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Review Article

Nutraceutical value of sesame oil – An update

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ABSTRACT

Sesame oil is one of the cooking oil used in the human diet since ancient times. Sesame oil is obtained from seeds of *Sesamum indicum* cultivated throughout the world. Sesamin and sesamol are antioxidant lignans present as rich concentration in sesame oil. Beneficial effect of sesame oil and its antioxidant lignans reported by researchers in various experimental animals and human models. The aim of this review to discuss the accumulating evidence that suggests that sesame oil possess a diverse range of biological action and may be beneficial for human to deviate from various diseases.

Keywords: Antioxidants; cardio protection; human diet; oxidative stress; sesame lignans; *Sesamum indicum*

INTRODUCTION

Sesame oil, derived from the seeds of plant species of *Sesamum indicum* Family *Pedaliaceae,* consists of various fatty acids and nonfat antioxidants, including tocopherol, sesamin, sesamolin, and sesamol (Fukuda, 1990). Sesame oil has been part of the human diet since ancient times. Sesame oil is one of the major dietary oils in Asian countries. Antioxidant lignan present in the sesame oil may contribute to improve human health (Saleem & Gauthaman, 2009). Sesamin and sesamolin are the most abundant lignans of sesame oil and the major fat soluble lignans (Liu et al., 2006). Sesamin and sesamolin are comprised of benzene and furfuran rings. The structural difference between them is that sesamolin contains oxygen between its benzene and furofuran rings (Marchand et al., 1997). Sesamin and sesaminol are the major phenolic constituents of sesame oil, which have been reported to possess a broad spectrum of pharmacological effects, including anti-mutagenic, antioxidant, antihypertensive, anti-inflammatory antithrombotic and cardio protective effects (Gauthaman & Mohamed Saleem, 2009). In this review, various pharmacological effects of sesame oil were documented by both animal and human study to support the nutraceutical value of sesame oil. Different kinds of pharmacological activity of sesame oil are presented in Figure 1.

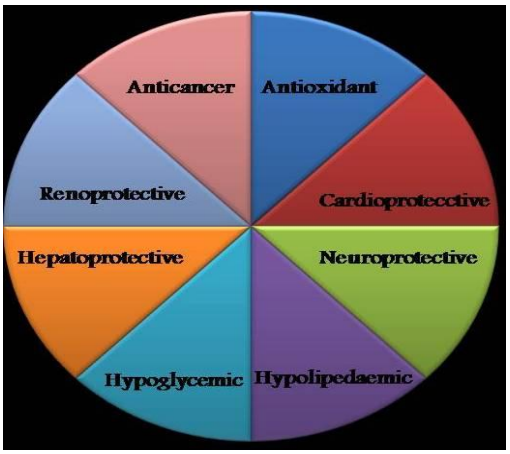

Figure 1: Pleiotropic effects of sesame oil

Antioxidants effect of sesame oil

Hsu et al. reported the antioxidative effect of sesame oil in animal models. They reported that a single dose of sesame oil decrease the oxidative stress and also protect the liver from oxidative injury by enhancing the antioxidant parameters. The protective effect might be due to inhibition of xanthine oxidase enzyme (Hsu & Liu, 2002; 2004; Hsu et al., 2004; Hsu et al., 2006). In another study, it has been reported that sesame oil decreasing the lipid peroxidation (LPO) by scavenging the reactive oxygen species (ROS) triggered by endotoxin lipopolysaccharide in rats (Kang et al., 1998; Nakai et al., 2003; Hsu & Liu, 2002; 2004). Many studies supported the antioxidant properties of sesame oil due to presence of sesamin and sesamolin, sesaminol in rich level. Furthermore, the scavenging property of sesame oil is more effective than either α-tocopherol or probucol in reducing the peroxyl radicals derived from 2,2'-azobis (2-amidinopropane) dihydrochloride

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(Kang et al., 2000). Researchers reported that administration of sesame oil during stress enhancing the antioxidative enzymes like glutathione peroxidase (GPx), superoxide dismutase (SOD), and catalase in rodents (Hemalatha et al., 2004; Hsu et al., 2004; 2005; 2006).

Hypoglycemic effect

Dietary supplementation of sesame oil for type II diabetic patients in combination with glibenclamide significantly altered the lipid parameters and serum sugar level when compared with glibenclamide alone treated patients. Sesame oil also enhanced the enzymatic and non-enzymatic antioxidants in diabetic patients. This study suggested that inclusion of sesame oil in the diet improve the hyperglycemic condition in type II diabetic patients (Sankar et al., 2011).

