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Review Article

Nutraceutical Importance of Sesame Seed and Oil: A Review of the Contribution of their Lignans

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ABSTRACT

Sesame seed is widely used in food and nutraceutical industries in many countries because of its high oil, protein and antioxidant contents. Sesame oil contains sesamin, sesamolin and sesaminol lignan fractions, which are known to play an important role in its oxidative stability and antioxidative activity. It is widely known as one of the natural health promoting foods that has the potential to prevent various disorders such as hypertension, hypercholesterolemia cancer and aging. Additionally, sesame oil may be useful in managing oxidative stress-associated diseases such as atherosclerosis, diabetes mellitus, obesity, chronic renal failure, rheumatoid arthritis, and neurodegenerative diseases including Alzheimer's disease. Moreover, sesame oil has multiple physiological functions such as decreasing blood lipids and arachidonic acid levels, increasing antioxidative ability and γ-tocopherol bioavailability, and providing anti-inflammatory function and potential estrogenic activity. Many health promoting effects are attributed to its lignans. Hence, this article highlights and discusses the potential health promoting effects of sesame and its oil with emphasis on the contribution of lignans.

Keywords: Functional food, Health promotion, Lignans, Nutraceutical, Sesame

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INTRODUCTION

Sesame (*Sesamum indicum* L.), a member of the *Pedaliaceae* family (Ashri 1998), is one of the ancient cultivated plants, mainly for its edible oil and food source. It is an economically important oil seed crop, which is widely cultivated in countries like China, India, Thailand, Mexico, Guatemala, El Salvador, Afghanistan, Pakistan, Bangladesh, Indonesia, Sri Lanka, Saudi Arabia and Turkey (Morris, 2002). Sesame is essentially used in the production of paste (tehineh) and in food formulations such as halaweh (sweetened tehineh), bennimix baby food, (BBF), breakfast cereal based-porridge mixed with sesame, java beans and salads (Abou-Gharbia *et al*., 2000; Abu-Jdayil *et al*., 2002; Kanu et al., 2007a; Kanu *et al.,* 2009a). It serves as a nutritious food for humans and is used widely in bakery and confectionery products (Abou-Gharbia *et al.,* 1997). Whole sesame is used in the production of a locally produced weaning food in Sierra Leone (Kanu *et al.,* 2007a) and proved to work markedly well in correcting protein/energy malnutrition.

The protein from sesame seed when extracted with water and protease, yielded good quantity with significant percentage of essential amino acids (Kanu *et al.,* 2007b, Kanu *et al.,* 2007c, Kanu *et al.,* 2009b). Sesame seed contains oil (44–58%), protein (18–25%), carbohydrate (∼13.5%), and ash (∼5%) (Mohamed and Awatif, 1998; Shyu and Hwang, 2002; Kahyaoglu and Kaya, 2006).

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The oil fraction shows a remarkable stability to oxidation (Yoshida *et al.,* 1995; Abou-Gharbia *et al.,* 2000). This could be attributed to endogenous antioxidants (lignans) together with tocopherols (Yoshida *et al.,* 1995). Sesame is widely known as one of natural healthy foods with risk reduction properties against various disorders including hypertension, hypercholesterolemia, and atherosclerosis (Hirata et *al.,* 1996; Kang *et al.,* 1999; Nakano *et al.,* 2002). Diet containing sesame seeds (200 g/kg) was shown to increase both the hepatic mitochondrial and peroxisomal fatty acid oxidation rate in rats. Noticeably, peroxisomal activity levels were increased >3 times in rats fed with diets containing sesame seeds than those fed with a control diet (Coulman *et al.,* 2005). Sesame diet also significantly increased the activity of hepatic fatty acid oxidation enzymes including acyl-CoA oxidase, carnitine palmitoyltransferase, 3-hydroxyacyl-CoA dehydrogenase and 3-ketoacyl-CoA thiolase (Sirato-Yasumoto *et al.,* 2001). In contrast, sesame diet lowered the activity of enzymes involved in fatty acid synthesis including fatty acid synthase, glucose-6-phosphate dehydrogenase, ATP-citrate lyase and pyruvate kinase (Sirato-Yasumoto *et al.,* 2001).

