

# A Review on Nutritional and Nutraceutical Properties of Sesame

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## Abstract

Sesame which is known for properties of good health consists of a plethora of nutrients viz., proteins, carbohydrates, antioxidants, lignans, tocopherols and other micronutrients. Benefits of this enigmatic crop include properties of anticancer, antioxidative, antiimmunoregulation and antihypersensitivity. Covering wide agro ecological regions of the world, different varieties of sesame seeds are available. They are seen growing in different parts of the world, where India being one of the major producers. The oil from this seed can be extracted by simple processes of solvent extraction and expelling. Alternatively, as the technology has advanced, supercritical extraction can also be employed. Sesame which is considered as an extremely beneficial medicine has inherent power to cure many diseases. Sesame has a ray of health benefits in lowering cholesterol, controlling blood pressure, dermatological disease management and many more areas. This review gives an overall impact about sesame, properties and its role in various sections.

**Keywords:** Gingelly; Sesame; Tocopherol; Hypocholesterolemic

## Introduction

Dating back to as early as 1600 BC, sesame seeds are the oldest condiment known to man. Sesame, *Sesamum indicum* L. belonging to the family Pedaliaceae, is widely cultivated in the tropical parts of Africa and Asia and about 36 species are said to be existent [1]. Their wild species are located mainly in Africa and only a few in India [2]. The original home of this crop is known to be Ethiopia [3]. The major sesame producers are India, Myanmar, China and Sudan with 68% of the total world production [4]. In the world, India ranks first in the production and area of sesame seeds and is grown in different seasons covering practically all agro-ecological zones [3,4].

Oil extracted from sesame is honoured as a rich food because of its high nutritive quality and stability [5]. It has many uses and it is markedly different from other vegetable oils due to its high nutritional and therapeutic values. Potential health benefits of sesame include anti oxidative, anticancer, anti hypersensitive and anti immunoregulatory actions [6]. The seeds are used for the production of oil, paste, salads and in various food formulations. From the chemical composition of sesame, it is known that the seeds contain 50-60% oil, 18-25% protein, 13.5% carbohydrate and 5% ash [7]. The noteworthy stability to oxidation can be attributed to its endogenous anti-oxidant lignans along with tocopherols [6]. Sesamin (0.4-1.1%), sesamol (0.3-0.6%) and traces of sesamol contribute to the unique properties of sesame oil [8]. In the eastern parts of the world, sesame has long been considered as a 'health food' that provides high energy and prevents ageing [9]. The oil is rich in unsaturated fatty acids (85%) and has a mild taste<sup>o</sup>. It is said to be plant breeder's dream crop because of its great genetic diversity [4] (Table 1).

Sesame is a rich source of calcium (approx 1%) and phosphorous (approx 0.7%) [5]. Sesame contains ample amounts of oleic (43%), linoleic (35%), palmitic (11%) and stearic acid (7%) which together comprise 96% of the total fatty acids [1].

## Varieties and Genetic Diversity

Sesame seeds are tiny, flat, oval with a nutty taste and delicate with

almost invisible crunch. They vary in size from small to large and come in a host of different colours, depending upon the variety, including white, yellow, black, grey, brown and red. The seeds from northeast region of India are black; those from eastern region are brown to black and from south are predominantly red or reddish brown. Seeds from other regions are white [3]. White and black seeded strains, on an average contain 55% and 47.8% oil respectively [10]. White and black sesame seed coat fractions have considerable anti-oxidant property but the same is better in black sesame coats [3,7]. The oil extracted from coated seeds possesses high oxidative stability than that of dehulled

ORIGIN	SEED COLOUR
USA	Light brown and brown
Palestine	Brown and white
Portugal	Greyish white
Turkey	Light brown and brown
Japan	Brown
Bulgaria	White and brown
Korea	White and brown
Brazil	Dark grey and white
India	White and dark grey
Venezuela	Greyish white and light brown
Ethiopia	Light brown
Tanzania	Greyish white
China	Black
Egypt	White and light brown

Table 1: Diversity of sesame seeds [38].