Wound healing effect

Shenoy et al. (2011) evaluated the wound healing effect of sesamol in an experimental animal model. Sesamol treatment significantly increased the tensile strength and hydroxyl proline level. These results indicate that sesamol could be a promising drug in normal as well as delayed wound healing processes.

Cardioprotective effect

Sesamin is one of the antioxidative lignin presents in the sesame oil, as per literature it is found that sesamin is a useful prophylactic treatment in hypertension and cardiovascular hypertrophy (Matsumara et al., 1995; Kang et al., 2000; Nakano et al., 2002). Kaneez et al. (2007) studied the cardioprotective effect of sesame oil against doxorubicin (DOX) induced myocardial injury. They found that sesame oil at a dose of 5 ml/Kg ameliorates the cardiotoxicity via endogenous antioxidant mechanism. Sankar et al. (2005) reported the protective role of sesame oil in hypertensive patients. They observed that consumption of sesame oil remarkably reduced the oxidative stress by increasing the antioxidant enzymes. The effect of sesame oil compared with nifedipine as known antihypertensive drugs. Sesame oil produced significant reduction in blood pressure when compared to nifedipine alone treated patients. The antihypertensive property of sesame oil might be due to presence of one or more antioxidative principle. In another study, sesame oil is mixed with sun flower oil and administered to the hypertensive patients. Nifedipine and oil mix significantly reduced the blood pressure and normalized the lipid level, electrolytes and enzymatic parameters (Sudhakar et al., 2011). Nakano et al. (2006) reported that administration of sesamin produced significant antihypertensive activity via endothelial nitric oxide-dependent vasorelaxation. It has been suggested that sesamin metabolites modulate the vascular tone and contribute to the *in vivo* antihypertensive effect of sesamin by inducing an endothelial nitric oxide-dependent vasorelaxation.

We have reported the cardioprotective properties of chronic oral administration of sesame oil in in-vitro model of myocardial ischemic reperfusion injury in rats. In this study, we observed that sesame oil administration at a dose 5 & 10 ml/kg produced significant protection via enhancing the endogenous antioxidant enzymes (Saleem et al., 2012). Sesamol is one of the antioxidative principle presents in the sesame oil protected the myocardium against isoproterenol induced myocardial toxicity via antihyperlipidemic action (Vennila & Pugalendi, 2012).

Karatzi et al. (2012a) studied the hemodynamic effects of sesame oil consumption against hypertensive patients. They observed that fifteen days treatment of sesame oil at a dose of 36 g significantly reduced the systolic blood pressure; heart rate was normalized and increased to the level of total antioxidant capacity. In another study, they found sesame oil consumption exerts a beneficial effect on endothelial function, and this effect is sustained with a long-term daily use (Karatzi et al., 2012b).

Anti-inflammatory activity

Sesame oil and its lignans interfere with an inflammatory pathways. Sesamin decreases the synthesis of arachidonic acid via inhibition of Δ5 desaturase activity. It also reduces the formation of pro-inflammatory mediators, including prostaglandin PGE2, Tumor Necrosis Factor- α (TNF-α), Interleukin-6 and Interleukin-10 in mice (Chavali et al., 1998; Umeda-Sawada et al., 2003). Chronic oral administration of sesame oil significantly altered the oxidative stress induced biochemical changes occurring in adjuvant arthritis; moreover, it improves endothelium-dependent relaxation of the aorta and tends to decrease hind paw edema (Sotnikova et al., 2009). Analgesic, antipyretic and anti-inflammatory activity of sesame oil at a dose of 5 and 10 ml/kg was evaluated in an experimental animal model. Sesame oil shows significant protective action in these models with the dose dependent activity (Mohamed Saleem et al., 2011).

Hypolipidemic action

Sesame oil reduced the accumulation of cholesterol by inhibition of absorption and decreasing synthesis of cholesterol (Hirose et al., 1991; Ide et al., 2001). It is found that administration of sesamin reduced the serum cholesterol in animal model and in another study, it is observed that sesamin inhibits the activity of liver microsomal 3-hydroxy-3-methylglutaryl Coenzyme A reductase (HMG-CoA reductase), the rate limiting enzyme of cholesterol synthesis in liver (Hirose et al., 1991). Satchithanandam et al. (1993; 1996) reported the hypocholestrolemic effect of sesame oil in an animal model. Supplementation of sesame oil reduced the serum cholesterol and LDL level in rats via inhibition of lymphatic absorption of cholesterol and fatty acids and also reduced synthesis of cholesterol in liver. In another animal model, it is found that sesame oil consumption decrease the triacylglycerols (TG) and cholesterol level in blood and liver (Ide et al., 2001). Sesame

oil consumption reduced the level of cholesterol and triglyceride and enhances the level of HDL in hypertensive patients (Sankar et al., 2005). Oral administration of sesame oil and N-acetylcysteine significantly restored the lipid level and hepatic steatosis on diet-induced hypercholesterolemic mice also enhanced the serum level of antioxidant enzyme (Korou et al., 2010).