Sesame contains the essential fatty acids (EFAs) such as linoleic acid and high levels of lignans that consist of sesamin, sesaminol, sesamol, sesamolinol, or sesamolin (Katsuzaki *et al.,* 1994). Several studies have reported the health-promoting properties of sesame (Sugano *et al.,* 1990; Yamashita *et al.,* 1995). The seeds and oil have been known as traditional health foods and have been used in ancient Chinese medicine for a long time. It was claimed in ancient Chinese books that consumption of sesame seeds (*Chih-Ma* in Chinese) provides high-energy and prevents aging (Namiki, 1995). However, the scientific evidence of those miraculous functions, especially the prevention of aging, has not been well established (Chen *et al.,* 2005a). Literatures have reported a number of health benefits accruing from the consumption of sesame seeds and sesame oil (Namiki, 1995; Yamashita *et al.,* 1995; Hirata *et al.,* 1996; Abou-Gharbia *et al.,* 1997; Nakano *et al.,* 2002). Sesame seed has been recently of particular interest as a promising source for preventing or slowing carcinogenesis by means of continual administration of its beneficial compound(s) with few side effects (Sheng *et al.,* 2007). Other health promoting effects are mainly attributed to the high mono unsaturated fatty acids such as linoleic acid (Katsuzaki *et al.,* 1994), and the different bioactive components in sesame including phytosterols, tocopherol, and lignans (Sugano *et al.,* 1990; Kang *et al.,* 1999).

In recent times, there is an accumulating body of evidence showing that sesame oil containing lignans or extracted lignans (Fukuda *et al.,* 1986a; Coulman *et al.,* 2005) also exert anti-cancer properties both in *in-vitro* studies and *in-vivo* animal bioassays (Salerno and Smith, 1991; Kapadia *et al.,* 2002). This possible cancer-preventive effect of sesame seed and oil may be partly attributable to the antioxidative action of the lignans (Hirose *et al.,* 1992) Coulman *et al.* (2005) stated that sesame seeds can be a rich source of lignans as flaxseeds. Though, the potential health promoting effects of sesame seed and oil have been reviewed, the main objective of this article was to comprehensively assess the nutraceutical importance of sesame seed and its oil with emphasis on the contribution of their lignans and potential health promoting effects.

Sesame Oil

Sesame oil (SO) contains a class of unique compounds known as lignans. Lignans comprise sesamin, sesamolin, and a small amount of sesamol (Namiki, 1995). They have multiple physiological functions, such as decreasing blood lipids (Hirata *et al.,* 1996) and arachidonic acid levels (Shimizu *et al.,* 1991), increasing antioxidative ability (Ghafoorunissa, 2004) and γ-tocopherol bioavailability (Lemcke-Norojarvi *et al.,* 2001) and providing anti-inflammatory function (Hsu *et al.,* 2005). Some sesame lignans (e.g., sesamin) are converted to the mammalian lignans, which may exert weak estrogenic and antiestrogenic activities (Peñalvo *et al.,* 2005; Wu *et al.,* 2006). Likewise, the antioxidant properties of lignans have been shown in several studies (Ide *et al.,* 2001; Kapadia *et al.,* 2002; Abe *et al.,* 2005). Sesame oil effectively attenuates oxidative stress triggered by endotoxin lipopolysaccharide (LPS) in rats (Hsu and Liu, 2002). Although, the exact mechanism by which dietary SO reduces oxidative stress is not very clear, it is strongly believed that the protective effect is due to the presence of lignans (sesamin, sesamol and sesamolin) and vitamin E (Ahmad *et al.,* 2006). This claim could be confirmed by further studies to ascertain the mechanism involved in the reduction of oxidative stress.

Oxidative stress is associated with various diseases, such as atherosclerosis, diabetes mellitus, chronic renal failure, rheumatoid arthritis, and neurodegenerative diseases (Abuja and Albertini, 2001). Currently, many drugs and treatments being investigated by researchers are directed towards preventing the damage caused by oxidative stress (Goodyear-Bruch and Pierce, 2002). Sesame oil - attenuated LPS induces oxidative stress and LPS-associated hepatic damage by reducing the nitric oxide (NO)-mediated hydroxyl radical generation and increases the activities of enzymatic antioxidants in rats (Hsu *et al.,* 2004). Administrating SO with potent anti-oxidative effect may therefore be another approach for managing oxidative stress-associated diseases.