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Location	Variety	Sesamin	Sesamolignin	Total lignans
Gujarat	White	6.6	4.5	11.1
Gujarat	Brown	7.6	8.2	15.8
Assam	Black	4.9	5.8	10.7
West Bengal	White	6.5	5.3	11.8
Bengal	Dehusked	8.1	4.8	12.9
Andhra Pradesh	Black	6.4	6.2	12.8
Gujarat	Black	3.1	3.2	6.2
Andhra Pradesh	White	5.7	3.6	9.3
Orissa	White	3.6	2.3	5.9
Assam	White	18.6	10.0	28.6

Table 2: Varieties of seeds and their lignan profile [28].

seeds [7]. Dehulling is necessary as the hull contains 2-3% oxalic acid, which chelates calcium and has a bitter flavor [11] (Table 2).

The production of sesame seeds is 170,000 tons per year in America; Mexico, Guatemala and Venezuela which impart 60% to the continent's production [12]. Samples of seeds from different states of India were analysed by K. Venkataramana Bhat et al. [13] using random amplified polymorphic DNA (RAPD) technique. Results showed the high level of genetic diversity, which indicated the nativity of the crop. Rajasthan and the north eastern states showed maximum diversity [13]. Throughout the world the area under the cultivation of sesame is 6 million hectares, where 65% of crop is used for extraction of oil and 35% is used as food [14].

Morphologically diverse seven genotypes of sesame are found, which represent different growing regions of India. These include CST 2002 and MT 34 from Uttar Pradesh, TKG 22 from Madhya Pradesh, AAUDT 9304-14-4 from Assam, B 67 and Rama from West Bengal [4]. In India, two sections of sesamum are found – *S. laciniatum* and *S. prostratum*. Another section includes *S. malabaricum* which is locally called as 'wild gingelly of Malabar' [15].

### Extraction of Oil

The industrialization of sesame oil is very important for food, cosmetic and pharmaceutical purposes. Final product quality and environmental aspects are the desired considerations for an adequate extraction process. Several processes for sesame oil production include mechanical milling followed by solvent extraction using organic liquids and solvent recuperation by distillation. Super critical extraction is an alternative process which uses pressurized fluids, minimising the use of liquid organic solvents [16].

Sesame seed gives about 45-50% by weight of highly stable oil after extraction. Lignan content contributes to 32.23% in the extract by solvent extraction. Whereas in case of supercritical extraction, the lignan content is found to be 1.5-3.5%. The main lignans account for about 10% of unsaponifiable matter in sesame oil [6]. By products obtained from sesame are rich sources of dietary fibres [7].

### Expelling

Expelling is the simplest method of oil extraction by crushing, without the intervention of any chemicals. The desired quality of seeds for crushing is got by naturally drying, cleaning and grading the seeds. Cleaning and grading removes physical impurities. Clean seeds are

later crushed in expellers and rotary machines by adding palm jaggery. Raw Sesame Oil obtained is stored in tanks. The sesame cake is packed and sold in the market as Animal Feed. Using filter press, raw sesame oil is filtered for fine particles. The Oil-Cake sludge from the filter press is added along with the sesame cake and crushed (Figure 1).

### Solvent extraction

Distribution of the solute between two immiscible liquid phases which are in contact with each other, due to the density difference is the principle behind solvent extraction [17]. In the process, unroasted seeds are first extracted by simple mechanical pressing followed by solvent extraction. Solvent extraction of sesame seeds with polar solvents and effective seed crushing generates more stable oil than non-polar solvents and pressed seeds. Compared to n-Hexane, Heptane-isopropanol proves to yield more stable oil. Oxidative stability of the oil is influenced by the extraction method. Solvent extraction can yield approximately 52-55 % oil from the seeds [18].

The disadvantages related with solvent extraction are complex extraction process, high cost and not suited for small scale processing. Management of organic solvents is one of the major problems [19-23].

