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Shamim Akhtar [a], Nauman Khalid [b], Iftikhar Ahmed [c], Armghan Shehzad [c] & Hafiz Ansar Rasul Suleria [d]

[a] Department of Botany, Pir Mehr Ali Shah Arid Agriculture University, Shamsabad, Muree Road Rawalpindi, Pakistan

[b] Department of Global Agriculture, Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo, 113-8657

[c] National Institute for Genomics & Advanced Biotechnology, National Agricultural Research Centre, Park Road, Islamabad, 45500, Pakistan

[d] National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

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PHYSICOCHEMICAL CHARACTERISTICS, FUNCTIONAL PROPERTIES AND NUTRITIONAL BENEFITS OF PEANUT OIL: A REVIEW

Shamim AKHTAR[1], Nauman KHALID[2], Iftikhar AHMED[3], Armghan SHEHZAD[3] and Hafiz Ansar Rasul SULERIA[4]

[1]*Department of Botany, Pir Mehr Ali Shah Arid Agriculture University, Shamsabad ,Muree Road Rawalpindi, Pakistan*

[2]*Department of Global Agriculture, Graduate School of Agricultural and Life Sciences, The University of Tokyo 1-1-1, Yayoi, Bunkyo-ku, Tokyo, 113-8657*

[3]*National Institute for Genomics & Advanced Biotechnology, National Agricultural Research Centre, Park Road, Islamabad-45500, Pakistan*

[4]*National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan*

***Corresponding author:**

Nauman Khalid

Department of Global Agriculture

Graduate School of Agriculture and Life Sciences

The University of Tokyo, Japan

+81-80-3385-0786

nauman_khalid120@yahoo.com

ABSTRACT

The legume Arachis hypogaea, commonly known as peanut or groundnut, is a very important food crop throughout the tropics and sub-tropics. Peanut is one of the most widely used legumes due to its nutrition and taste and it occupies a rank of major oilseed crop in the world. It has been recognized as a functional food, due to its role in a healthy promoting effect. Peanut oil contains a well balanced fatty acid and antioxidant profile that provide protection against harmful substances especially free radicals. This paper gives an overview of scientific literature available on phytochemical and functional properties of peanut oil. Owing to its unique organoleptic properties associated with its cardioprotective and anti-inflammatory properties, peanut oil has found, recently, its place on the highly competitive international edible oil market.

Keywords: *Peanut oil, Phytochemicals, nutrition, functional properties, cardioprotective properties*

BACKGROUND

Human diet contains variety of macro and micronutrients with several types of vitamins, minerals, antioxidants and other beneficial phytochemicals. All of these are necessary for maintaining a healthy life. The macronutrients are sources of different kinds of proteins, carbohydrates, and fats (lipids) and the food industry is concerned to supply these as primary products or as constituents of a wide range of foods (Gunstone, 2011a). A healthy supply of

macronutrients will generally contain the necessary micronutrients. Regardless of the impression given by many uniformed sources that fat is an undesirable part of the diet, it remains an essential requirement. Awareness that both the quantity and the quality of the fat consumed are important elements of a healthy diet is the main challenge of this highly developed world.

The lipids have important physical, chemical, and nutritional properties and these have to be brought into appropriate balance. Nutritionists may indicate a recommended quantity and quality of fat and seed producers, farmers, and those in the agricultural and food businesses may strive to produce material to meet these targets. There are concerns at the present time with consumption levels of *trans* acids which need to be reduced and of omega-3 acids which need to be raised, and with the growing problem of obesity (Gunstone, 2002b).

Almost all vegetable oils are obtained from beans or seeds and are categorized into two valuable commodities; oil and protein rich meal. Seed extraction is normally achieved by pressing or with solvent extraction techniques. Seeds give oil in different proportions. Using USDA figures for 2008-09, world average oil yields are: soybean (18%), rapeseed (39%), sunflower (41%), groundnut (32%), coconut oil (62%), and 44% palmkernal (Gunstone, 2011a).

Arachis hypogaea, commonly known as peanut or groundnut is very important food crop of tropical and subtropical areas. This genus is endemic to South America (Bertioli et al., 2011). The probable centre of origin of *Arachis hypogeae* was in Gran Panatanal (Mato Grosso, Brazil) and also on the eastern slopes of the Bovilian Andes (FAO, 2011). All species of this genus are unusual when compared to other legumes as they produce their fruit below the ground. The species of this genus are diverse in habitat including grasslands, open patches of forest and in temporarily flooded areas. Based on its morphology and sexual compatibilities the genus has

been subdivided into 80 species and nine infrageneric taxonomic sections. Most of the wild species are diploids; however cultivated groundnut is tetraploid with an AABB-type genome. Cultivated peanut has very narrow genetic base (Bertioli et al., 2011). Groundnut is major food crop with its world annual production of about 38 million tones. Peanut is particularly important in Asia, where its production is about 64% of the world (Bertioli et al., 2011).

Insert Figure 1 here

WORLD PEANUT AND PEANUT OIL PRODUCTION

World peanut production totals approximately 29 million metric tons per year (Table 1). China, India and United States constitute the world largest producer. Worldwide peanut exports are approximately 1.25 million metric tons. The United States, Argentina, China, India, Vietnam, and some African countries are significant exporters. Canada, Mexico and Europe accounts for 80% of peanut product importers mainly from US markets (Soyatech, 2011).

Insert Table 1 here

During 2008 Asia and Africa contributed 94% of the world's peanut oil production (5.45 million tons) while the contribution of America was only 4% (FAO, 2011). Peanut seeds have an important contribution towards diet in many countries, as they are rich in protein, lipids and fatty acids for human nutrition. They are rich source of oil, containing 47-50% oil content (Grosso et al., 1997; Sanders, 2002). Lipid chemistry largely affects the flavor and quality of peanuts and peanut products (Andersen and Gorbet, 2002).