Kaur and colleague (2000) reported that SO increases cell resistance to lipid peroxidation (LPO) and it has been suggested that sesamin found in SO enhances hepatic detoxification of chemicals and reduces the incidence of chemically induced mammary tumors (Hirose *et al.,* 1992). Furthermore, studies have shown that SO lowers cholesterol levels and hypertension in humans (Sankar *et al.,* 2004) and reduce the proliferation of certain cancer cells *in vitro* (Miyahara *et al.,* 2001). The observed effects have been attributed to the chemical composition of the oil, characterized by a low level of saturated fatty acids and the presence of antioxidants (Miyahara *et al.,* 2001). It was observed that SO reduces serum cholesterol levels in rats compared to corn oil in spite of the comparable fatty acid composition of the two oils (Koh, 1987).

Sesame oil, in comparison to other dietary oils such as groundnut and sunflower, offers better protection against increased blood pressure, hyperlipidemia and lipid peroxidation by increasing enzymatic and non-enzymatic antioxidants (Sankar *et al.,* 2005). Studies have demonstrated that SO and one of its active ingredients, sesamol to be a strong antitumor promoting agent when compared with resveratrol and sunflower oil (Kapadia *et al.,* 2002). With the increasing knowledge on the dietary and health benefits of sesame, the market demand for its seeds and oil is likely to increase. These attributes of SO are due to the EFAs such as linoleic acid and oleic acid it contains.

Lignans

Lignans and lignan glycosides present in the sesame oil appear to be the most important functional components. Recently, much attention has been focused on the sesame lignans because they have potent antioxidative activity capable of preventing SO from peroxidation, even at low concentrations (Suja *et al.,* 2004). The main sesame lignans are sesamin and sesamolin, which are found in SO (Table 1) and possess no antioxidative activity (Kamel-Eldin and Appelpvist, 1994). However, small amounts of sesaminol, piperitol, sesamolinol, pinoresinol, (+)-episesaminone,hydroxymatairesinol,allohydroxymat-airesinol and larisiresinol, do possess free phenolic groups and, therefore, antioxidant activity has been reported in sesame seeds (Fukuda *et al.,* 1985, Nagashima and Fukuda, 2004).

Table 1: Lignan Contents (ppm) of Seed and Oil.

Sample	Sesamol	Sesamin	Sesamolin	Total Lignan Content
White seed extract in methanol	3834±6.2	3993±4.1	2054±4.7	9881±6.4
Red seed extract in methanol	2092±5.2	3610±7.9	2941±1.8	8643±9.6
Black seed extract in methanol	4306±4.9	2037±3.8	3563±4.1	9905±9.0
Oil/ white seed	Trace	4278±1.8	2740±2.7	7018±2.5
Oil/ red seed	Trace	4193±4.2	1821±3.7	6014±3.0
Oil/ black seed	Trace	1154±3.9	502±6.6	1653±4.9

Adapted from Suja *et al.* (2005)

During SO manufacturing, sesamolin can be converted to other lignans, including sesamol, sesamol dimmer and sesaminol (Fukuda *et al.,* 1986a). Sesamolin is transformed into sesamol and sesamol dimmer on heating, while upon chemical refining and bleaching, it is transformed into sesamol and sesaminol (Nagata *et al.,* 1987). During bleaching, sesamolin is first decomposed into sesamol and oxonium ion by protonolysis in the presence of acidic clay and heat, resulting in the formation of a new carbon-carbon bond and subsequent production of sesaminol. Therefore, an intermolecular transformation was suggested for conversion sesamolin to sesaminol during bleaching (Fukuda *et al.,* 1986b).

Epimerization of the SO lignans also happens during bleaching, in which episesamin and episesaminol are formed (Fukuda *et al.,* 1986c). Comparison of autoxidation of commercial oils at 60°C revealed that soybean, rapeseed, sunflower safflower and corn oil began to oxidize 5-20 days after incubation, whereas refined sesame oil was oxidized after 35 days (Fukuda *et al.,* 1988). Under this condition, roasted sesame oil was shown to remain unaltered even after 50 days (Fukuda *et al.,* 1988).

The oxidative stability of sesame oil is due to the presence of sesamolin, sesamin, sesamol, and γ-tocopherol (Yoshida and Takagi, 1999). In addition, its stability increases when sesamol is produced from sesamolin during the roasting process of dehulled sesame seed (Yoshida and Takagi, 1997). Lignan glycosides, which exist mainly in the defatted sesame oil, are hydrophilic antioxidants. The major lignan glycosides found in sesame are sesaminol glucosides, pinoresinol glucosides and sesamolinol glucosides (Kuriyama *et al*., 1993). Several studies have shown that dietary sesame lignans have effects like reducing liver damage and serum cholesterol level, increasing vitamin E activities, α-tocopherol availability and decreasing thiobarbituric acid reactive substance (TBARS), which are important in lipid peroxidation of membranes leading to aging process (Kato *et al*., 1998; Ikeda *et al*., 2003).