Sharma et al. (2012) studied the potential role of sesamol in a chronic high-cholesterol/high-fat diet (HFD)-induced cardiometabolic syndrome (CMetS) in rats and also explored the molecular mechanism driving this activity. The results suggest that sesamol attenuates oxidative stress, inflammation, IR, hepatic steatosis and hypertension in HFD-fed rats via modulating PPARγ, NF-κB, P-JNK, PPARα, LXRα, SREBP-1c and e-NOS protein expressions, thereby preventing CMetS.

Gastro protective action

Hsu et al. (2009) reported the gastro protective action of sesame oil on ethanol-induced gastric mucosal lesions. Administration of sesame oil significantly decreased the ulcer induced by ethanol. They found that the protective action of sesame oil via reduced mucosal lipid peroxidation, as well as glutathione and nitric oxide production in acidified ethanol-treated stomachs. Ji et al. (2010) studied the therapeutic value of sesame oil in the treatment of small bowel obstruction. The study showed that sesame oil was a safe and effective adjunct to the standard treatment of partial adhesive small bowel obstruction.

Effect on experimental septic rats

Sepsis is one of the major problems to cause high mortality for hospitalized patients. Sesame oil administration to septic rats reduced the free-radical generation and also decreases the hepatic lipid peroxidation by inhibiting superoxide anion and nitric oxide (Hsu et al., 2008a, b; Hsu et al., 2006b).

Effect on liver and kidney

Effect of sesame oil on liver injury caused by acetaminophen (APAP) & lead-plus-lipopolysaccharide (Pb + LPS) overdose has been documented. Sesame oil at a dose of 8 ml/kg significantly regressed to all the parameters altered by these two agents and protected the rats against acute liver injury. In acetaminophen, induced model sesame oil increased the glutathione and inhibited lipid peroxidation via inhibition of ROS. In Pb + LPS model sesame oil inhibited the tumor necrosis factor-α, interleukin-1β, and nitric oxide production in serum and liver tissue. The inhibition of proinflammatory cytokines and nitric oxide might be involved in sesame oil associated protection against Pb + LPS-induced acute hepatic injury in mice (Chiang et al., 2005; Hsu et al., 2007a; Chandeasekaran et al., 2008). Sesame oil at a dose of 8 ml/kg significantly reversed the altered biochemical and antioxidative parameters induced by cumulative over dose of APAP. The protective action of sesame oil against APAP induced oxidative liver injury via stabilization of glutathione and inhibition of ROS (Chandeasekaran et al., 2010).

Hsu et al. (2007b) reported the protective action of sesame oil against cisplatin induced hepatic and renal damage. They observed that sesame oil offered the therapeutic effect against cisplatin induced organ damage via inhibiting nitric oxide-associated LPO in mice. Li et al. (2012) reported that sesame oil significantly decreased the blood urea nitrogen (BUN) and creatinine in acute iron intoxicated rats. Sesame oil showed both prophylactic and therapeutic effect against iron induced renal injury. Li et al. (2011) reported that subcutaneous injection of sesame oil protected the kidney from ferric-nitrotriacetate injected mice. In this study, they observed that sesame oil produced both prophylactic and therapeutic effect against acute renal injury in mice.

Protective role of sesame oil at a dose of 0.5 ml/kg against acute kidney injury induced by the synergistic action of aminoglycoside and iodinated contrast in rats has been reported. Sesame oil significantly altered the kidney function by inhibiting renal oxidative stress in rats (Hsu et al., 2011).

Goksu Erol et al. (2012) studied the nephroprotective action of sesame oil against cyclosporine induced nephrotoxicity. They observed that sesame oil and omega-3 fatty acid acid treatments produced significant protection against cyclosporine induced nephrotoxicity. However, impaired renal function not altered by these treatments. Cypermethrin is one of the pyrethroid pesticides producing liver and kidney toxicity. Chronic oral administration of sesame oil at a dose of 5 ml/kg significantly altered the biochemical parameters and histological changes produced by cypermethrin (Abdou et al., 2012). Sesame oil also protected the kidney from gentamicin induced nephrotoxicity at single oral dose administration (Periasamy et al., 2010; Hsu et al., 2010).