VALUE-ADDED PRODUCTS OF PEANUT

Peanuts have many value-added products that have been developed with a number of applications in bakery, confectionery and the general consumer market. An overview of peanut processing and different products are mentioned in Fig. 2. Among these the most important are:

Peanut Flour

Made from raw peanuts which have been cleaned, blanched and electronically sorted to select the highest quality peanuts, the nuts are then roasted and naturally processed to obtain lower fat peanut flour with a strong roasted peanut flavor. Peanut flour is used in confectionery products, seasoning blends, bakery mixes, frostings, fillings, cereal bars and nutritional bars. Peanut flour, because of its high protein content (45-50%), is a good protein source in addition to its function as a flavoring agent(APC, 2011). Peanut flour at a level of 4-8% in formulation has been found to extend the shelf life of confectionary products (Soytech, 2011). Recent studies reported the rheological, foaming, emulsifying and water holding properties of peanut flour and declared that peanut flour as a potential additive to increase the protein contents of various food commodities especially baked goods (Win et al., 2011a).

Peanut Oil

Peanut oil is extracted from shelled and crushed peanuts with a variety of methods such as hydraulic pressing; expeller pressing; and/or solvent extraction. There are generally three types of peanut oil i.e. Refined Peanut oil, Gourmet Peanut oil and 100% peanut oil.

Refined Peanut oil

Refined peanut oil, like all processed vegetable oil, has been refined, bleached and deodorized. This process removes the allergic protein component of the oil, making it non-allergenic. Refined peanut oil is the main type utilized in major fast-food chains of the world especially United States (Peanut Institute, 2011). Refined peanut oil is a highly stable allergen free and trans fat free cooking oil that has a pleasant flavor. Refined peanut oil is very low in saturated fats and is popular oil for frying applications due to its high smoke point. Based on the "Food Allergen Labeling and Consumer Protection Act of 2004, Sec. 203, subsection 7, part C.c.1.qq.2.1" under conformation Amendments, stats that highly refined oils are exempted as major food allergens and thus no petition is needed.

Gourmet Peanut oil

Gourmet roasted peanut oils are not refined and are considered specialty oils. Some of this gourmet peanut oil may be roasted, aromatic oil, which provide a wonderful peanut aroma and flavor to many food products. Gourmet peanut oil provides significant levels of vitamin E and phytosterols (Peanut Institute, 2011).

100% peanut oil

This type is highly aromatic usually called 100% peanut oil, some time it's blended with other oils. This type has a strong roasted peanut flavor and aroma usually consumed as flavoring compounds, confections, sauces and baked goods (Peanut Institute, 2011).

Roasted Peanuts

Roasted peanuts have different varieties and variation. Different coatings can be applied to the peanuts prior to and after roasting to provide a variety of products including such flavors as honey, smoked, sweet, hot and spicy, and salty. Roasted peanut kernels were found to be rich in antioxidants as that of blackberries and strawberries (Talcott et al., 2005; Win et al., 2011b).

Roasting was found to increase the antioxidant capacity if intact peanuts due to formation of Maillard reaction products (Talcott et al., 2005). The phenolics present in the roasted peanut may vary between commercial peanut cultivars (Win et al., 2011b).

Peanut Butter

Until the 1940s, the only 25% of edible peanuts in America were used as peanut butter by 1964; it rose to 63% (Galvez et al., 2006). There are many types of peanut butter ranging from organic to reduced-fat. Peanut butter may be classified by texture and by the grades. There are three texture classifications. Smooth- even texture with no perceptible grainy peanut particles, regular-definitely grainy texture with perceptible peanut particles not more than 1/16 inches in diameter and chunky-partially fine and partially grainy particles with substantial amounts larger than 1/16 inches in diameter (Woodroof, 1973; Galvez et al., 2006).

In peanut butter, peanuts are roasted, blanched and sorted before grinding into a creamy consistency. Peanut butter contains a minimum of 90 percent peanuts; sweeteners and salt can be added to enhance flavor while small amounts of stabilizers are used to prevent oil separation. Reduced fat peanut butters are now commercially available which provide a fat reduction of at

least 25% (APC, 2011). Peanut butter also contains sweetener, salt, emulsifier and other ingredients. A typical peanut butter consists up of 90% peanut paste, 1-5% hydrogenated vegetable oil, 1-6% sweetener, 1-1.50% salt and 0.5-1.5% emulsifier (Lima et al., 2000). Peanut butter is rich in variety of minerals, Özcan and Seven (2003) evaluated peanut butter made from different peanut cultivars from Turkey, and their results proved that peanut butter contains sodium, potassium, phosphorus, iron, zinc, copper, magnesium, aluminum, barium and strontium in a good amount.

Insert figure 2 here

PEANUT OIL EXTRACTION METHODS

Commercially peanut oil is extracted by three different methods; Oil Extraction Hydraulic pressing, expeller, and/ solvent extraction. When hydraulic pressing is used, it is followed by hot solvent extraction for nearly total recovery of the oil. Expeller extraction relies on friction and pressure within the expeller, which causes the meal to heat, thus facilitating the oil extraction process. This process removes approximately 50% of the peanut oil. The remaining oil is extracted using hexane, which is later removed through an evaporation–condensation system. Solvent extraction involves utilization of petroleum hydrocarbons or other solvents. This method gives higher efficiency with hexane, 95% ethanol, or absolute ethanol (Woodroof, 1983; Moreau et al., 2004). Extracted oil is refined by deacidification with sodium hydroxide to neutralize the free-fatty acids, washing with water at about 82^{o}C to remove the sodium

hydroxide, and then bleaching with bleaching clay at about 100°C under reduced pressure. The refined oil is then deodorized by heating under vacuum and blowing superheated steam through the oil. Deacidification and deodorization of peanut oil and other edible oils by dense carbon dioxide extraction has now been developed and effectively utilized (Ziegler and Liaw, 1993). The main purpose of the refining process is to remove nontriacylglycerol components, including free fatty acids, nonhydratable phosphoacylglycerols, sterols, pigments, glucosides, waxes, hydrocarbons, and other compounds that may be detrimental to the flavor or oxidative stability of the refined oil (Hoffman, 1989; Moreau et al., 2004).

