten in fried form, or mixed in sweet balls. In eastern part of the world people prefer roasted flavour of sesame. Roasted variety of sesame is used as a topping on many baked foods such as burgers, breads, cakes, cookies and crackers. In Japanese cuisine tofu is prepared from mashed sesame seed and arrowroot starch (Sato *et al*., 1995). Sesame flavour is also popularly used in Korean cuisine as well in the form of Korean food in which sesame plant leaves are used in the form of wrap eaten with meat preparations and other vegetables.

Earlier majorly sesame was commercialized in the form of sesame oil only but now a days with the advancement in technologies it is not only restricted to the areas where it grew but it is also sold in the form of meal, confections, bakery, paste etc. Sesame seeds are also consumed directly and it is liked as well because of its particular nutty flavor. Roasted flavour of sesame seed is also used in making spreads. De-hulled sesame seeds are used as toppings on various products like breads sticks, cookies, breads, energy bars which also improves overall acceptability of the product (http://www.naturland.de/).

5. Bioactive Constituents of Sesame

5.1 Sesame Lignans

According to Haworth and Kelly (1936) lignans are described as a group of phenylpropanoid dimmers. The central carbon is linked by its propyl side chains to C6–C3 units (Umezawa, 2003; Willfor *et al.,* 2006). Therefore we can define lignans as a group of natural compounds which are referred as oxidative coupling products of β-hydroxyphenylpropane. They comprise dimmers of phenyl propane units. According to International Union of Pure and Applied Chemistry (IUPAC) nomenclature, the lignans are 8, 8''-coupled dimers of coniferyl or cinnamyl alcohols. They are widely found as a minor component in variety of plants of the plant kingdom, especially in bark of wood (Namiki, 2007).

Sesame seeds contain many antioxidant lignan compounds which include lipid-soluble lignans and water-soluble lignan glucosides. Most of them are fat soluble lignans and therefore elute into the oil on extraction. So far 16 varieties of lignans have been isolated from sesame, rests are glycosylated and hence been isolated from the oil free meal. Sesamin and sesamolin are the major aglycon lignans (Budowski and Markley, 1951; Bedigian *et al*., 1986). The minor aglycon includes Sesamol, sesaminol, sesamolinol, pinoresinol, matairesinol, lariciresinol and episesamin (Osawa *et al*., 1999; Liu *et al*., 2006). The lignan glycosides also consist of mono- di- and triglucosides of sesaminol, sesamolinol and pinoresinol (Hemalatha, 2004). Sesaminol triglucoside, sesaminol diglucoside and sesaminol monoglucoside are the most plentifullignan glycosides in sesame.

Sesamin and sesamolin have been reported to have many pharmacological properties, e.g. antioxidant activity (Suja *et al*., 2004), anti-proliferative activity (Yokota *et al*., 2007), enhancing antioxidant activity of vitamin E in lipid peroxidation systems (Ghafoorunissa *et al*., 2004), lowering cholesterol levels (Visavadiya and Narasimhacharya, 2008), increasing hepatic fatty acid oxidation enzymes (Ashakumary *et al.*, 1999), showing antihypertensive effects (Lee *et al*., 2005; Nakano *et al*., 2008), neuro-protective effects against hypoxia or brain damage (Cheng *et al.*, 2006) and reducing the incidence of breast and prostate cancer (Adlercreutz, 2002).

The extra-ordinarily high oxidative stability in sesame oil has been related closely with the presence of the lignans such as sesamolin and sesamin, sesamol. (Abou-Gharbia *et al*., 1997; Abou-Gharbia *et al.*, 2000; Lee *et al.*, 2010; Shahidi and Naczk, 2004). Sesamin and sesamolin are major lignans found in sesame seeds and their content in sesame seeds are reported as 200-500 mg/100 g and 200-300 mg/100 g, respectively (Kamal-Eldin and Appelqvist, 1994; Shahidi and Naczk, 2004).

During high temperature roasting process, sesamolin can degrade into sesamol or sesamol dimmers, while chemical refining and bleaching process converts sesamolin into sesaminol and sesamol. Increase of sesamol formation in sesame oil as sesame seeds received high thermal energy from roasting processing has been reported (Shahidi and Naczk, 2004). Sesamin and sesamolin are reported not to possess high free radical scavenging activity compared to sesamol.

5.1.1 Chemistry and Biosynthesis of Sesame Seed Lignans

5.1.1.1 Oil Soluble (or oil dispersed) Lignans

According to Namiki *et al*. (1995) sesamin and sesamolin have been deliberated the major oil soluble lignans in sesame seeds. Sesamin (1), Sesamolin (2), Sesaminol (3), Piperitol (4), Sesamolinol (5), Pinoresinol (6), (+)-episesaminone (7), Sesangolin (8), 2- Episesalatin (9), Hydroxymatairesinol (10), Allohydroxymatairesinol (11) and Larisiresinol (12) are present in small quantities. These oil soluble lignans holds the phenolic group site which are responsible for antioxidant activity in sesame seeds (Nagashima and Fukuda, 2004).