Neuroprotective action

Ahmad et al. (2012) reported that incorporation of sesame oil in diet enhancing the antioxidant enzyme. They evaluated the antioxidant potential of sesame oil in 6-Hydroxydopamine (6-OHDA)-induced neurotoxicity in mice. The mice pretreated with sesame oil diet showed the protective role via increasing the antioxidant enzyme and also inhibit activation of NADPH oxidase dependent inflammatory mechanism due to 6-OHDA induced neurotoxicity in mice. Hussien et al. (2011) reported that chronic administration of sesame oil in female rat decreased the oxidative stress induced by cypermethrin via enhanced antioxidant enzymes in rat brain. In this study, they observed that administration of sesame oil also preserved the histopathological damage induced by cypermethrin in rat brain. Sesamin at a dose of 30 mg/kg protecting the brain from middle cerebral artery occlusion in experimental rat. The results suggested that sesamin reduced the brain cell

death and generation of free radicals in rat brain (Khan et al., 2010).

Effect on multiple sclerosis

Ghazavi & Mosayebi, (2012) studied the protective role of sesame oil at a dose of 4 ml/kg against multiple sclerosis (MS). MS is induced in an animal model by experimental autoimmune encephalomyelitis (EAE) is a Th1 cell mediated autoimmune disease of the CNS. The results observed in this study indicated that sesame oil significantly lowered the clinical symptoms of EAE and also delayed the onset of disease. Thus, inclusion of sesame oil in the diet may be effective for MS patients.

Anticancer effects

Sesamin found to be shows anti-proliferative and antiangiogenic activity. Akl et al. (2012) studied the antiproliferative action sesamin in combination with α-tocotrienol. The results of this study revealed that the anti-proliferative effect of sesamin in combination with α-tocotrienol associated with inhibition of endothelial growth factor dependent mitogenic signaling in mammary tumor cells. Tanabe et al. (2011) studied the possible link between EphB2 and autophagy in presence of sesamin. The present study reveals a novel function for EphA1 and EphB2 in the induction of autophagy by sesamin, suggesting a tumor suppressor role for these proteins in colorectal cancer. In another study, it has been reported that sesamin may have been potential against cancer and other chronic diseases through the suppression of a pathway linked to the NF-kappaB signaling (Harkumar et al., 2010).

Miscellaneous

Endotoxin is a potent inducer of lipid peroxidation (LPO), which is associated in the development of endotoxemia. 3, 4-Methylenedioxyphenol (sesamol) is one of the sesame oil lignans with a high anti-LPO effect. Sesamol dose dependently reduced serum LPO in endotoxin-challenged rats, decreased hydroxyl radical and peroxynitrite, but not superoxide anion counts, increased the activities of superoxide dismutase, catalase, and glutathione peroxidase in endotoxin-treated rats, reduced nitric oxide (NO) production and inducible NO synthase expression, and attenuated hepatic and renal injuries induced by endotoxin in rats. We concluded that sesamol might protect against organ injury by decreasing NO-associated LPO in endotoxemic rats (Hsu et al., 2006c).

Jiang et al. (2011) reported that sesamin an active lignan from sesame oil could stimulate melanogenesis in B16 cells via the up-regulation of MITF and tyrosinase, which was, in turn, due to the activation of cAMP signaling.

Oil pulling therapy is effective and has been used in the Indian traditional system for strengthening the teeth and to prevent the decay, bleeding gums. Asokan et al. (2011a) reported that oil pulling by using sesame oil prevent the halitosis and organism equal to chlorhexidine. The myth that the effect of oil-pulling therapy on oral health was just a placebo effect has been broken and there are clear indications of possible saponification and emulsification process, which enhances its mechanical cleaning action (Asokan et al., 2011b). The oil pulling therapy showed a reduction in the plaque index, modified gingival scores, and total colony count of aerobic microorganisms in the plaque of adolescents with plaque-induced gingivitis (Asokan et al., 2009).

Periasamy et al. (2012a) investigated the protective effect of prophylactic sesame oil against monocrotaline-induced sinusoidal obstruction syndrome (SOS) in rats. A single prophylactic dose of sesame oil protects against SOS by downregulating MMP-9 expression, upregulating TIMP-1 expression, and inhibiting oxidative stress. However, in another study, they found that oral administration of sesame oil does not protect the rats against monocrotaline-induced SOS (Periasamy et al., 2012b). Srinivasan & Liu, (2012) studied the comparative effect of sesame oil and peanut oil against monocrotaline induced toxicity in rats. The results indicated that sesame oil is more efficacious than peanut oil against acute monocrotaline poisoning in rats.