Super critical Fluid extraction technique (Alternate method)

Supercritical fluid extraction has emerged as a striking separation technique because it does not introduce any residual organic chemicals. Supercritical CO_2 is the most commonly used supercritical fluid (Matricardi et al., 2002), other includes food grade butane (Sanders, 2001).

Aqueous enzymatic oil extraction method

This method is ecofriendly extraction and based on simultaneous isolation of oil and protein from oilseed by dispersing finely ground seed in water and separating the dispersion by centrifugation into oil, solid, and aqueous phases. The presence of certain enzymes during extraction enhances oil recovery by breaking cell walls and oil bodies (Rosendahl et al., 1996; Zhang et al., 2011). For peanuts, a multistep aqueous extraction process has been described with a recovery of about 98% (Rhee et al., 1972). More recently, the relatively new technique of enzyme-assisted aqueous extraction has been applied to peanuts with a reported oil recovery of

86–92% (Sharma et al., 2002). Similarly, Lanzani et al. (1975) reported a 74-78% recovery of peanut oil by an enzyme-assisted aqueous extraction using protease, cellulase, and α- 1,4-galacturonide glycano-hydrolase either separately or in combination. 86-92% recovery of peanut oil was obtained by Sharma et al. (2002) by using multi-activity proteases from *Aspergillus flavus*, Protizyme^{TM} (Sharma et al., 2002; Jiang et al., 2010; Zhang et al., 2011).

PHYSICO-CHEMICAL CHARACTRISTICS OF PEANUT OIL

The physical and chemical properties of fats and oils are determined by their fatty acid composition and their position within the triacylglycerol (TAG) molecule. Peanut oil is pale yellow in color with distinctive nutty taste and odor obtained from the processing of its kernel. However, refining may result in odorless oil (Sanders, 2002). Peanut oil is rich in oleic content that is associated with its good oxidative and freezing stabilities. The oil is non-drying in nature that solidifies from 0-3^{o}C (O'Brien, 2004; Padley et al., 1994; Young, 1996). Aflatoxins being associated with proteins are carcinogenic in nature and are absent in refined oil. However, some aflatoxins are present in crude oil or lightly processed oil (Sanders, 2002). The various chemical and physical characteristics for peanut oil are given in Table 2.

Insert Table 2 here

Fatty acids composition

Major fatty acid in peanut oil includes palmitic (C16:0), oleic (C18:2) and linoleic acids (C18:2). Generally, stearic acid (C18:0), arachidic (C20:0), eicosenoic (C29:1), behenic (C22:0) and lignoceric acids (C24:0) are present in minute quantities. Linolic fatty acids are present in trace amounts (C18:3) (Casini et al., 2003). According to the Codex Alimentarius the archidic

and higher fatty acid content of Peanut oil should be less than 48g/kg. High percentage values of C20:0 and C22:0 in other oils including olive oil could be related to adulteration with peanut oil (Young, 1996). Peanut oil contains approximately 80% unsaturated and 20% saturated fatty acids (Cobb and Johnson, 1972). In mature peanuts, the oil is 96% triacylglycerol (Sanders, 1980) with the main fatty acids being palmitic, oleic, and linoleic (Ahmed and Young, 1982). The long-chain fatty acids are usually found at about or slightly less than 2%. The percent of free fatty acids in peanut oil varies between 0.02% and 0.6% (Guthrie et al., 1949). The overview of fatty acid profile of peanut oil is presented in Table 3.

Insert Table 3 here

Because of its excellent oxidative stability peanut oil is a premium cooking and frying oil (O'Brien, 2004). It has been preferred over soybean oil during frying, however it develops some flavor defects with long term use (Young, 1996). Considerable importance was given to the role of the oleate/linoleate ratio (O/L) and iodine value (IV) in governing product shelf life. Low IV and high O/L ratio are associated with greatly enhanced shelf life and decreased rancidity of the product (Andersen and Gorbet, 2002). The fatty acid composition of peanut oil is variable depending on the genotype, seed maturity, climatic conditions, growth location and interaction between above mentioned factors (Young, 1996). Lower temperatures during seed development usually associated with more unsaturation (Brown et al., 1975; Casini et al., 2003). Generally it has been proved that oleic acid increases and linoleic acid decreases with seed maturity. When the seed progressed from intermediate through nearly-mature to mature stages, palmitic and linoletic acids decreased while oleic acid increased (Hinds, 1995). Some other studies showed

that there was no influence of different years or planting date on fatty acid profile (Andersen and Gorbet, 2002). The influence of the soil type in Eastern Caribbean was analyzed and it was found that seeds grown on the volcanic clay loam contained more stearic acid as well as long chain and total saturated fatty acids but less linoleic and total unsaturated acids than samples from volcanic sandy loam (Hinds, 1995). Worthington et al., (1972) demonstrated the influence of genotypes on the fatty acid composition of peanuts. The variety affected the composition of peanut oil grown in USA. Generally the three major fatty acids (Palmitic, oleic and linoleic acid) were more affected than the minor fatty acids.