5.1.1.2 Glycosylated Lignans

They are majorly found in defatted sesame flour (DSF), due to the development of antioxidant activity after the treatment of DSF with β – glucosidase the availability of water – soluble and potential antioxidant lignans in sesame seeds were scrutinized. Katsuzaki *et al.*, 1992; 1993; 1994 a,b quarantined and categorized as Sesaminol triglucoside (13), Sesaminol diglucoside (14a), Sesaminol monoglucoside (15), Pinoresinol triglucoside (16), Two isomers of pinoresinol diglucoside (17a,b), Pinoresinol monoglucoside (18).

According to Namiki (1995) sesamolin and sesamolinol retain an oxygen bridge between their respective benzene and furofurann rings. This characteristic feature is ominously present in genus *sesamum* lignan structure exclusively, whereas sesamin is a very common lignan present in numerous plant species and in their different parts. Certain groups in the sesame species lignans such as methylenedioxyphenyl group (-O-CH_2-O-) are also witnessed in other lignans like dibenzocyclooctadiene lignans (Chang *et al.*, 2005).

Table 1: Nutritional profile of sesame seeds

Nutrients	Amounts	Nutrients	Amounts
		Fatty Acid Composition Seed	
Proximate Principles			
Moisture (g)	5.3	Linoleic (18:2)	16
Protein (NX6.25)	18.3	α Linolenic acid (18:3)	0.4
Fat (g)	43.3	Total polysaturates	16.4
Mineral (g)	5.2	Total saturates	6
Crude Fibre (g)	2.9	Oleic (18:1)	18
Carbohydrates (g)	25	Oleic (18:1)	18
Energy (Kcal)	563		
Calcium (mg)	1450	**Essential Amino Acids**	
Phosphorus (mg)	570	Approximate total (g/100gms)	2.93
Iron (mg)	9.3	Arginine (mg/gmN)	750
		Histidine (mg/gmN)	170
Vitamin Content		Lysine (mg/gmN)	170
Carotene (μg)	60	Tryptophan (mg/gmN)	80
Thiamine (mg)	1.01	Phenylalanine (mg/gmN)	370
Riboflavin (mg)	0.34	Tyrosine (mg/gmN)	230
Naicin (mg)	4.4	Methionine (mg/gmN)	180
Folic Acid (μg) Free	51	Cystine (mg/gmN)	120
Folic Acid (μg) Total	134	Threonine (mg/gmN)	230
		Leucine (mg/gmN)	500
Mineral and Tr Elements			
		Isoleucine (mg/gmN)	250
Copper (mg)	2.29	Valine (mg/gmN)	290
Mangenese (mg)	1.32		
		Fatty Acid Composition Oil	
Molybdin (mg)	0.204		
Zinc (mg)	12.2	Palmitic (16:0)	9.7
Cromium (mg)	0.087	Stearic (18:0)	4
		Total saturates	13.7
Fatty Acid Compositi of Seed			
		Palmitoleic (16:1)	0.1
Fat	40	Oleic (18:1)	41.2
Palmitic (16:0)	4	Total monosaturates	41.3
Stearic (18:0)	1.6	Linoleic (18:2)	44.5
Total monosaturates	18	Total polysaturates	44.5

Source: Indian Council of Medical Research (1991).

Table 2: Ancient recipes of sesame seeds across the world

S. No.	Recipe Name	Region	Recipe
1	*Til Pitha*	India (Assam)	A type of pancake made with special class of rice preparation and generally made only on special occasions like Bihu in Assam. Bora saul, a glutinous type of rice is soaked and ground.
2.	*Til Ladoo*	India (Punjab and Tamil Nadu)	Ladoos are made with mixing white and black sesame seeds with jaggary, grated coconut and rice, and then shaped in round ball.
3.	*Idli milagai podi*	India (Tamil Nadu)	It's a coarse mixture of ground dry spices that typically contains dried chillies, washed black gram (bean), chickpea and sesame seeds.
4.	*Tilgul Poli*	India (Maharashtra)	*Tilgul poli* is the main preparations made on Sankranti. This is a traditional recipe for 'Makar Sankranti'. It contains sesame seeds and jaggery. *Gulpoli* is prepared as a *naivedyam* (offering) for God.
5.	*Tahini*	Jordan	It's a paste of roasted sesame seeds. In this recipe it is combined with curds which make it a unique bitter-sour product. The paste is widely used to make salad dressings, dips and sauces.
6.	*Daqqa*	Egypt	It is a spice blend in combination of coriander, cumin, fennel, mint, nigella seeds, nuts, pepper, salt and thyme
7.	*Gyin thohk*	Myanmar	It's a ginger salad along with fermented tea leaves, peanuts, garlic and coconut.

Source: SAARC oils and fats today, (November 2011)

Formation of lignan is entirely dependent on the stage of seed maturity (Kato *et al.*, 1998). The mature seeds have the capacity for proficiently converting (+) - pinoresinol into (+) - piperitol and (+) - sesamin, whereas the younger seeds have the latent to transform (+) – sesamolin (Jiao *et al*., 1998) and sesaminol content is amplified with termination of seed maturation (Ono *et al.,* 2006).

It was also reported that sesame seeds undergoes phenomenal changes during germination process. During early phase of germination only (+) - episesaminone tri- and diglucosides are produced. It was also noticed that in early level of germination that is precisely near to 48h, sesamin and sesamolin almost fades off. However, increment in the content sesaminol diglucoside has been reported (Kuriyama *et al*., 1995; Ishiyama *et al*., 2006).