Arumugam & Ramesh (2011) studied the protective role of sesame oil against 4-Nitroquinoline-1-oxide (4-NQO) -induced oxidative DNA damage and lipid peroxidation (LPO) in rats. Oral administrations of sesame oil prevent the DNA damage in a dose-dependent fashion. This study indicates that the antioxidant, sesame oil, effectively protected DNA damage and LPO induced by 4-NQO. Kanimozhi & Prasad (2009) reported the protective effect of sesamol against radiation-induced DNA damage in mice. The results suggested that sesamol protect γ-radiation-induced DNA damage in mice lymphocytes, which may be attributed to its antioxidant property.

CONCLUSION

Protective roles of sesame oil in various disease conditions are well documented. From the literature, it has been found that sesame oil and its antioxidant lignans sesamin and sesamol shows different pharmacological activity like cardioprotective, hypoglycemic, anticancer, anti-inflammatory, renoprotecctive, hepatoprotective, gastro protective and neuroprotective action. These all pharmacological effect offered by sesame oil via antioxidative mechanism. So, incorporation of sesame oil in the human diet may be alleviates all the life-threatening diseases.

REFERENCES

Abdou HM, Hussien HM, Yousef MI. Deleterious effects of cypermethrin on rat liver and kidney: protective role of sesame oil. J Environ Sci Health B 2012; 47(4):306-14.

Ahmad S, Khan MB, Hoda MN, Bhatia K, Haque R, Fazili IS, Jamal A, Khan JS, Katare DP. Neuroprotective Effect of Sesame Seed Oil in 6-Hydroxydopamine Induced Neurotoxicity in Mice Model: Cellular, Biochemical and Neurochemical Evidence. Neurochem Res 2012;37(3):516-26.

Akl MR, Ayoub NM, Sylvester PW. Mechanisms Mediating the Synergistic Anticancer Effects of Combined γ-Tocotrienol and Sesamin Treatment. Planta Med 2012. In Press

Arumugam P, Ramesh S. Protective effects of sesame oil on 4-NQO-induced oxidative DNA damage and lipid peroxidation in rats. Drug Chem Toxicol 2011;34(2):116-9.

Asokan S, Emmadi P, Chamundeswari R. Effect of oil pulling on plaque induced gingivitis: a randomized, controlled, triple-blind study. Indian J Dent Res 2009;20(1):47-51.

Asokan S, Kumar RS, Emmadi P, Raghuraman R, Sivakumar N. Effect of oil pulling on halitosis and microorganism causing haltiosis: a randomised controlled pilot trial. J Indian Soc Pedod Prev Dent 2011a; 29(2):90-4.

Asokan S, Rathinasamy TK, Inbamani N, Menon T, Kumar SS, Emmadi P, Raghuraman R. Mechanism of oil-pulling therapy - in vitro study. Indian J Dent Res 2011b;22(1):34-7.

Chandrasekaran VR, Chien SP, Hsu DZ, Chang YC, Liu MY. Effects of sesame oil against after the onset of acetaminophen-induced acute hepatic injury in rats. JPEN J Parenter Enteral Nutr 2010;34(5):567-73.

Chandrasekaran VR, Wan CH, Liu LL, Hsu DZ, Liu MY. Effect of sesame oil against acetaminophen-induced acute oxidative hepatic damage in rats. Shock 2008; 30(2): 217-221.

Chavali SR, Zhong WW, Forse RA. Dietary alpha-linolenic acid increases TNF-alpha, and decreases IL-6, IL-10 in response to LPS: Effects of sesamin on the delta5 desaturation of omega6 and omega3 fatty acids in mice. Prostaglandins Leukot Essent Fatty Acids 1998; 58: 185-191.

Chiang JP, Hsu DZ, Tsai JC, Sheu HM, Liu MY. Effects of topical sesame oil on oxidative stress in rats. Altern Ther Health Med 2005; 11(6): 40-45.

Fukuda Y. Food chemical studies on the antioxidants in sesame seed. Nippon Shokuhin Kogyo Gakkaishi 1990; 37: 484-492.

Gauthaman K, Mohamed Saleem TS. Nutraceutical value of sesame oil. Phcog Rev 2009;3:264-9

Ghazavi A, Mosayebi G. The mechanism of sesame oil in ameliorating experimental autoimmune encephalomyelitis in C57BL/6 mice. Phytother Res 2012; 26(1):34-38

Goksu Erol AY, Avcı G, Sevimli A, Ulutas E, Ozdemir M. The protective effects of omega 3 fatty acids and sesame oil against cyclosporine A-induced nephrotoxicity. Drug Chem Toxicol. 2012. In Press

Harikumar KB, Sung B, Tharakan ST, Pandey MK, Joy B, Guha S, Krishnan S, Aggarwal BB. Sesamin manifests chemopreventive effects through the suppression of NF-kappa B-regulated cell survival, proliferation, invasion, and angiogenic gene products. Mol Cancer Res 2010;8(5):751-61

Hemalatha S, Raghunath M, Ghafoorinissa. Dietary sesame oils inhibits iron induced oxidative stress in rats (corrected). Br J Nutr 2004; 92: 581- 7.