Triacylglycerol composition

Majority of the peanut oil fatty acids are present at TAGs (93.3-95.8 wt%) (Padley et al., 1994; Sanders, 2002). Seed Maturation influences over TAG content of the obtained oil showing an increment of ca.10% from an early maturation stage accounting for 25.3% of oil (TAG content 85.3%) to a fully stage with 48.2% of oil (TAG content 95.8%) (Sanders, 2002). Sempore and Bezard (1986) while working on African peanut oil identified 30 TAG by HPLC-RID reporting the major TAG as OOL (17%), PLO (13%), LLO (12%) OOO (10%), POO (8%). Whereas (P=Palmitic , O= oleic , S= Stearic and L=Linoleic acids). These authors found very long chain fatty acid associated with unsaturated fatty acids, preferably with two molecules of linoleic acid. In another study contrasting results were found. Two samples of peanut from an unknown origin were analyzed by HPLC combined with atmospheric pressure chemical ionization MS (APCI-MS). Following results were shown, TAG: OOO (34-46%), OOL (13-17%), POO (10-12%), and LLO (6.4%) (Tuberoso et al., 2007). Similar experiments were

performed and main TAG from polish peanut oil analyzed by HPLC-UV techniques were; OOO (31.2%), POP (18.4%), OOL (15.9%), POO (11.6%), LLP (6.9%) (Tuberoso et al., 2007). Diversity between samples analyzed was greatly related to the origin of peanut. In comparison to other vegetable oils including olive, soybean or sunflower oil, the high percentage (›12%) of TAG with CN higher than 54 is remarkable. TAG from 56 and 60 CNs are mainly a combination of two C18 and one long-chain (C20-C40) fatty acid *per* TAG molecule (Manganaro et al., 1981). These TAG molecules could be used to identify alterations of other oil with peanut oil. This higher melting fraction with non-crystalline properties usually hinders the use of peanut oil as salad oil (Krishmamurthy and White, 1996; Young, 1996). In peanut oil more than 160 TAG were identified by HPLC-tandom MS (Dorschel, 2002), most of them are di- and tri-unsaturated (POO, SOO, PLO, OOO, OLO, LLO and LLL). Natural peanut oils contains non-random enantiomeric structures of highly asymmetric position of the long-chain saturated fatty acids (Andersen and Gorbet, 2002; Padley et al., 1994). The long –chain saturated fatty acids (C20-C24) are confined almost exclusively to the sn-3 position, whereas the Palmitic and Stearic acids are more predominant in the sn-1 and sn-3 positions. However, oleic acids are distributed almost evenly in the three positions, whereas Linoleic acid is preferably found in the sn-2 position (Young, 1996). Concentrations of specific TAG species are variable with variety and location (Sanders, 2002). Generally, a higher percentage of oleic and Linoleic acid in the TAG are directly related to the particular fatty acid in the *sn*-2 position (Sanders, 2002). Oil fatty acid profile is important from nutritional point of view. Along with fatty acid profile the distribution of the fatty acids in three positions of the glycerol skeleton is also important. It has been proved that the *sn*-2 position is conserved during the whole digestive process while fatty acids from s*n*-1

and *sn*-3 are released by principal lipase. Long-chain fatty acid are preferentially present at these positions and with melting points higher than human body temperature (C18:0, C20:0, C22:0 and C24:0) remain free and solid in the intestinal lumen, showing weak intestinal absorption and no effects on plasma lipids (Dubois et al., 2007).

MINOR COMPOUNDS

Free fatty acids (FAAs) and diacylglycerols (DAGs)

Raw peanut oil contains FFAs and DAGs. Crude oil contains FFA as low as 0.3%, but most of commercial oils contains 0.5-1.5% (Padley et al., 1994). FFA and DAG levels considerably variable with peanut maturity (Ayres, 1983). Along with other factors, the degree of damage to the kernels also affects FFA content. Strongly mature peanuts generally have an FFA content of less than 0.5%. Sometimes, if the peanuts are high in mold damage and/or consists of immature kernels, levels up to FFA may reaches up to 5% (Ayres, 1983). High percentages of FFA may indicate poor handling, immature kernels, mold infestation, or pronounced ester hydrolysis (Sanders et al., 1992), Whereas FFA are eliminated at different processing steps, DAG are partially remove. They constitute an important index not only for the original quality of the oil but also for the resulting refined oil. In peanut DAG with 34 and 36 CNs are commonly n peanut oil as 1,2- and 1,3-isomers, being the reported DAG the following: 1,2-PO, 1,2-PL, 1,3-PO, 1,3-PL, 1,2-OO, 1,2-OL, 1,3-OO, 1,3-OL, and 1,3-LL (Frega et al., 1993).

Phospholipids (PLs)

In peanut the major constituents of the cell membrane are PLs and has a high degree of unsaturation (Singleton and Stikeleather, 1995). The PL content (0.3–0.7%) is low in peanut oil.

Following are the major PL in conventional peanut oils: phosphatidylcholine (PC: 38.3–66.4%), phosphatidic acid (PA: 2.2– 11.8%), phosphatidylethanolamine (PE: 13.3–21.9%), phosphatidylinositol (PI: 15.7–30.9%), and phosphatidylglycerol (PG: non-reported up to 2.5%) (Jonnala et al., 2006; Singleton and Stikeleather, 1995). PL composition ranges of high-oleic peanut cultivars varies comparing breeding lines with their parental lines (Jonnala et al., 2006). Although statistical differences were found among the PL contents and the composition of breeding lines and parent lines, these variations were within the range reported for traditional peanut varieties.