5.1.2 Alterations in Sesame Lignan during Processing Activities

It has been reported by Budowski and Markley, (1951) that sesame oil is best therapeutic oil as it resistant to oxidation in comparison to other edible oils. This leads to sustaining sesame oil for a longer period of time during storage from rancidity and free fatty acid content. Fukuda *et al*. (1988) reported the sesame oil remain unaltered in comparison to soybean, rapeseed, safflower and corn oil. It was found that all these edible oils start getting oxidized at 60˚C within a time span of 5-20 days of incubation. On contrary refined sesame oil was starting oxidized after 35-40 days and roasted sesame oil remain in frangible even after 50-60 days of storage. Refined sesame oil contains approximately 6-60 mg of sesaminol (Fukuda *et al*., 1986a). During the bleaching process the sesamolin is disintegrated into sesamol and oxonium ion by protonlysis leading to formation sesaminol with new carbon- carbon bond, this inter molecular adaptation indicates the transfiguration of sesamolin to sesaminol (Fukuda *et al.*, 1986b). It is well evident that refining of sesame oil results in reduction of γ- tocopherol still refined oil holds a strong antioxidant activity in comparison to the crude sesame oil.

According to Fukuda *et al.* (1986a) sesaminol potential as an antioxidant is similar to that of the sesamol and γ- tocopherol. The antioxidant activity of refined sesame oil is by enlarge attributed to sesaminol and residual γ- tocopherol as sesamol developed from sesamolin is impassive by deodorization.

The roasting condition determines the qualitative characteristics of the roasted sesame oil which includes flavor, color and oxidative stability. It has been seen that oxidative stability and browning of the roasted sesame oil are increased with the increase in roasting temperature and time. Sesamol content are not directly interconnected with increase in roasting temperatures, still sesamol is produced from sesamolin during the course of roasting by thermal degradation. It

Table 3: Bioactivities of major sesame lignans

Bio act constituent	Structure	Yield in sesame oil	Activity
Sesamin	Furofuran type lignan withβ-β' linked structure	0.4%	• Lipid and glucose metabolism • Hypertension • Anti-inflammatory activity by inhibiting delta 5-desaturase. • It increases γ tocopherol levels in plasma and liver of humans. • Free radical scavenging. • It protects liver against ethanol- and carbon tetrachloride induc damage. • It inhibits vascular superoxide production. • Promote angiogenesis • It provides neuro protection. • It exhibits bactericide and insecticide activities.
Sesamolin	one acetal oxygen bridge in a sesamin structure	0.3 %	• Increase both the hepatic mito-chondrial and the peroxisomal fatty a oxidation rate. • Synergistic for pyrethrum insecticides • Inhibits mutagenesis induced by H_2O_2
Sesaminol	bulky samin group at the ortho position of phenol group	0.1 %	• Inhibiting the membrane lipid peroxidation • Microsomal peroxidation induced by ADP-Fe^{3+}/NADPH • Oxidation of LDL induced by copper ions • Increase the availability of tocopherols • Inhibit oxidative damages in DNA
Sesamol			• Antioxidant activity • Free radical scavenging activity • High antioxidant activity of it is helps in protecting cell membra against lipid peroxidation, preventing LDL oxidation and microsor peroxidation • It has estrogen agonistic effect therefore useful for conventio hormone replacement therapy in postmenopausal women.
Other lignans			• Chlorosesamone, Hydroxysesamone and 2,3-epoxysesamone ha inhibitory effects on the spore germination of the pathogenic fun *Cladosporium fulvum.* • Episesamin reported to possess anticancer activity against hum lymphoid leukemia cells.

Source: Dar and Arumugam, 2013

was also reported by Namiki (1995) that all these bioactive components do not work in isolation and be responsible for the high oxidative stability of roasted sesame oil. All these bioactive components work synergistically inside the roasted sesame oil against oxidative deterioration.

5.1.3 Bioactivity of Sesame Seed Lignans

5.1.3.1 Adequacy of Insecticidal Activity

Eagleson, (1942) was the first one to observe that sesame oil act as an insecticidal stimulant in strengthening the noxious effects of pyrethrins and reteones. According to Bureau of Entomology and Quarantine of the United States Department of Agriculture (USDA), verified sesamin as the compound conscientious for the synergistic activity, along with it sesamolin was also isolated and identified as another potential component present in sesame oil which can be acting insecticide. Haller *et al.* (1942a) and Haller *et al.* (1942b) found that synergistic response of sesamin compounds with pyrethrins and retenones also requires the fundamental features of methylenedioxyphenyl. Research carried out by Moore and Hewlett (1958) established that 3, 4-methylenedioxy substituent as a structural feature responsible for the insecticidal synergism with pyrethrins.