Hirose N, Inoue T, Nishihara K. Inhibition of cholesterol absorption and synthesis in rats by sesamin. J Lipid Res 1991; 32: 629-38.

Hsu DZ, Chen KT, Chien CH, Li YH, Huang BM, Chuang YC, Liu MY. Sesame oil attenuates acute iron – induced lipid peroxidation – associated hepatic damage in mice. Shock 2006a; 26: 625-630.

Hsu DZ, Chen KT, Chu PY, Li YH, Liu MY. Sesame oil protects against lead-plus-lipopolysaccharide-induced acute hepatic injury. Shock 2007a; 27(3): 334-337.

Hsu DZ, Chen KT, Li YH, Chuang YC, Liu MY. Sesamol delays mortality and attenuates hepatic injury after cecal ligation and puncture in rats: role of oxidative stress. Shock 2006b; 25(5): 528-532.

Hsu DZ, Chen KT, Lin TH, Li YH, Liu MY. Sesame oil attenuates Cisplatin-induced hepatic and renal injuries by inhibiting nitric oxide-associated lipid peroxidation in mice. Shock 2007b; 27(2): 199-204.

Hsu DZ, Chiang PJ, Chien SP, Huang BM, Liu MY. Parenteral sesame oil attenuates oxidative stress after endotoxin intoxication in rats. Toxicology 2004c; 196(1-2): 147-153.

Hsu DZ, Chien SP, Li YH, Chuang YC, Chang YC, Liu MY. Sesame oil attenuates hepatic lipid peroxidation by inhibiting nitric oxide and superoxide anion generation in septic rats. JPEN J Parenter Enteral Nutr 2008b; 32(2): 154-159.

Hsu DZ, Chien SP, Li YH, Liu MY. Sesame oil does not show accumulatively enhanced protection against oxidative stressassociated hepatic injury in septic rats. JPEN J Parenter Enteral Nutr 2008a; 32(3): 276-280.

Hsu DZ, Chu PY, Liu MY. Effect of Sesame Oil on Acidified Ethanol-Induced Gastric Mucosal Injury in Rats. JPEN J Parenter Enteral Nutr 2009; 33(4):423-7.

Hsu DZ, Li YH, Chu PY, Chien SP, Chuang YC, Liu MY. Attenuation of endotoxin-induced oxidative stress and multiple organ injury by 3,4-Methyl enedioxyphenol in rats. Shock 2006c;25(3): 300-305.

Hsu DZ, Li YH, Chu PY, Periasamy S, Liu MY. Sesame oil prevents acute kidney injury induced by the synergistic action of aminoglycoside and iodinated contrast in rats. Antimicrob Agents Chemother 2011; 55(6): 2532-6.

Hsu DZ, Liu CT, Li YH, Chu PY, Liu MY. Protective effect of daily sesame oil supplement on gentamicin-induced renal injury in rats. Shock 2010;33(1):88-92.

Hsu DZ, Liu MY, Li YH, Chien SP. Effects of sesame oil on oxidative stress and hepatic injury after cecal ligation and puncture in rats. Shock 2004b; 21: 466-469.

Hsu DZ, Liu MY. Effects of sesame oil on oxidative stress after the onset of sepsis in rats. Shock 2004a; 22: 582-585.

Hsu DZ, Liu MY. Sesame oil attenuates multiple organ failure and increase survival rate during endotoxemia in rats. Crit Care Med 2002; 30: 1859-1862.

Hsu DZ, Liu MY. Sesame oil protects against lipopolysaccharide- stimulated oxidative stressin rats. Crit Care Med 2004b; 32: 227-231.

Hsu DZ, Su SB, Chien SP, Chiang PJ, Li YH, Lo YJ, Liu MY. Effect of sesame oil on oxidative stress associated renal injury in endotoxemic rats: involvement of nitric oxide and proinflammatory cytokines. Shock 2005;24: 276-280.

Hussein HM, Abdou HM, Yousef MI. Cpermethrin induced damage in genomic DNA and histopathological changes in brain and haematotoxicity in rats: The protective effect of sesame oil. Brain Re Bull 2011. http://dx.doi.org/10.1016/j.brainresbull.2011.10.02.