Although, the necessity to convert lignans to enterolactone to be biologically active is still an unproven hypothesis, lignans are phytoestorgens and their conversion to enterolactone is considered very important in preventing hormone-dependent cancers (like breast and prostate) and cardiovascular diseases (Kilkkinen, 2004). Consumption of sesame seeds was shown to increase plasma and urinary exertion of enterolactone and enterodiol (Peñalvo *et al*., 2005). Epidemiological and laboratory studies have also shown that high plasma and urinary concentration of enterolactone were inversely correlated with the risk of certain chronic diseases, such as breast cancer (Pietinen *et al*., 2001), prostate cancer (Hedelin *et al*., 2006) and coronary heart disease (Kilkkinen *et al.,* 2006).

Phytoestrogen, including mammalian lignans and isoflavones, are structurally and functionally comparable to estradiol-17β and are capable of producing estrogenic effect (Coulman *et al.,* 2005). Mammalian lignans bind to the estrogen receptors (ER) with a lower affinity compared to the endogenous estrogen and may exert both estrogenic and antiestrogenic effects (Murkies *et al.,* 1998). It has been shown that the concentration of enterolactone in the prostate fluid is significantly higher than their plasma level (Morton *et al.,* 1997). Estradiol-17β stimulates hepatic production of sex hormone-binding globulin. This protein binds both estrogens and androgens, regulating the levels of free hormones in the plasma. It has also been shown that intervention with sesame seed in postmenopausal women can increase the level of sex hormone-binding globulin in serum (Wu *et al.,* 2006). However, whether this effect is exerted by sesame seed lignans or mammalian lignans produced from sesame seed lignans in the gut is not clear. In this regard, more research is still needed in that area. Moreover, it has been shown that enterolactone up-regulates low density lipoprotein (LDL) receptor activity in human hepatoma cell line (HepG2) (Owen *et al.,* 2004). This suggests another possible mechanism for cholesterol lowering effect of sesame seed and its lignans.

Sesamol

Sesamol is an effective antioxidant found mainly in roasted sesame or in processed SO (Budowski, 1964). It is a phenolic derivative with a methylenedioxy group (Figure 1), and like vitamin E, it is known to be an antioxidant present mainly in processed SO (Uchida *et al.,* 1996; Ando *et al.,* 2000). It was observed that antioxidant efficacy of sesame cake extract is due to the presence of sesamol and other compounds (Suja *et al.,* 2004). Sesamol has been shown to inhibit the excessive production of nitric oxide in the lipopolysaccharide/gamma-interferon stimulated C6 astrocyte cells (Soliman and Mazzio, 1998). It also inhibits the formation of carcinogenic imidazoquinoxaline type heterocyclic amines through the unstable free radical maillard intermediates (Kato *et al.,* 1996). Studies have shown that sesamol can act as a metabolic regulator and possesses chemopreventive, antimutagenic, and antihepatotoxic properties (Kaur and Saini, 2000; Kapadia *et al.,* 2002).

The biological effects of sesamol on health include its inhibitory effects on lipid peroxidation of liposomes when induced by Fe^{2+} on the lipid peroxidation of rat liver microsomes and also when induced by ascorbate/Fe^{3+} ions on carbon tetrachloride and NADPH of lipid peroxidation on the mitochondria (Uchida *et al.,* 1996).

It also carries out the synergistic suppression of carcinogenesis when combined with other antioxidants (Hasegawa *et al.,* 1992). An *in-vitro* study indicated that sesamol inhibited the mutagenicity of mutagens in various strains of *Salmonella typhimurium (*Kaur and Saini, 2000). Sesamol could also attenuate the production of nitric oxide and hydrogen peroxide and reduce monoamine oxidase (MAO) activity in glial astrocyte cells (Mazzio *et al.,* 1998). Since a distinct relationship exists between MAO activity and the development of neurodegenerative diseases associated with aging such as Alzheimer's disease and stroke, sesamol might play a role in the prevention of these diseases. This could be scientifically investigated to know the mechanism involved.