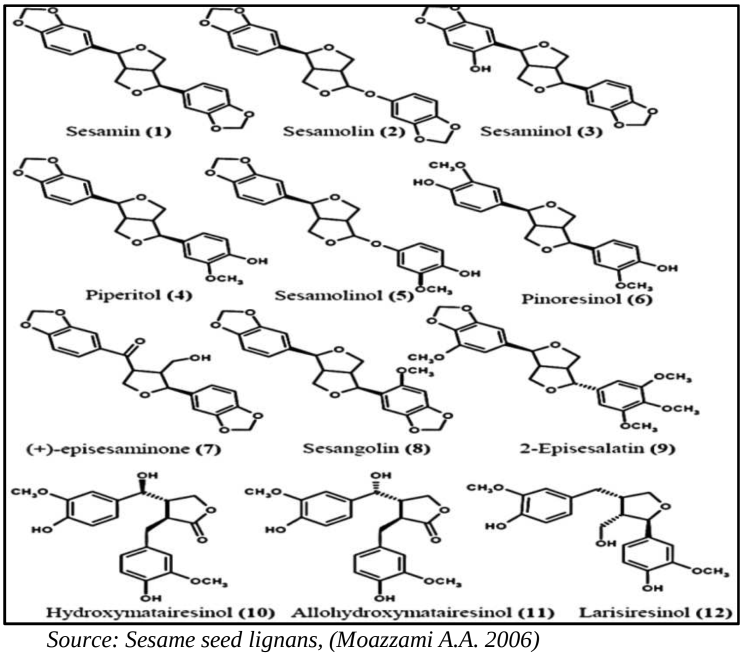
5.1.3.2 Response on Fatty Acid Metabolism

In a study carried on rats showed that sesamin reduces the activity of enzymes involved in fatty acid synthesis and their gene expression which involves acetyl-CoA carboxylase, fatty acid synthase, ATP citrate lyase, and glucose-6-phosphate dehydrogenase. With the increase in the concentration of sesamin in the diet, the mRNA level of the sterol regulatory element binding protein-1 (SREBP-1) and the levels of precursor form of this protein decreases (Ide *et al*., 2001). It was later found that, mixing of sesamin and episesamin in equally increases mRNA expression of most of the enzymes involved in fatty acid oxidation the rat liver (Tsuruoka *et al*., 2005; Ide *et al.,* 2009). Sesame seed lignans contribute in the commencement of peroxisome proliferator activator receptor-alpha (PPARα) which stimulates fatty acid oxidation in the liver and skeletal muscle (Ide *et al*., 2001). This further increases enzymes involved in β-oxidation of fatty acids. Sesamin also showed increased expression of carnitine palmitoyl transferase (CPT), which is a rate-limiting enzyme in β-oxidation of fatty acids. The uncoupling proteins (UCPs) levels increased with the activation of PPARα which restrict the competence of mitochondria and increases the calories required to produce energy (Ashakumary *et al*., 1999; Kushiro *et al.,* 2002; Kushiro *et al.,* 2004). The increased expression of UCPs as well as β-oxidation enzymes of fatty acids proportionally increases the ability to burn fat which in turn increases energy expenditure. Sesame lignans are also capable of inhibiting the esterification of fatty acids and help in promoting ketogenesis (Fukuda *et al*., 1998; Umeda-Sawada, 1998).

5.1.3.3 Impact on Levels of Cholesterol in Body

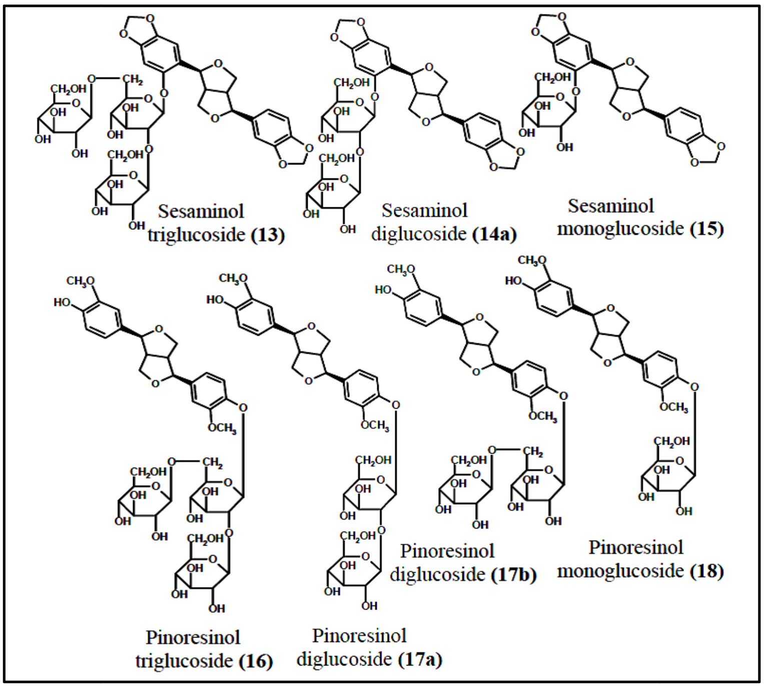
Sesame oil has a capacity to decrease hepatic 3-hydroxyl-3-methylglutaryl coenzyme A reductase (HMG-CoA reductase) enzyme activity along with its intestinal absorption. HMG-CoA reductase is rate limiting enzyme in cholesterol synthesis hence reduction in serum and liver cholesterol in rats (Hirose *et al*., 1991). In a study by Hirata *et al.* (1996) on 12 hypercholesterolemic men shows reduction of total cholesterol by 9%, LDL-C by 16.5% and apoprotein B by 10.5%. Two variants of sesamin capsules i.e. 32 mg for 4 weeks followed by 65 mg for 4 weeks were prepared and given to the subjects.