Ide T, Ashakumary L, Takahashi Y, Kushiro M, Fukuda N, Sugano M. Sesamin, a sesame lignan, decreases fatty acid synthesis in rat liver accompanying the down regulation of sterol regulatory element binding protein-1. Biochim Biophys Acta 2001; 1534: 1-13.

Ji ZL, Li JS, Yuan CW, Chen WD, Zhang YN, Ju XT, Tang WH. Therapeutic value of sesame oil in the treatment of adhesive small bowel obstruction. Am J Surg 2010;199(2):160-5.

Jiang z, Li S, Liu Y, Deng P, Huang J, He G. Sesamin induces melanogenesis by microphthalmia associated transcription factor and tyrosinase up regulation via cAMP signaling pathway. Acta Biochem Biophys Sin (Shanghai) 2011; 43(10): 763-770

Kaneez FS, Al-Salam S, Alaaeldin AH. Sesame Oil as a Protective Agent Against Doxorubicin Induced Cardio Toxicity in Rat. American Journal of Pharmacology and Toxicology 2007; 2(4): 159-163.

Kang MH, Naito M, Sakai K, Uchida K, Osawa T. Mode of action of sesame lignans in protecting low density lipoprotein against oxidative damage in vitro. Life Sci 2000; 66: 161-171 (2000).

Kang MH, Naito M, Tsujihara N, Osawa T. Sesamolin inhibits lipid peroxidation in rat liver and kidney. J Nutr 1998;128: 1018-1022.

Kanimozhi P, Prasad NR. Antioxidant potential of sesamol and its role on radiation-induced DNA damage in whole-body irradiated Swiss albino mice. Environ Toxicol Pharmacol 2009;28(2):192-7.

Karatzi K, Stamatelopoulos K, Lykka M, Mantzouratou P, Skalidi S, Manios E, Georgiopoulos G, Zakopoulos N, Papamichael C, Sidossis LS. Acute and long-term hemodynamic effects of sesame oil consumption in hypertensive men. J Clin Hypertens (Greenwich) 2012a; 14:630-636.

Karatzi K, Stamatelopoulos K, Lykka M, Mantzouratou P, Skalidi S, Zakopoulos N, Papamichael C, Sidossis LS. Sesame oil consumption exerts a beneficial effect on endothelial function in hypertensive men. Eur J Prev Cardiol. 2012b. In Press

Khan MM, Ishrat T, Ahmad A, Hoda MN, Khan MB, Khuwaja G, Srivastava P, Raza SS, Islam F, Ahmad S. Sesamin attenuates behavioral, biochemical and histological alterations induced by reversible middle cerebral artery occlusion in the rats. Chem Biol Interact 2010;183(1):255-63.

Korou LM, Agrogiannis G, Pantopoulou A, Vlachos IS, Iliopoulos D, Karatzas T, Perrea DN. Comparative antilipidemic effect of N-acetylcysteine and sesame oil administration in diet-induced hypercholesterolemic mice. Lipids Health Dis 2010;9:23.

Li YH, Chien SP, Chu PY, Liu MY. Prophylactic and therapeutic effects of a subcutaneous injection of sesame oil against iron-induced acute renal injury in mice. JPEN J Parenter Enteral Nutr 2012 36: 344-348.

Liu Z, Saarinen NM, Thompson LU. Sesamin is one of the major precursors of mammalian lignans in sesame seed (Sesamum indicum) as observed in vitro and in rats. J Nutr 2006; 136: 906-912.

Marchand PA, Zajicek J, Lewis NG. Oxygen insertion in Sesamum indicum furanofuran lignans. Diastereoselective synthesis of enzyme substrate analogues. Can J Chem 1997; 75: 840-849.

Matsumara Y, Kita S, Morimoto K, Akimoyo MF, Oka N, Tanaka T. Antihypertensive effect of sesamine. Protection against deoxycorticosterone acetate salt-induced hypertension and cardiovascular hypertrophy. Biol Pharm Bull 1995; 18: 1016-1019.

Mohamed Saleem TS, Darbar Basha S, Mahesh G, Sandhya Rani PV, Suresh Kumar N, Madhusudhana Chetty C. Analgesic, Anti-pyretic and Anti-inflammatory Activity of Dietary Sesame Oil in Experimental Animal Models. Pharmacologia 2011; 2: 172-177.

Nakai M, Harada M, Nakahara K, Akimoto K, Shibata H, Miki W, Kiso Y. Novel antioxidative metabolites in rat

liver with ingested sesamin. J Agric Food Chem 2003; 51: 1666-70.