### Supercritical extraction

The principle behind supercritical extraction is that, near the critical point of the solvent, its properties change rapidly with slight

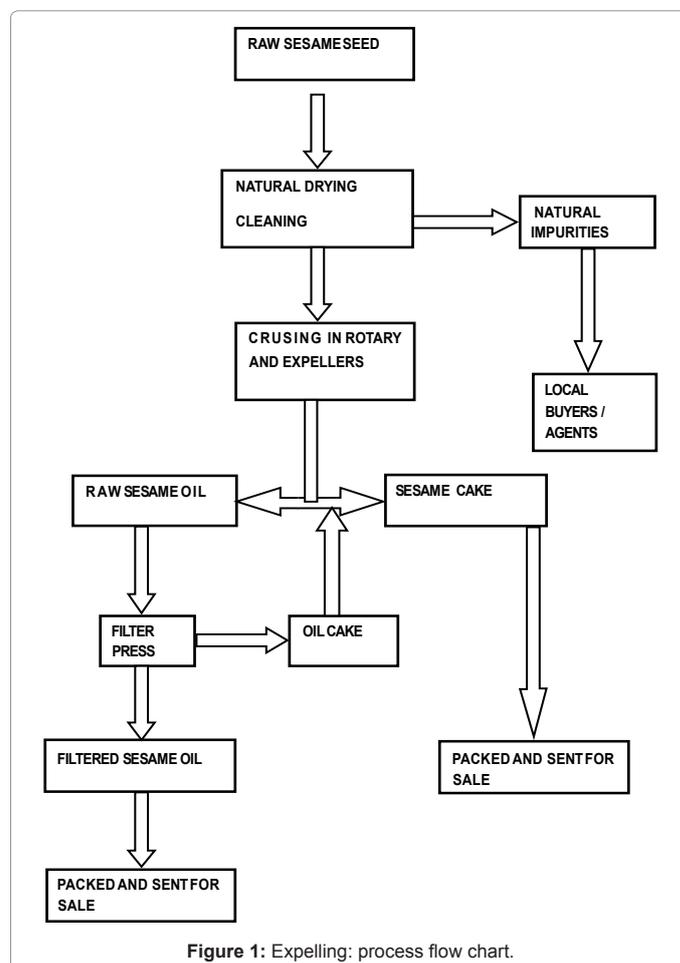


Figure 1: Expelling: process flow chart.

variations in the pressure involved [24]. Supercritical extraction of sesame is usually carried out using carbon dioxide and propane as solvents. Extraction of oil using carbon dioxide includes 313 to 333 K temperature range, pressure variation of 19 to 25 MPa and constant flow rate of 3cm<sup>3</sup>/min and that using propane includes 303 to 333K range of temperature, pressures from 8 to 12 MPa and a constant flow rate of 0.8cm<sup>3</sup>/min [6]. As the pressure and the supercritical CO<sub>2</sub> flow rate is increased, the extraction yield can be improved and the time of the extraction process can also be reduced [25]. The sesame seeds used in the process are required to be dried and milled with specified particle diameter [6].

This process is more environmental friendly and the analytes can be extracted faster [24]. The disadvantage in this process includes the toxicity of the solvent and difficulty in the understanding the phase behaviour between the solvent and oil [6] (Figure 2).

## Healthy Essence of Sesame

### A general note

Sesame oil, queen of oils is an ingredient of varieties of food. It is used as a substitute for olive oil, as a salad oil and for cooking fish and vegetables in many parts of the world. Aqua hulled, double washed and dried sesame seeds are used on hamburger buns. Roasted natural sesame seeds are used in the preparation of bread, breadsticks, cookies, chocolates and ice creams. Mechanically hulled sesame seeds are the basis for candies and creamy, sweet wholesome tahini. The antioxidant property of refined sesame oil contributing for its greater shelf life makes it suitable for food industry. Sesame seed sprouts, sesame broccoli rice, ginger sesame chicken, sesame granula, hummus, sesame spread, tangerine and sesame, sesame seed sauce and sesame pasteries are a few recipes of sesame [26]. The de-oiled meal obtained from extraction of sesame oil is mainly utilized as cattle and poultry feed [6,26].

## Medical Uses

### Regulating cholesterol

In recent times it has been important to identify the dietary components that lower or regulate cholesterol levels. Any natural substance interfering in the cholesterol metabolism preventing hypocholesterolemic atherosclerosis has gained therapeutic importance. The major

lignan sesamin, present in sesame seeds is mainly related to lipid metabolism through a series of biochemical actions in both humans and animals [27].