In a similar study conducted by Chen *et al.* (2005) shows that with the consumption of 40g roasted sesame seeds by 21 hypercholesterolemic men reducation in serum total cholesterol by 6.4% and LDL- cholesterol by 9.5% was observed. A study by Wu *et al.* (2006) also observed similar results with the intervention of 50g of roasted sesame seed in 24 postmenopausal women subjects. In all above mentioned intervention studies, High density lipoprotein cholesterol remained unchanged. In another experiment carried out with an attempt to see the effect of combination of sesamin and phytosterols in rats. It was seen that though both have magnificent cholesterol reducing property but there interaction resulted in nullified effect due absorption of sesamin by the phytosterols (Moazzami *et al*., 2007).



Source: Sesame seed lignans, (Moazzami A.A. 2006)

Fig 2: Oil soluble or oil dispersed sesame lignans.



Source: Sesame seed lignans, (Moazzami A.A. 2006)

Fig 3: lignan glucosides isolated by Katsuzaki *et al.* (1992, 1993, 1994a, b) in deffated sesame flour.

5.1.3.4 Effect on Alcohol Metabolism

Episesamin and sesamin has a potential to modulate the enzyme activities of glutamate transaminase (GOT), aspartate aminotransferase (AST), glutamic pyruvic transaminase (GPT) and alanine aminotransferase (ALT). They are also capable of modulating bilirubin concentrations which are elevated by the inhalation of ethanol (Akimoto *et al*., 1993). Consumption of equal content of sesamin: episesamin inhibit the elevation of hepatic enzymes involved in ethanol. The effectiveness of sesamin in alleviating the symptoms of intoxication of alcohol or tobacco withdrawal was associated mainly with increased mRNA levels of aldehyde dehydrogenase 1 family members (Tsuruoka *et al.*, 2005; Kiso *et al*., 2005).

In studies compiled on sesamin and episesamin it has been found that they are proficient in increasing the production of dihomo-γ-linoleic acid at the cost of arachidonic acid. The filamentous fungus *mortierella alpine* forms a complex with lipids which is rich in this acid by inhibiting Δ5 desaturation. Sesamin also inhibit the activity of acyl-CoA: 1-acyl lysophosphatidylcholine acyltransferase (LPCAT) which is responsible for channelizing fatty acids substrates to phosphatidylcholine for subsequent desaturation (Chatrattanakunchai *et al*., 2000). Theses inhibitory steps has further implications on reduction of prostaglandin E2 and thromboxane B2 which also originates from arachidonic acid and well as interleukin -1 beta (Umeda- Sawada *et al*., 2003). Consumption of sesamin and alpha tocopherol together by Dawley rats for 3 weeks results in effects of inflammatory eicosanoids and changes in the immune function, e.g. Reduction of the plasama histamine, decreased production by mesenteric lymph node lymophcytes of Immunoglobulin E (IgE), elevated levels in Immunoglobulin M (IgM), Immunoglobulin A(IgA), Immunoglobulin G (IgG) (Gu *et al*., 1995).

5.1.3.5 Hypertension

Various studies conducted on hypertensive rats shows that sesamin have antihypertensive effects. According to Matsumura *et al.* (1995) sesamin feeding for 5 weeks alleviate the development of deoxycorticosterone acetate (DOCA) helps in lowering

Table 4: Major sesame seed lignans and lignan glucosides range, molecular formula, UV absorption and extinction coefficient

Sesame lignans	Range (mg/100 seed)	Molecular formula (Mwt)	λ_{max} (nm)	ε ($g^{-1}L$)
Sesamin	77-930	$C_{20}H_{18}O_6$	287	23.02
		354	236	26.01
Sesamolin	61-530	$C_{20}H_{18}O_7$	288	21.79
		370	235	24.85
Sesaminol	0.3-1.4	$C_{20}H_{18}O_7$	238	3.99
		370	295	3.85
Sesamolinol	6-28	$C_{20}H_{20}O_7$	231	3.95
		372	287	3.80
Sesaminol triglucoside	14-91	$C_{38}H_{52}O_{24}$ 856	235 288	3.97 3.88
Sesaminol diglucoside	8.2-18.3	$C_{32}H_{40}O_{18}$ 694	236 290	4.00 3.94
Sesaminol monoglucoside	5.4-19.5	$C_{26}H_{28}O_{12}$ 532	236 290	3.80 3.82

Source: Sesame seed lignans, (Moazzami A.A., 2006)

the systolic blood pressure from 198 mmHg in the control group to 152 mmHg in the sesame consuming group. Sesamin helps in inhibition of arotic production of superoxide anion radical, endothelin-1 by the endothelial cells and urinary 8- hydroxyl-2'-deoxyguanosine. Sesamin has been also found operative in stroke prone spontaneously hypertensive rats (SHRSP) by improving their antihypertensive and antithrombotic activities (Noguchi *et al*., 2001). Sesamin induced endothelial nitric oxide- dependent vasorelaxation is explained by an antioxidative effect caused by the catechol metabolites (Nakano *et al.*, 2006).