Nakano D, Itoh C, Takaoka M, Kiso Y, Tanaka T, Matsumura Y. Antihypertensive effect of sesamin.IV. Inhibition of vascular superoxide production by sesamin. Biol Pharmacol Bull 2002;25(9): 1247-1249.

Nakano D, Kwak CJ, Fujii K, Ikemura K, Satake A, Ohkita M, Takaoka M, Ono Y, Nakai M, Tomimori N, Kiso Y, Matsumura Y. Sesamin metabolites induce an endothelial nitric oxide dependent vasorelaxation through their antioxidative property- independent mechanisms: possible involvement of the metabolites in the antihypertensive effect of sesamin. J Pharmacol Exp Ther 2006;318(1): 328- 335.

Periasamy S, Chien SP, Liu MY. Therapeutic Oral Sesame Oil Is Ineffectual Against Monocrotaline-Induced Sinusoidal Obstruction Syndrome in Rats. JPEN J Parenter Enteral Nutr. 2012a. In Press

Periasamy S, Liu CT, Hsu DZ, Liu MY. Sesame oil accelerates kidney healing following gentamicin-induced kidney injury in rats. Am J Nephrol 2010;32(5):383-92.

Periasamy S, Yang SS, Chen SY, Chang CC, Liu MY. Prophylactic Sesame Oil Attenuates Sinusoidal Obstruction Syndrome by Inhibiting Matrix Metalloproteinase-9 and Oxidative Stress. JPEN J Parenter Enteral Nutr. 2012b. In Press

Saleem T. S. Mohamed, Chetty C. Madhusudhana, Kavimani S. Sesame oil enhances endogenous antioxidants in ischemic myocardium of rat. Rev bras farmacogn 2012; 22(3): 669-675.

Sankar D, Ali A, Sambandam G, Rao R. Sesame oil exhibits synergistic effect with anti-diabetic medication in patients with type 2 diabetes mellitus. Clin Nutr. 2011;30(3):351-8.

Sankar D, Sambandam M, Ramakrishna R. Modulation of blood pressure, lipid profiles, and redox status in hypertensive patients taking different edible oils. Clinica Chimica Acta 2005; 355: 97-104.

Satchithanandam S, Chanderbhan R, Kharroubi AT. Effect of sesame oil on serum and liver lipid profiles in the rat. Int J Nutr Res 1996; 66: 386-392.

Satchithanandam S, Reicks M, Calvert RJ, Cassidy MM, Kritchevsky D. Coconut oil and sesame oil affect lymphatic absorption of cholesterol and fatty acids in rats. J Nutr 1993; 123: 1852-1858.

Sharma AK, Bharti S, Bhatia J, Nepal S, Malik S, Ray R, Kumari S, Arya DS. Sesamol alleviates diet-induced cardiometabolic syndrome in rats via up-regulating PPARγ, PPARα and e-NOS. J Nutr Biochem 2012. In Press

Shenoy RR, Sudheendra AT, Nayak PG, Paul P, Kutty NG, Rao CM. Normal and delayed wound healing is improved by sesamol, an active constituent of Sesamum indicum (L.) in albino rats. J Ethnopharmacol 2011;133(2):608-12

Sotnikova R, Ponist S, Navarova J, Mihalova D, Tomekova V, Strosova M, Bauerova K. Effects of sesame oil in the model of adjuvant arthritis. Neuro Endocrinol Lett 2009;30 Suppl 1:22-4.

Srinivasan P, Liu MY. Comparative potential therapeutic effect of sesame oil and peanut oil against acute monocrotaline (Crotalaria) poisoning in a rat model. J Vet Intern Med 2012;26(3):491-9.

Sudhakar B, Kalaiarasi P, Al-Numair KS, Chandramohan G, Rao RK, Pugalendi KV. Effect of combination of edible oils on blood pressure, lipid profile, lipid peroxidative markers, antioxidant status, and electrolytes in patients with hypertension on nifedipine treatment. Saudi Med J 2011;32(4):379-85.

Tanabe H, Kuribayashi K, Tsuji N, Tanaka M, Kobayashi D, Watanabe N. Sesamin induces autophagy in colon cancer cells by reducing tyrosine phosphorylation of EphA1 and EphB2. Int J Oncol 2011;39(1):33-40

Umeda-Sawada R, Fujiwara Y, Abe H, Seyama Y. Effects of sesamin and capsaicin on the mRNA expressions of delta6 and delta5 desaturases in rat primary cultured hepatocytes. J Nutr Sci Vitaminol 2003; 49: 442-446.

Vennila L, Pugalendi KV. Efficacy of sesamol on plasma and tissue lipids in isoproterenol-induced cardiotoxicity in wistar rats. Arch Pharm Res. 2012;35(8):1465-70.