Sesamin

Sesamin (Figure 1) is the most abundant lignan in SO (Fukuda *et al.,* 1986c). It enhances hepatic detoxification of chemicals, reduces the incidence of chemically induced mammary tumors, and protects against oxidative stress (Hirose *et al.,* 1992, Akimoto *et al.,* 1993). Sesamin, the major SO lignan, was also shown to cause an increase in γ-tocopherols (Jiang *et al.,* 2001) in the plasma and the liver and a reduction in liver cholesterol of rats contrary to secoisolariciresinol diglucoside, the major lignan glucoside in flaxseed (Frank *et al.,* 2004;Coulman *et al.,* 2005). A trial in young women showed a 43% increase in serum γ-tocopherol level by ingesting 100 mg sesamin daily from SO for 1 month (Lemcke-Norojarvi *et al.,* 2001), an amount that can be obtained from 25 g SO. In another study, plasma γ-tocopherol increased by 19% in volunteers only after 3 days of intervention with muffins containing sesame seed (equal to a daily dose of 35 mg sesamin and 13 mg sesamolin) (Cooney *et al.,* 2001). It was also shown that the urinary excretion of γ-tocopherol metabolites was significantly lower in volunteers after the consumption of sesame oil muffins (Frank and Kamal-Eldin, 2004).

These data suggest that sesamin can possibly inhibit the catabolism of γ-tocopherol, which results in its higher bioavailability observed in human and animal studies (Yamashita *et al.,* 1992; Cooney *et al.,* 2001; Lemcke-Norojarvi *et al.,* 2001; Ikeda *et al.,* 2002; Sontag and Parker, 2002). Sontag and Parker, (2002) suggested a cytochrome P450 4F2 mediated ω-hydroxylation pathway for γ-tocopherol catabolism, which was inhibited by sesamin. Furthermore, studies have demonstrated that administration of SO and its lignans increases blood and tissue concentrations of γ-tocopherol without altering those of α-tocopherol in rats (Kamal-Eldin *et al.,* 2000; Ikeda *et al.,* 2002). Dietary sesame seeds however seems to elevate α-tocopherol in animals. Abe *et al.,* (2005) concluded that dietary sesame seeds elevate α-tocopherol concentration in rat brains. They showed that the concentration of α-tocopherol in the brain of rats (the cerebrum, cerebellum, brain stem, and hippocampus) fed with 50 mg α-tocopherol/kg with sesame seeds was higher than that of those fed with 500 mg α-tocopherol/kg without sesame seed. These results suggest that the dietary sesame seeds are more useful than the intake of an excess amount of α-tocopherol, for maintaining a high α-tocopherol concentration and inhibiting lipid peroxidation in the various regions of the rat brain (Abe *et al.,* 2005).

Sesamin enhances hepatic detoxification, reduces the incidence of chemically-induced tumors, protects against oxidative stress and inhibits Δ5-desaturase in polyunsaturated fatty acid (PUFA) biosynthesis (Shimizu *et al.,* 1991; Hou *et al.,* 2004). The inhibition of delta-5 desaturase activity by sesamin results in an accumulation of dihomo-γ-linolenic acid (DGLA) that can displace arachidonic acid and decrease the formation of pro-inflammatory mediators, such as prostaglandin E2 (PGE2) and leukotriene B_4 (Chavali *et al.,* 1998). Proinflammatory mediators, such as PGE2, can influence the production of cytokines, which mediate inflammatory responses during inflammation and infection (Pruimboom *et al.,* 1994). However, the reduction in PGE2 in mice, exerted by sesamin and sesamol, poses different effects on interleukins and tumor necrosis factor-alpha (TNF-α) possibly because of different mechanisms (Coulman *et al.,* 2005). Despite lack of differences in the levels of arachidonic acid, the PGE2 level was reported to be significantly lower in mice fed sesamin or sesamol supplemented diets. PGE2 plays crucial roles in various biological events such as neuronal function, female reproduction, vascular hypertension, tumorigenesis, kidney function and inflammation (Kobayashi and Narumiya, 2002). Therefore, sesamin, sesamol or their metabolites decrease the activity of cyclooxygenase and the biosynthesis of prostaglandins (Chavali *et al.,* 1998).