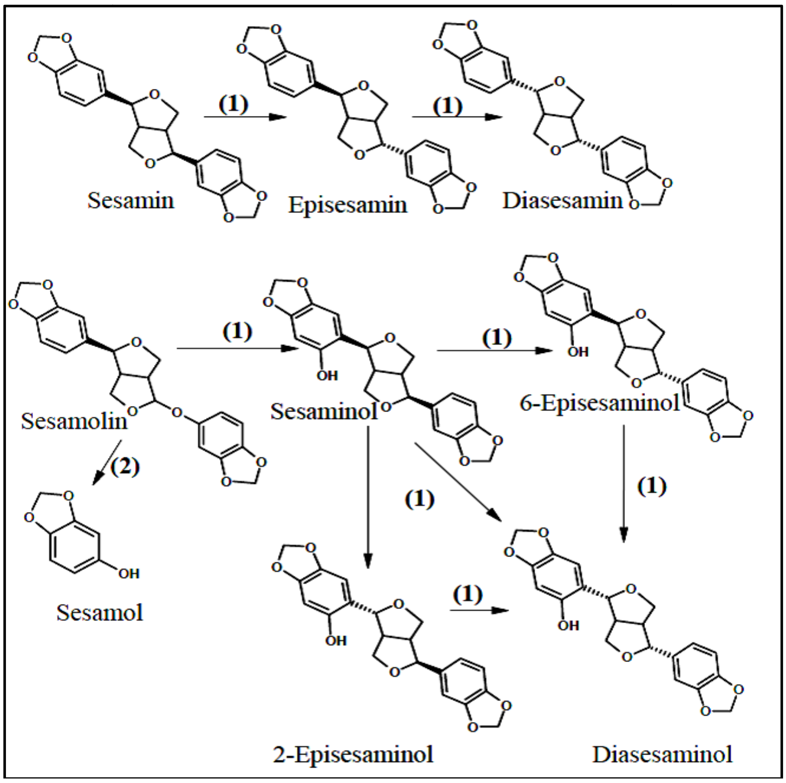
5.2 Tocopherol

Tocopherols are lipophilic, phenolic compounds of plant origin and are the major constituents of vitamin E. It is a series of organic compounds consisting of various methylated phenols. Tocopherol vitamers are free radical scavengers that work as lipid-soluble antioxidants, and therefore supposed to provide protection against various diseases such as cancer, cardiovascular disease, and neurodegenerative disorders (Hemalatha and Ghafoorunissa, 2004; Williamson *et al.*, 2007).

α, β and γ tocopherol levels were 0.034–0.175 μg/g, 0.44–3.05 μg/g, and 56.9–99.3μg/g respectively indicating that the sesame seed accessions contained higher levels of γ tocopherol compared with α tocopherol and β tocopherol (Hemalatha and Ghafoorunissa, 2004; Williamson *et al.,* 2007). According to Jiang *et al.* (2001) γ- tocopherol, the most profuse form in sesame seeds. It may be important to various human ailments, in comparison with α-tocopherol, which is the predominant form of vitamin E present in tissues and takes part in primary forming supplements, because of its effective trap for lipophilic electrophiles than α-tocopherol.

α-Tocopherol which functions as a chain-breaking antioxidant for lipid peroxidation in cell membranes and also as a free radical scavenger for singlet oxygen (O·) (Liebler, 1993). Due to its anti-inflammatory action α-tocopherol inhibits the production of the superoxide radicals by converting in activated form of neutrophils which leads to a linkage of neutrophils to endothelial cells resulting in migration of transendothelial (Rocksen *et al*., 2003). α-tocopherol in sesame has a successful effect on antiaging due to the synergistic effect with sesame lignans leading to inhibiting of metabolic decomposition. The collaborative synergy of γ-tocopherol with sesaminol or sesamin of sesame seed makes it to comparable to that of α-tocopherol (Namiki, 2007; Yamashita *et al*., 1992).

Both flax seed and sesame seeds were reported to contain more than 40% fat, 20% protein and vitamin E mainly γ-tocopherol and considerable amounts of plants lignans. However, flax seed contains 54% of α-linolenic Acid but sesame seeds only 0.6% and moreover chemical structures of both flax seeds and sesame seeds were different. Dietary studies in rats showed that sesame seeds and its lignans have induced higher γ-tocopherol and lower thiobarbituric acid reactive substances (TBARS) concentrations; whereas a flax seed has no such effects (Yamashita *et al*., 2003). Further α-linolenic acid produced stronger plasma cholesterol lowering effects and higher TBARS concentrations.



Source: Sesame seed lignans, (Moazzami A.A. 2006)

Fig 4: Transformation of sesame lignans during bleaching and hydrolysis.

According to Yamashita *et al*. (1992) a significant Vitamin E activity has been reported in sesame seeds which not exclusively because of the enclosed γ-tocopherol content in the seed but due to the synergistic effect of both the sesame lignans and γ-tocopherol.

5.3 Phytosterols

Plant sterols are considered as an emerging bioactive constituent, majorly present in all vegetable foods. As phytosterols belongs to the family of non pharmacological controlling agent for plasma lipid levels. It has been scrutinized well as vehicle in various functional foods or nutraceuticals. Phytosterols resemble to cholesterol in humans both structurally and biosynthetically. Phytosterols comes from the family of triterpenes, along with a tetracyclic ring and a side chain attached to carbon 17. Cholesterol contains 8 carbon atoms on its side chain, whereas phytosterols contains 9-10 carbon atoms along with it also contains either an additional double bond or methyl or ethyl group. Phytosterols can be further classified as sterols and stanols due to the presence or absence of double bond at 5 carbon position (Devaraj and Jialal, 2006).