Dietary sesamin and episesamin has shown significant increase in the gene expression of mitochondrial and peroxisomal fatty acid oxidation enzymes such as carnitine palmitoyltransferase, acyl-CoA dehydrogenase, acyl-CoA oxidase, 3-hydroxyacyl-CoA dehydrogenase, enoyl-CoA hydratase, and 3-ketoacyl-CoA thiolase thus increasing the hepatic activity of fatty acid oxidation which is due to enhanced ketone body production. This hepatic fatty acid metabolism accounts for lowering the serum lipid level [28,29]. Sesamin also increases the activity and gene expression of malic enzyme which has lipogenic activity [28]. Alpha-tocopherol greatly accentuates the hypocholesterolemic action of sesamin, although which alone does not affect the concentration of serum cholesterol [30].

### Neurological role

A characteristic feature of Alzheimer's disease (AD) i.e. a neurodegenerative disease is seen to be cognitive decline, memory impairment and behavioural abnormalities as a result of neural loss. This can be explained by subtle alterations of synaptic efficacy prior to the neuronal death. Neurotrophic factors such as nerve growth factor (NGF) play a vital role in neuronal differentiation, development and synaptic plasticity [31].

When sesamin and episesamin (sterioisomer of sesamin) are ingested, sesamin is metabolised by cytochrome P40 to SC1 (2-(3,4-methylenedioxyphenyl)-6-(3, 4-dihydroxyphenyl)-3,7-dioxabicyclo Octane) which is then metabolized to SC2. Similarly episesamin is metabolized to EC1 and then EC2. These compounds are further metabolized to SC-1m, SC-2m EC-1m and EC-2m by catechol-O-methyl transferase (COMT). The primary metabolites of this cycle exhibit the most potent neural differentiation activity [31].

### Benefits in regulation of blood pressure

It is impressive to state that sesame oil which is rich in polyunsaturated fatty acids-PUFA, sesamin and vitamin E greatly reduces hypertension when compared to the blood pressure lowering drugs [32]. Sesamin feeding significantly decreases the wall thickness and area of aorta and superior mesenteric artery. It also decreases histological renal damage such as the thickening of tunica intima and fibrinoid degeneration of the arterial wall, a feature not observed in normal diet [33]. Sesamin is valuable for prophylactic treatment to fight the development of cardiac hypertrophy and renal hyper tension [34].

### Antioxidant properties

The important antioxidants sesaminol, sesamol, sesaminol and sesamin maintain the fats including Low Density Lipoproteins (LDL) which cause arteriosclerosis and are believed to promote the integrity of body tissues. These antioxidant lignans have shown hypocholesterolemic and immunomodulatory effect [35]. Vitamin E, a fat soluble antioxidant, protects the body from harmful oxidizing compounds. Sesame seed oil contains gamma tocopherols along with sesamol and sesamin which possess Vitamin E like activity.

### Dermatological use

UV light produces various reactive oxygen species (ROS) in the skin causing skin damage such as sunburns, wrinkles and skin cancer [36].

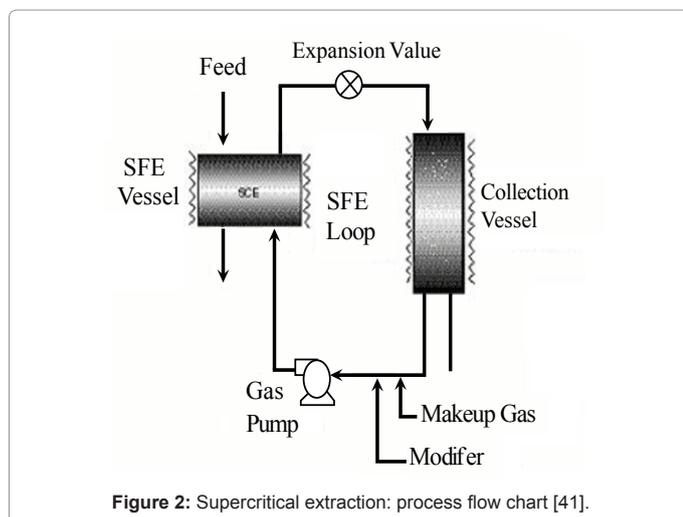


Figure 2: Supercritical extraction: process flow chart [41].