Premature harvesting of peanut may also results in changes in PL concentration. Along with premature harvesting other factors are also important, these include curing at a high temperature, and/or exposed to freezing temperatures (Singleton and Stikeleather, 1995). In many cases, oil refining becomes difficult as the quality of oil is affected. Singleton and Stikeleather (1995) studied the effects of these stress events and proved that immature seeds presented higher total PL content and higher concentrations of PA, PE, and PC than mature peanuts. It was explained that the decrease in concentration of PA and PC with maturation was due to these PL as these are the precursors to the formation of the other PL. The concentration of all PL was increased in the heat-damaged sample (at 408^{o}C), except for PG. whereas in the freeze-damaged sample, a significant increase in concentration was observed for PA and PG. However the concentrations of PC and PE decreased to very low levels when compared to the control sample. Major PC molecular species were also determined. In mature peanuts, 40.7 and 59.3% of C18:2 and C18:1 was found. Immature peanuts resulted in greater concentrations, but equal proportions of the above mentioned species. Molecular species found in the high

temperature cure sample had a higher degree of saturation due to the presence of C18:1 and C16:0 molecular species (72.8%). This was attributed to the oxidation of the more unsaturated molecular species by heat stress.

Sterols

Sterols are the predominant compounds in the unsaponifiable material of vegetable oils, accounting for 60– 80%. Remaining 10-25% is covered by hydrocarbons, tocopherols, and others. Vegetable oil sterols, generally known as plant sterols, can be divided into three groups: 4-desmethylsterols (the cholestane series), i.e., normal phytosterols (PSs); 4-monomethylsterols (usually known as methylsterols); and 4, 40-dimethylsterols (the lanostane series, also known as triterpene alcohols). The three sterol groups are different in the conformation of carbon 4 in the steroid skeleton (Wretensjo, 2004). The desmethylsterols have no methyl group at position 4, while the 4 monomethyl- and 4, 40-dimethylsterols contain one and two methyl groups at this position, respectively. The desmethylsterols (or normal PSs) usually account for more than 50% of the unsaponifiable ematerial, while 4-monomethylsterols and 4, 40-dimethylsterols together constitute 10–30%. Sterols are mainly found as free molecule or sterol ester forms, but they also can occur as sterol glucosides and acylated sterol glucoside (Wretensjo, 2004). Table 4 gives the complete profile of minor components present in peanut oil.

Insert Table 4 here

Peanuts and its products including peanut oil, peanut butter, and peanut flour, are good sources of Phytosterols and these are in comparison with other high quality edible oils (Table 5). Depending on the peanut variety, roasted peanuts contain 61–114 mg PS/100 g, 78–83% of which is in the form of β-sitosterol (Awad et al., 2000).

Peanut oil has higher percentage of Δ-5-avenasterol than soybean oil. The unsaponifiable fraction of peanut oil contains 0.15–0.90% hydrocarbon sterol esters and 0.59–1.22% free sterols (Ayres, 1983). Steryl ester and free sterol components of two commercial peanut varieties were examined resulting that free PSs of both Florunner- and Startype peanuts consisted of about 65% of the total sterols in the oil (Worthington et al., 1972). Unrefined peanut oil contains up to 434 mg PS/100 g, while refining the oil results in reduction in PS concentration in the oil (Young, 1996). Further refining, such as deodorization, results in significant loss in PSs. However, hydrogenation after refining has a minimal effect on PS loss (Awad et al., 2000). Conventional refining does not significantly affect sterol composition expressed as percent of total sterols. The relative proportions of the major sterols remain constant throughout the process (Wretensjo, 2004). Jonnala et al. (2006) found that a high oleic peanut line (Tamrun OL 01) had higher total PS content (725 mg/100 g oil) than those for the parent lines (670 and 350 mg/100 g oil). In all samples collected, β-sitosterol was the major phytosterol (PS) (75–90% of the total PSs). In addition campesterol (6– 14%) and stigmasterol (3–11%) were also found. Genetic engineering is a great tool for developing peanut cultivars resistant to a broad spectrum of pathogens that pose a recurring threat to peanut health. Transgenic peanut lines with increased resistance to fungal diseases, showed no major changes in the PS content with respect to non-transformed cultivars, when compared to parents (Jonnala et al., 2006).

Triterpenic alcohols

Triterpenic alcohols in peanut oil represent the 0.14% of the oil (Fedeli et al., 1966). Triterpenic alcohols composition of peanut oil includes: cycloartanol (1.9%), β-amyrin (6.9%), cycloartenol (33.1%), 24-methylene cycloartenol (46.1%), and cyclobranol (8.1%) (Padley et al.,

1994). Squalene has been detected in peanut oil in significant higher concentration than in soybean oil and represents more than the 20% of the olive oil content (Carrı´n and Carelli, 2010; Tuberoso et al., 2007). It is a triterpene hydrocarbon with secondary antioxidant activity compared to that of phenols and tocopherols (Tuberoso et al., 2007).

Tocopherols

Tocopherols are natural antioxidants. Four types of tocopherols are found in peanuts oil (Carrı´n and Carelli, 2010). It was noticed that caustic and alkali chemical refining can remove tocopherols and tocotrienols by 10– 20% but 30–60% can be lost with deodorization or steam distillation (O'Brien, 2004). Refined peanut oil contain tocopherols of 53 mg/100 g and mostly as α- and γ -tocopherol. Casini et al., (2005) considering four harvest periods, found total tocopherol levels between 199 and 815.6 ppm to crude type runner peanut oil from Argentina. They concluded that tocopherol content increases with higher precipitations and lower soil temperatures. Significant differences within the tocopherol profile among maturity stages of runner- and virginia-type peanut cultivars were studied by Hashim et al., (1993). In a multi-year study of oil composition factors of peanuts from several origins, data indicated that tocopherol content was consistently different in peanuts from various origins (Sanders et al., 1992). Higher tocopherol content was consistently found in peanuts produced in the US compared to those produced in China or Argentina. The highest levels reported in US peanuts on a whole seed basis were almost 250 ppm, while the lowest levels were about 100 ppm. Misuna et al., (2008) determined the antioxidant activity of 8 commercial peanut varieties by DPPH assay and concluded that peanut oil has antioxidant activity of 0.17% (W/V) respectively.