In plants, sterols are found in the form of free sterols or conjugates where 3- β- hydroxyl group is esterified into a fatty acid or a glycosylated with glucose or a 6- fatty acyl hexose. Cereals contains most common form i.e. glycosides (Moreau *et al*., 2002). Phytostanols is a sub group of phytosterol which is fully saturated in nature is a native component of cereals like (wheat, corn, rice and rye), vegetables and fruits. There concentrations are lower than that of the phytosterols (Dutta and Appelqvist, 1997; Laakso, 2005).

There are across 200-250 different varieties of phytosterols have been recognized till date; β- sitosterol (24-α-ethylcholesterol) is the most copious among them. Along with it most frequently found phytosterols in plant food material includes campesterol (24-α-methylcholesterol) and stigmasterol (δ^{22}, 24-α-ethylcholesterol). Ergosterol ($\delta^{7,22}$, 24-α-methylcholesterol) is found commonly in linseed oil and cottonseed oil, it is also a major sterol of yeast. 98

% of the dietary intake is contributed by sitosterol, campesterol and stigmasterol (Kritchevsky and Chen, 2005).

There is induced reduction of total plasma and LDL cholesterol levels with eventual reduction in cholesterol absorption with the intake of phytosterol. Earlier studies found that stanols are better in decreasing cholesterol absorption in comparison to sterols. But according to recent studies it was found that when sterols and stanols are incorporated in butter or margarine the effect on cholesterol absorption and subsequently, on plasma cholesterol levels are comparable. Phytosterols also have a better reduction capacity to suppress HMG-CoA reductase activity when compared to cholesterol (Lagarda *et al*., 2006).

Along with reduction in blood cholesterol levels, phytosterols are also capable in anti-cancer properties (colon cancer), anti- atherosclerotic, anti-inflammatory and antioxidative effects. Phytosterols reduces the levels of fat soluble vitamins in the plasma as fat soluble vitamins circulate with the LDL and phytosterols lowers the levels of LDL and hence in return reduction of fat soluble vitamins like vitamin β-carotenoids, however many studies have also shown that vitamin A,D,E, α-carotenoids and lycopene affected by phytosterol content. Therefore, it is recommended to add carotenoids in the form of fruits and vegetables per day in order to maintain carotenoids levels in range with phytosterol supplementation (Marangoni and Poli, 2010). Besides, lignans and tocopherols, sesame seeds are the rich source of phytosterols. Sesame seeds contain all three major types of phytosterols (Park *et al*., 2010).

6. Health Benefits of Sesame Seeds

Needless to say that sesame is rich in nutrients and many other nutraceutical components which help to make up the numerous health benefits of sesame seeds that have been experienced for thousands of years.

6.1 Helps in Preventing Diabetes

Magnesium and other nutrients present in sesame seeds, and especially sesame oil, have been shown to combat diabetes. According to Sankar *et al.* (2010) found that sesame oil improves the effectiveness of the oral anti-diabetic drug glibenclamide in type 2 diabetic patients. Another study concluded that substitution of sesame oil as the sole edible oil has an additive effect in further lowering blood pressure and plasma glucose in hypertensive diabetics (Sankar *et al.*, 2006).

6.2 Reduces Blood Pressure

Another study by Sankar *et al.* (2006) concludes sesame oil has been shown to lower blood pressure in hypertensive diabetics. Substitution of sesame oil in dietary oils brought down systolic and dystolic blood pressure to normal, in addition decreasing lipid peroxidation and antioxidant status. Moreover magnesium has been shown to help in lowering blood pressure and sesame seeds are loaded with magnesium.

6.3 Promotes Cardiovascular Health

Further adding to the health benefits of sesame seeds, sesame seed oil can also boost heart health by preventing atherosclerotic lesions. Sesamol, which also harnesses anti-atherogenic properties, is thought to be one reason for the beneficial effects; sesamol has been shown to possess over dozens of beneficial pharmacologically active properties, many of which may contribute to improving cardiovascular health. In a study by Reena *et al.* (2010) found that sesame oil blended with coconut oil lowers the rate and extent of platelet aggregation in comparison to the rats fed only on the coconut oil. It has been also found that blending of coconut oil with sesame oil reduced both atherogenic and thrombogenic potentials of the coconut oil. In another study by Saleem *et al.* (2012) concluded that chronic supervision of sesame oil promotes protective action on cardiovascular through acknowledged antioxidant property. Karatzi *et al.* (2013) reported that daily consumption of sesame oil by hypertensive men results in positive effect on endothelial dysfunction. Recently it has found that consumption of sesame oil improves the endogenous antioxidants in ischemic myocardium (Saleem *et al*., 2012).