The antioxidants present in sesame act as a defence against these ROS. Chen et al. [37] reported that the mutation caused by UV irradiation on p53 gene can be prevented by topical application of alpha-tocopherol. Dietary intake of  $\alpha$ -tocopherol reduces photocarcinogenesis induced by UVB light [36]. Application of sesame oil with turmeric powder in milk on the facial skin, makes it smooth, soft removing pimples [37].

### Sesame in Ayurveda

Sesame oil is known since vedic times and is the most esteemed oil in ayurveda. Sesame oil is known for its healing properties and has a reputation as a sedative in Tibetan medicine and also used for millennia in Chinese system of medicine [37-39]. In ayurveda, sesame is known to cure Tridoshas [37]. During Abhyanga, a form of massage, the oil is rubbed externally on the skin to improve energy flow and help free the body from impurities. In ayurveda, sesame oil is regarded as an anti bacterial mouthwash and it can also be applied to nostrils to relieve anxiety and insomnia. The pain associated with premenstrual syndrome (PMS) can be overcome by applying the oil on to the abdomen region [38,39]. According to traditional system of medicines, sesame is known to cure bleeding dysentery, burns, ear pain, headache and impotency [37].

### Other Uses

Gram negative bacteria causing nosocomial infection is a serious concern in the developing countries. Owing to this problem sesame kernel meals have shown the presence of novel anti microbial peptides. Through HPLC and mass spectrometric analysis, a major peptide of approximately 5.8 kDa (in both white and black cultivars) has been identified to be an antimicrobial peptide having bactericidal activities against *Klebsiella* species, responsible for human urinary infection [40]. Thus, it proves to be a potential method for hospital infection control and also to decrease the bacterial resistance to synthetic antibiotics [14].

Sesamin, a non fat portion of sesame seed oil, curbs delta-5-desaturase activity and cause compilation of dihomo-gamma-linolenic acid (DGLA), which deracinate arachidonic acid, and subsequently decreases the formation of pro inflammatory mediators [14,41]. Diets containing sesame seed oil and quila (a spawning that emulsifies fat) exert cumulative effect that decreases the levels of dienoic eicosanoids along with IL-1 beta, elevating the levels of IL-10 with marked increased capacity of endurance.

### Nutraceutical and Pharmaceutical Applications

Many plant based nutraceuticals are developed from sesame, the intake of which is related with dietary and non dietary phytochemicals and health [6]. The antioxidant and health promoting property of sesame lignans (sesamin and sesamol) increases both hepatic mitochondrial and peroxisomal fatty acid oxidation rate. Consumption of sesame seed increases plasma gamma-tocopherol and enhances vitamin-E activity which can prevent cancer and heart disease. Sesame seed contains cephalin which has hemostat activity. Fibres from sesame are used as an antidiabetic, antitumor, antiulcer, cancer preventive and cardioprotective [26].

For pharmaceutical applications, sesame oil is used as a solvent for intramuscular injections and has nutritive, demulcent, and emollient properties and as a laxative. It was used to cure toothaches and gum diseases in 4<sup>th</sup> century. It is also used for the treatment of blurred vision,