Phenolic compounds

Phenolic compound Resveratrol (3,40,5-trihydroxystilbene) is found naturally in fruits, nuts, flowers, seeds, and bark of different plants. Peanut is one of the natural sources of resveratrol (Wang et al., 2005). It exhibits antiplatelet, anti-inflammatory, anticancer, antimutagenic, and antifungal properties. Along with other properties it is also a potent antioxidant, ROS scavenger and metal chelators. Resveratrol reduces lipid peroxidation as well as oxidation and nitration of platelet and plasma proteins (Olas and Wachowicz, 2005). Resveratrol is usually found in fresh kernels of peeanuts or in peanut products like butter or roasted nuts. The content of resveratrol varies widely with varieties, peanut product, and processing. For fresh peanuts resveratrol content varies from 0.01–1.79 mg/g (Sobolev and Cole, 1999) up to 2.3–4.5 mg/g (Wang et al., 2005). Neither the scientific data have not been reported about resveratrol content in peanut oil nor were phenolic compounds detected in cold-pressed peanut oil (Tuberoso et al., 2007).

GENETICALLY MODIFIED PEANUT OIL

Peanut breeding programs are continually developing new and improved varieties with higher yields and grades, disease and insect resistance, virus and nematode resistance, drought and aflatoxin resistance, improved shelling characteristics, better processing qualities, longer shelf life, and enhanced flavor and nutrition. Using classic breeding techniques, commercial peanut varieties have been developed that incorporate a high-oleic fatty acid trait. The developed lines do not have meaningful differences from normal peanut varieties in oil content, flavor, color, or texture (Haumann, 1998; Sanders, 2002).

The high-oleic varieties have produced oil with a fatty acid composition somewhat similar to olive oil; oleic increased to 80% (±2%), linoleic was reduced to 2 to 3%, and palmitic

decreased to 9% (±1%). Oxidative stability results have been recorded as much as 14.5 times better for high-oleic peanut oil, depending on the method of measurement. In recent research studies with human subjects, it was found that higholeic peanut oil produced significant positive changes in blood lipids, including a reduction in LDL cholesterol and triglyceride levels, but did not affect the beneficial high-density lipoprotein (HDL) cholesterol levels. These findings align with numerous studies that have shown that diets high in mono- and polyunsaturated fatty acids and low in saturated fatty acids can be heart healthy (Haumann, 1998; Sanders, 2002).

FRYING QUALITY

The frying quality and storage stability of peanut can be improved by adding 30% palm olein. Changes in the viscosity of free fatty acids, peroxide value and polymer content during frying and storage was studied (Ali et al., 2011). It was proved that the oil blend which contains 70% groundnut oil and 30% palm olein (with high quality) are more stable as compared to the only groundnut oil during the frying and during 3 periods of storage. The oil blend showed lower values of viscosity of free fatty acid, peroxide value and polymer content by the end of frying and at the end of storage (96 days) as compared to the peanut oil (Ali et al., 2011). Blending peanut oil with palm oil can reduce its price and improve its quality and stability.

NUTRITIONAL PROPERTIES AND HEALTH BENEFITS OF PEANUT OIL

Peanuts have been enjoyed throughout history. Although their benefits may not have been fully recognized early on, peanuts have provided complex nutrition to many diets that improve health. Their health benefits became clearer in later years as population studies consistently showed a reduced risk of heart disease when peanuts were consumed in small

amounts on a daily basis (Sabate, 2003). Since that time, extensive research continues to show that peanuts, peanut butter, and peanut oil all help prevent chronic diseases including heart disease, diabetes, and cancer. Peanuts, peanut butter, and peanut oil have been shown to have potent lipid lowering effects and may act to reduce inflammation, which is one of the underlying mechanisms that triggers chronic disease (Jiang et al., 2002). Their unique nutrient profile and bioactive components are proving to play a beneficial role in many areas of health.

The consumption of either peanuts or processed peanuts has been shown to be beneficial to health. This is mainly due to their desirable lipid profile, which is higher in unsaturated fatty acids than in saturated fatty acids. Peanuts have high lipid content, ranging from 47% to 50%, and for that reason they are a good source of oil. The oil extracted from peanuts by cold-pressing has the most desirable nutritional values, a very light nutty aroma, and a light to dark yellow color (Jiang et al., 2002).

Peanut oil is naturally trans fat-free, cholesterol-free, and low in saturated fats. It consists mostly of oleic acid (n-9), a monounsaturated fatty acid (MUFA) (52%), and linoleic acid (n-6), a polyunsaturated fatty acid (PUFA) (32%) (Beare-Rogers et al., 2001;Özcan, 2010). The oil is also a source of natural occurring compounds such as antioxidants, vitamin E, phytosterols, squalene, and *p*-coumaric acid, which are all beneficial in maintaining health. Peanut oil shows many positive biological effects, which are mostly connected with its high oleic acid content. A number of studies have shown the unique properties of this fatty acid and the importance of maintaining its intake at as high a level as possible. Oleic acid has been shown to have a positive influence on cardiovascular risk factors, such as lipid profiles, blood pressure, and glucose

metabolism. These beneficial effects were first observed for olive oil, which is also rich in oleic acid, but they are now also being reported for peanut oil, as well as peanut seeds alone, or even products made of peanuts (Özcan, 2010).