Table 2: Serum Biological Parameters in the Rats treated with Sesaminol Glucosides

Treatment	TG (mg/dl)	GLU (mg/dl)	T-Cho (mg/dl)	VLDL (%)	LDL (%)	HDL (%)
0 ppm SG	29.5±5.96[a]	143.3±12.74	53.3±3.72	5.3±1.03	0.7±0.52	94.0±1.26
250 ppm SG	32.3±18.15	155.0±25.63	55.3±8.54	4.8±0.50	0.5±0.58	94.8±0.50
500 ppm SG	15.2±6.65[b]	139.8±24.10	52.8±6.31	7.3±1.21	1.0±0.00	91.7±1.21

[a] Values of mean ±SD. [b] Significantly different from control (0 ppm SG group) by Welch's *t*-test ($P<0.01$). SG = Sesaminol glucosides, TG =Triglycerides, GLU = Glucose, T-Cho = total cholesterol, VLDL= very low density lipoprotein, LDL=low density lipoprotein, HDL= high density lipoprotein. **Adapted from Sheng *et al.* (2007)**

Sesamin strongly influences lipid metabolism in experimental animals (Ashakumary *et al.,* 1999) and in humans (Hirata *et al.,* 1996). Hirose *et al.,* (1991) showed that serum and liver cholesterols were reduced in rats fed diet containing 0.5% sesamin. Consumption of 32 mg sesamin capsules for 4 weeks followed by 65 mg sesamin capsules for 4 weeks reduced total cholesterol (TC) by 9%, low density lipoprotein-cholesterol (LDL-C) by 16.5% and apoprotein B by 10.5% in 12 males with hypercholesterolemia (Hirata *et al.,* 1996). Wu *et al.,* (2006) also observed similar reductions in TC and LDL-C in 24 postmenopausal subjects following a 5-week intervention with 50 g pulverized roasted sesame seed. HDL-C was unchanged in all mentioned human studies after intervention of sesamin or sesame seed (Hirata *et al.,* 1996; Chen *et al.,* 2005b; Wu *et al.,* 2006). Since the diet can be an effective means to lower blood levels of total and LDL cholesterol (Delahanty *et al.,* 2001), drug therapy may be reserved for patients who are at high risk for CHD (Expert Panel, 1993).

Hirose *et al.* (1991) established that the hypocholesterolemic activity of sesamin can, at least in part, be explained by the inhibition of the intestinal absorption of cholesterol as reflected by the significant reduction in cholesterol in the thoracic lymph and a significant reduction in the activity of liver microsomal 3-hydroxy-3-methylglutaryl coenzyme A reductase, which is a rate-limiting enzyme in biosynthesis of cholesterol. Kushiro *et al.,* (2002) reported that sesamin greatly increased the hepatic fatty acid oxidation rate. An activity and gene expression of hepatic fatty acid oxidation enzymes presumably through the activation of peroxisome proliferator activated receptor (PPAR) α, a member of the PPAR family that is abundantly expressed in the lives of living organisms (Ashakumary *et al.,* 1999). Sesamin also increases the activity and gene expression of the malic enzyme involved in the regulation of fatty acid synthesis. The gene of malic enzyme, like that of many fatty acid oxidation enzymes possesses a peroxisome proliferator response element in the promoter (Hertz *et al.,* 1996). The responses of the activity and gene expression of this enzyme may reflect the activation by sesamin of PPAR. However, Kushiro *et al.* (2002) also observed that sesamin decreased the activity and gene expression of fatty acid synthase, pyruvate kinase, and those of lipogenic enzymes. This suggests that sesamin increases hepatic fatty acid oxidation but decreases hepatic fatty acid synthesis (Ide *et al.,* 2001).

Sesaminol

Among the sesame lignans, sesaminol (Figure 1) was shown to have the most effective antioxidative activity in *in-vitro* experimental systems (Kang *et al.,* 2000; Ohtsuki *et al.,* 2003). Coulman *et al.* (2005) concluded that sesaminol triglucoside is the major lignan glucoside in sesame seeds and that almost 32% of total lignans in sesame seeds are in glucosylated form. Although the sesaminol glucosides (SGs) directly have no role in antioxidative defense system against various oxidative damages**,** they could be hydrolyzed to form sesaminol by intestinal beta-glucosidase after ingestion of sesame seeds, thereby working as antioxidants (Katsuzaki *et al.,* 1994).