NUTRITIONAL INFORMATION	SESAME SEEDS	SESAME OIL	SESAME FLOUR	SESAME MEAL
Water (g/100g)	1.60	0	6.61	5
Food Energy (Calories) (kcal/100g)	586	884	382	567
Protein (g/100g)	18.08	0	40.32	16.96
Total Lipid (fat)(g/100g)	50.87	100	11.89	48
Ash (g/100g)	5.40	0	6.05	4
Carbohydrate (g/100g)	24.05	0	35.14	26.04
Total Dietary Fibre (g/100g)	5.5	0	N/A	N/A
Total Sugars (g/100g)	N/A	0	N/A	N/A
Calcium (mg/100g)	960	0	150	153
Iron (mg/100g)	19.2	0	14.3	14.55
Magnesium (mg/100g)	362	0	362	346
Phosphorus (mg/100g)	659	0	810	774
Potassium (mg/100g)	582	0	425	406
Sodium (mg/100g)	12	0	41	39
Zinc (mg/100g)	7.29	0	10.7	10.23
Copper(mg/100g)	4.214	0	1.432	1.457
Manganese(mg/100g)	2.54	N/A	1.403	1.427
Selenium( $\mu$ /100g)	35.5	0	N/A	N/A
Vitamin C (mg/100g)	0	0	0	0
Thiamin (mg/100g)	0.240	0	2.53	2.573
Riboflavin (mg/100g)	0.200	0	0.27	0.275
Niacin (mg/100g)	6.700	0	12.6	12.816
Pantothenic Acid (mg/100g)	0.052	0	2.76	2.807
Vitamin B6 (mg/100g)	0.816	0	0.152	0.146
Folate ( $\mu$ g/100g)	100	0	29	30
Folic Acid ( $\mu$ g/100g)	0	0	0	0
Food Folate ( $\mu$ g/100g)	100	0	29	30
Folate (Dietary Folate Equivalents/100g)	100	0	29	30
Vitamin B12 ( $\mu$ g/100g)	0	0	0	0
Vitamin A ( $\mu$ g/100g)	3	0	69	66
Vitamin A (IU/100g)	50	0	3	3
Retinol ( $\mu$ g/100g)	0	0	0	0
Vitamin E ( $\mu$ g/100g)	N/A	1.4	N/A	N/A
Vitamin K ( $\mu$ g/100g)	N/A	13.6	N/A	N/A
Alpha-carotene ( $\mu$ g/100g)	N/A	0	N/A	N/A
Beta-carotene ( $\mu$ g/100g)	N/A	0	N/A	N/A
Beta_cryptoxanthin ( $\mu$ g/100g)	N/A	0	N/A	N/A
Lycopene ( $\mu$ g/100g)	N/A	0	N/	N/A
Lutein & Zeaxanthin ( $\mu$ g/100g)	N/A	0	N/A	N/A
Saturated Fatty Acid (g/100g)	1.252	14.2	1.634	6.722
Monosaturated Fatty Acids (g/100g)	3.377	39.7	4.405	18.127
Polyunsaturated Fatty Acids (g/100g)	3.919	41.7	5.113	21.039

Table 3: Nutritional aspects of sesame [39].

dizziness and headaches. The oil is more efficient than isotonic chloride solution in curing nasal mucosa dryness due to winter. The high polyunsaturated fat content in oil reduces cholesterol. Sesame oil has been used by Indians as an antibacterial mouthwash, to relieve anxiety and insomnia. Malignant melanoma growth was selectively inhibited due to the presence of large amount of linoleate in triglyceride form in sesame oil [26].

## Biodiesel

Biodiesel, a fatty acid based ester obtained by transesterification of triglycerides and low boiling short chain alcohols is a substitute for fossil fuels. Diesel engines, boilers or other combustion equipments need not be modified for the use of biodiesel. It is a renewable source and does not contribute to global warming as CO<sub>2</sub> emission can be reduced by 78% [1]. Other advantages include excellent biodegradability, low toxicity, outstanding lubricity and superior combustion efficiency.

Present studies indicate that sesame can be used for the production of biodiesel by the use of methanol in the presence of NaOH as catalyst. Biodiesel produced by this method are under the limits of required standards. Few undesirable properties of triglycerides which result in severe engine deposits, injector coking and piston ring sticking have necessitated chemical alterations thus preventing the use of sesame oil directly.

## Conclusion

India is the largest producer of sesame, which has high nutritive and therapeutic qualities. Sesame is a rich source of macro and micro nutrients including proteins, dietary lignans, vitamins, calcium, phosphorous and others but not many value added products other than sesame oil has been developed (Table 3). When analysed, it is found that the by-products obtained extraction of oil contains comparatively high nutritive value and in future, can be consumed as a supplement for protein rich food. With the advancement in technology sesame oil when blended with rice bran or Soya or other oil can be of a great advantage with respect to nutritional aspects. Nutraceuticals and pharmaceutical products of sesame can decrease the risk of neurological, dermatological, cancer and heart disease. The future of sesame lies in its by-products and biodiesel application.

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