Anti-inflammatory Activity

Inflammation in the body is a mechanism thought to be at the center of the majority of chronic disease. Certain inflammatory factors in blood like C-reactive protein (CRP), for example, have been identified as predictors of cardiovascular disease. Population studies and smaller human studies have led to the understanding that some dietary factors may play a role in reducing inflammation (Nettleton et al., 2006). Certain fats, antioxidants, dietary fiber, arginine, and magnesium are components that have been shown to help regulate inflammation (Sales et al., 2008).

Peanut oil contains resveratrol that could effectively inhibit lipopolysaccharide (LPS)-induced nitric oxide (NO) production. This resverastol perform effective anti-inflammatory activity. This compound might be of importance in further development for nutraceutical or chemopreventive applications (Chang et al., 2006; Djoko et al., 2007; Kang et al., 2010). Resveratrol treatment of mice presented protection against colitis through up-regulation of SIRT1 in immune cells in the colon (Singh et al., 2010). Recently it was invested that resveratrol, in an ex vivo model, inhibited TNF-R and IL- 6 released from macrophages, hence suppressing macrophage- CM-induced inflammatory response in adipocytes (Djoko et al., 2007). Also, resveratrol exerts anti-inflammatory effects in microglia and astrocytes by inhibiting different pro-inflammatory cytokines and key signaling molecules (Lu et al., 2010).

Antitumor Activity and anticancerous Activity

Peanuts and peanut oil contains different phytochemicals such as β-sitosterol, resveratrol, campesterol, and sigmasterol (Fig 3), this gives a strong evidence of protective role in different cancers like breast, colon and especially prostate (Awad et al., 2000; Lopes et al., 2011). It was noticed that roasted peanuts contain 61–114 mg PS/100 g depending on the peanut variety, 78–83% of which is in the form of β-sitosterol. Unrefined peanut oil contains 207 mg PS/100 g, these higher values gives confirmation of strong anticancerous property of peanut oil (Awad et al., 2000).

Insert figure 3 here

In vitro, ex vivo, and model animal studies reveals that resveratrol and its counter parts inhibit cellular events associated with the beginning, promotion, and progression of tumors. Resveratrol inhibits free radical formation, which will inhibit tumor formation; it acts as an antimutagen (Bishayee et al., 2010). Oral administration of resveratrol at a daily dose of 15 mg/kg was effective as chemopreventive treatment for pulmonary metastasis of the CT26 cells (Weng et al., 2010). Abbasi et al., (2009) confirms that the volatile fraction from a Pakistani cultivar exhibits antiradical activities by both DPPH and phosphomolybdenum complex methods, as well as an antioxidant potential similar to that of butylated hydroxytoluene (BHT).

A study conducted by Hwang et al., (2008) showed that roasted and defatted peanut dregs (a by-product in peanut oil production) exhibit antimutagenic and antiproliferative effects at 100 mg/ml concentration. At this concentration, they inhibited the proliferation of leukemia U937 and HL-60 cells by 56% and 52%, respectively, showing anticancer activity (Hwang et al., 2008). Consumption of peanuts was also shown to have cancer-protective effects. A prospective cohort with a 10-year follow-up study, conducted by Yeh et al., (2006) showed that peanut

consumption may help to reduce colorectal cancer risk in women. This anticancer effect is suggested to be a result of the action of nutrients found in peanuts, such as folic acid, phytosterols, phytic acid, and resveratrol, which have been reported to have anticancer effects (Yeh et al., 2006). These results suggest potential applications for peanuts and their by-products as natural chemotherapeutic or chemopreventive agents.

Peanut oil and Cardiovascular diseases

Almost two decades ago research pointed to the fact that those who frequently ate peanuts had a lower risk of heart disease. The effects are evident in all ages, in male or female, and even in various conditions, such as in those who have diabetes (Emekli-Alturfan et al., 2007; Fraser and Shavlik, 1997; Hu et al., 1998; Li et al., 2009).

Early work with animals suggested a high atherogenic potential when peanut oil was fed in relatively high doses. Chemical treatment to randomize peanut oil resulted in decrease in atherogenicity, as triacylglycerol structure was believed to be involved (Kritchevsky et al., 1973). Ahmed and Young (1982) indicated that the Kritchevsky study did not provide adequate proof of this claim, due either to lack of inclusion of other vegetable oils for comparison or lack of adequate data for sound statistical analysis. In the past ten years, consistent data in numerous epidemiological studies proved that an amazingly high 30–50% reduction in cardiovascular disease in people was recorded who ate nuts, including peanuts, four to five times each week.

Various clinical studies have indicated consistent reduction in total and LDL cholesterol in subjects consuming diets of peanuts and peanut oil. Various experiment using different diets showed that the diet including peanuts and peanut butter, including peanut oil, and the diet

including olive oil (all low in saturated fat and cholesterol and high in monounsaturated fat) lowered total cholesterol and LDL cholesterol. Each of these three diets lowered triacylglycerol levels without lowering the beneficial HDL cholesterol (Kris-Etherton et al., 2001). Peanut is a rich source of β-sistosterol, which offers protection from colon, prostrate and breast cancer. It includes inhibition of tumor growth and stimulation of apoptosis. β-sistosterol, when incorporated in to the tumor membranes stimulates the sphingomyelin cycle, which may mediate the observed inhibition of tumor growth and stimulation of apoptosis (Awad et al., 2000; Awad et al., 2007; Awad et al., 2001).