6.4 Sesame Seed Oil for Oral Health/ Gingivitis

One of the most prominent benefits of sesame seeds and sesame oil revolves around removing dental plaque and boosting oral health. They are involved in an activity known as oil pulling, which involves swishing oil around in your mouth hereby you can boost oral health and even whiten up your teeth. One of the study showcase the oil pulling benefits on the oral level, where oil pulling with sesame oil was shown to reduce the amount of streptococcus mutants in both teeth plaque and mouth saliva, and boost overall health (Ashokan *et al*., 2008)

6.5 Protects Against DNA Damage from Radiation

Sesamol a compound found in sesame seeds and sesame oil, has been shown in some studies to protect against DNA damaged caused by radiation (Kanimozhi and Prasad, 2009; Ramachandran, 2010). Further, sesamol has been shown to extend life in mice treated with radiation, partly by preventing damage to the intestines and the spleen (Parihar *et al*., 2006).

6.6 Prevents Cancer

Not only do sesame seeds contain an anti-cancer compound called *phytate*, but the magnesium in sesame seeds also possess anti-cancer properties. According to Wark *et al.* (2012) it was found that the risk of colorectal tumours decreased by 13% and the risk of colorectal cancer decreased by 12% with consumption of every 100 mg of magnesium.

6.7 Boosts Bone Health

In addition to promoting healthy skin, zinc has also been shown to boost bone mineral density and bone health as a whole. A study by Hyun *et al.* (2004) found a correlation between zinc deficiency and osteoporosis in the hip and spine area. Moreover, sesame seeds are a great source of calcium – a known trace mineral that is essential for bone health and preventing related conditions.

6.8 Boosting Digestive Health, Relieving Constipation

Sesame seeds are rich in fiber, which is known to pave way for a healthy digestive system and a healthy colon. Sesame seed coats have high total dietary fibre content (42 g/100 g seed coat dry matter). Insoluble fibre was the largest fraction, more than 26%. Compared with cereal derivatives (corn bran, wheat bran, oat bran, and rice bran; soluble dietary fibre ranged between 0.4 and 4.1%), the soluble dietary fibre content of sesame seed coats is considerably higher.

6.9 Provides Relief from Rheumatoid Arthritis

A mineral that is important for anti-inflammatory and antioxidant enzyme systems, copper is known for reducing pain and swelling associated with arthritis. Additionally, this mineral helps provide strength to blood vessels, bones and joints.

6.10 Promotes Respiratory Health, Prevents Asthma

High magnesium content in sesame seeds able to prevent asthma by and other respiratory disorders by preventing airway spasms.

6.11 Enhances Wound Healing

Wound healing is an intricate cellular process which relies on the discharge of various signalling components involved in wound healing and to organize them as well. These signalling components include inflammatory cells, endothelial cells, keratinocytes and fibroblasts which are essential in the due course of injury (Martin, 1997). The wound healing undergoes four major phases which includes haemostasis, inflammation, proliferation and remodelling (Falanga, 2005). Delayed wound healing is a problematic issue seen mostly in elderly, bed ridden, immune compromised, diabetic patients and patients who are on steroid therapy.

As sesame oil has been used in wound healing and it major component sesamol anti-oxidative properties can be also used for rapid wound healing (Fukuda *et al*., 1981) It was found that sesamol has both antioxidant activity and anti- clastogenic activity (Parihar *et al*., 2006). In a study by Shenoy *et al.* (2011) found that sesamol is a capable entity which encourages wound healing. However, it was also found that sesamol oral consumption requires higher doses because of poor oral absorption.

6.12 Promote Healthy Skin

Sesame seeds are rich in zinc, which is an essential mineral for producing collagen and giving skin more elasticity. Zinc also helps in repairing of damaged tissues in the body. Sesame oil is also popularly used to sooth burns and prevents skin related disorders.

6.13 Anti-inflammatory Properties

Steroids and non-steroidal anti-inflammatory drugs (NSAIDs) are the main choices for controlling inflammation. However, their adverse effects limit their clinical use. Recently, sesame oil and its lignan sesamol have been proved to be potent anti-inflammatory agents. They have an excellent protective effect against endotoxin-associated inflammatory damage because they inhibit the release of inflammatory mediators. Sesamol also inhibits endotoxins from binding to its receptor; this reduces inflammatory transcription factor NF-κB activation. In summary, sesame oil or sesamol may be beneficial for reducing the inflammatory response in inflammation-associated diseases (Liu, 2013).

7. Conclusion

Since, the ancient time, India is being the largest producer of sesame. Sesame is an affluent source of nutritive and therapeutic properties. It is a rich source for major and minor nutrients including proteins, dietary lignans, dietary fibre, phytosterols, tocopherols, vitamins, calcium, phosphorous and others. Besides these abundant nutrients still sesame has not been used widely in development of value added products which can meet the simultaneous challenge of malnutrition and healthy snacking. Nutraceuticals and pharmaceutical products developed from both sesame and sesame by- products can reduce the risk of various ailments like neurological, dermatological, cancer and cardiovascular diseases etc.

Sesame has also tremendous potential for enhancing the shelf life and longevity of other oils with its bioactive constituents. Therefore with the new expansion of technology sesame oil can be blended with vulnerable oil with shorter shelf life can be of a great advantage with respect to nutritional aspects and extending their shelf life. Along with the sesame oil, defatted sesame flour has also a prospective of anti-oxidative sources which can be used as the future replacement for chemical antioxidants in food industry.

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