Sesaminol shows inhibitory effect on endogenous lipid peroxidation as well as oxidative DNA damage in rat plasma and liver (Ikeda *et al.,* 2003). Sesaminol also has inhibitory effect on inflammatory hepatic ischemia-reperfusion injury in rats (Utsunomiya *et al.,* 2003). In a recent study, it was clearly confirmed that dietary sesaminol glucosides (SGs) inhibited the development of colonic precancerous lesions *in vivo* (Sheng *et al.,* 2007). The beneficial effect of SGs might be attributed to the antioxidative property and/or down-regulation of serum triglycerides (Table 2). Recently, Sheng *et al.* (2007) stated dietary SGs may be a promising chemopreventive agent against colon cancer. It needs to verify if this could be applicable to humans as the study was conducted on rats.

Nevertheless, sesaminol glucosides could have a protective effect on Aβ-induced neuronal cell death via antioxidant property, and could be useful as a therapeutic agent for treatment of oxidative stress-induced neuronal degeneration diseases such as Alzheimer's disease (Lee *et al.,* 2005). Sesaminol glycosides have protective effects against $A\beta_{25-35}$-induced deficit in learning and memory in mice (Kim *et al.,* 2003). They prevent beta-amyloid (Aβ) and H_2O_2-induced cell death of pheochromocytoma (PC12) cells accompanied by the suppression of $A\beta_{25-35}$-induced ROS generation. They also help the elevation of intracellular calcium level, 8-oxodG formation and inhibition of apoptotic related gene expressions as well as nuclear factor-κB (NF-κB) and extracellular signal-regulated kinase (ERK) signal activation (Lee *et al.,* 2005). Consequently, sesaminol glycosides might have beneficial effects on the neuronal cell survival through reduced inflammatory reaction which may eventually prevent the formation of inflammatory complex of the neuronal plagues in Alzheimer's disease (Lee *et al.,* 2006).

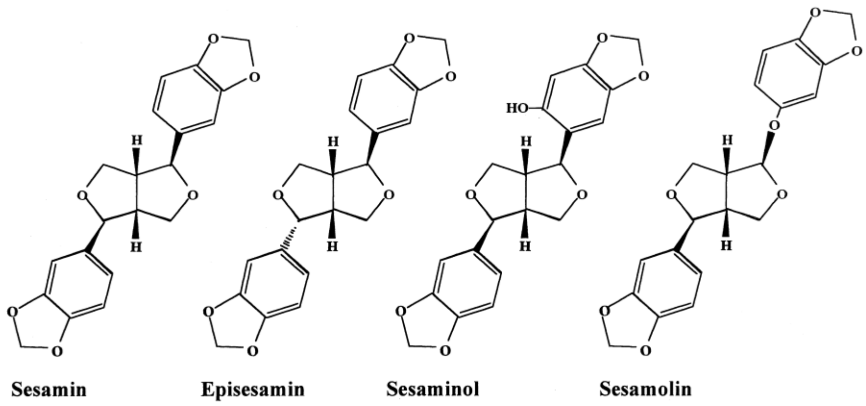

Figure 1: Chemical Structure of Sesame Lignans. Source: Ide *et al*. (2003)

CONCLUSION

The major functional ingredients in sesame are the lignans such as sesamin, sesamol, sesaminol and sesamolin, which could be extracted under appropriate conditions and used as food supplements in various formulations. The lignans significantly contribute to the nutraceutical importance and the potential health promoting effects of sesame seed and its oil because of the EFAs in the sesame oil. Sesame and its related products should be encouraged in diet as one of the circumventive measures against disorders such as hypertension, hypercholesterolemia, cancer, oxidative stress, and neurodegenerative diseases like Alzheimer's disease. Sesamin and sesamol have been shown to increase survival after cecal ligation and puncture and increase the interleukin 10 (IL-10) levels in mice with a non-lethal dose of endotoxin in mice (Chavali *et al.,* 2001). Seeds, in which sesamin and sesamolin could be found, have metabolites that exert antioxidative activity similar to other antioxidants. Silymarin and quercetin, suppress LPS-induced NO production in microglia and macrophage through inhibition of signal transduction pathway or nuclear transcription factors (Wang *et al.,* 2002; Hou *et al.,* 2003). Similar effects on hepatic fatty acid oxidation and synthesis were also observed when rats were fed with diets containing pure sesamin or episesamin (figue1) (0.2%) for 15 days suggesting the possible involvement of sesame oil lignans in the induction of the observed changes in hepatic fatty acid metabolism (Kushiro *et al.,* 2002).

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