Peanut, peanut oil, and fat-free peanut flour reduced the cardiovascular disease factor and the development of atherosclerosis in animals consuming an atherosclerosis inducing diet. This was confirmed in recent human clinical trials (Ghadimi et al., 2010; Stephens et al., 2010). Peanut oil consumption can also elicit significant blood pressure reduction in normolipidemic adults (Sales et al., 2008). Stephens et al. (2010) evaluated cardiovascular effects on Syrian golden hamsters by giving diet rich in fat-free peanut flour, peanuts, and peanut oil. They found that all samples were able to retard the development of atherosclerosis in animals consuming an atherosclerosis-inducing diet. In addition, the results showed they were able to retard the increase of aortic cholesteryl ester, a primary metabolic parameter associated with the development of atherosclerosis, suggesting that peanuts, peanut oil, and fat-free peanut flour retard the development of atherosclerosis.

The form in which peanuts are consumed and the method of processing (such as roasting or adding flavor) appear not to affect their CVD protective properties, as shown in a study conducted by McKiernan et al. (2010). Results of this randomized study, with 118 subjects from

different countries, showed that consumption of 56 g of raw, roasted unsalted, roasted salted or honey-roasted peanuts, or ground peanut butter daily for 4 weeks resulted in a significant increase in the HDL cholesterol level and decrease in the total cholesterol, LDL cholesterol, and TAG levels in individuals classified as having elevated fasting plasma lipids compared with those with normal fasting plasma lipids. These results suggest that the processing attributes do not compromise the lipid-lowering effects of peanuts (McKiernan et al., 2010).

Protection against Alzheimer's disease

Peanut oil is a rich source of vitamin E and other phytochemicals. Niacin and vitamin E are two important constituents that provide protection against Alzheimer's disease. In almost 4,000 people 65 years or older, niacin from food slowed the rate of cognitive decline (Morris et al., 2004). In another study, 815 people, 65 years or older without Alzheimer's disease, were followed for almost four years. Although the consumption of vitamin E from supplements had no effect on the incidence of Alzheimer's, vitamin E intake from food was protective (Morris et al., 2002). In those who were in the top fifth of intake, incidence of Alzheimer's disease was reduced by 70%.

A study from the University of Georgia found that vitamin E levels in peanuts are over 26% higher than what is reported in the US Department of Agriculture Nutrient Database for Standard Reference (Shin et al., 2009). Peanuts have resveratrol, another bioactive component

recognized as being beneficial in Alzheimer's disease and other nerve degeneration diseases (Chen et al., 2005).

Anti-diabetic activities

Peanuts were also proved to be beneficial in lowering the risk of type 2 diabetes. People with this type of diabetes do not produce adequate amounts of insulin for the needs of the body, and cannot use insulin effectively. A study conducted on INS-1 (a rat pancreatic beta cell line) showed that oleic acid and peanut oil high in oleic acid were able to enhance insulin production. Pre-treatment with oleic acid reversed the inhibitory effect of TNF-α on insulin. Peanut oil ultimately reversed the negative effects of inflammatory cytokines observed in obesity and non-insulin dependent diabetes mellitus. Type 2 diabetic mice that were administered a high oleic acid diet derived from peanut oil had decreased glucose levels compared to animals given a high fat diet with no oleic acid (Vassiliou et al., 2009).

Researchers from the Harvard School of Public Health, in a prospective cohort study of more than 83,000 women, found that women who consumed nuts or peanut butter had a significantly lower risk for type 2 diabetes. Women who reported eating nuts at least five times per week reduced their risk of type 2 diabetes by almost 30%, and those who ate peanut butter reduced their risk for type 2 diabetes by almost 20%, compared to women who rarely or never ate nuts or peanut butter. The reduced risk was independent of known risk factors for type 2 diabetes, such as body mass index (BMI), family history of diabetes, physical activity, smoking, alcohol use, and dietary factors (Jiang et al., 2002).

PEANUT ALLERGY

In recent years, concern for peanut allergy has increased. Peanut allergy is associated with a higher incidence of fatal food-induced anaphylaxis than any other food allergy, for unknown reason. Hypersensitivity to foods occurs in 6–8% of children and about1%of adults. In the US, in survey it was suggested that 0.7% of children are allergic to peanuts in varying degrees. Avoidance is the only current method to deal with food allergy. Significant research efforts are in process to deal with peanut allergy. Various peanut allergens have been identified and all are proteins (Burks, 2008). Refined peanut oil after all protein removal is not allergenic; however, oils contaminated with peanut protein can produce significant allergic reactions in peanut-sensitive individuals. Cold-pressed oils are more likely to contain peanut proteins as compared to hot-pressed oils (Gunstone, 2011b).

CONCLUSIONS

The peanut oil, extracted from peanut, has been used as functional product since old time. Peanut oil is traditionally used for cooking, massaging, and healing. Its chemical composition highlights the interest of many laboratories to use it in their best-selling products. Recently, various studies were realized, in vitro or on human and animal models, suggesting that peanut oil could play a beneficial role in cardiovascular disease prevention and its consumption could protect against atherosclerosis through a variety of biological mechanisms. It is because of its high contents of specific antioxidants and mono and polyunsaturated fatty acids, that peanut oil could be useful in preventing cardiovascular diseases and cancer. Its consumption could also increase antioxidant compounds in the serum of healthy men. Experimental studies have shown

the antiproliferative and pro-apoptotic effects of polyphenols and sterols extracted from peanut oil on prostate cancer cell lines and breast cancer cell lines. The utilization of peanut oil in diet will gives best results in combating diseases like cancer, diabetes and cardio vascular diseases.

FIGURE CAPITATION

Figure 1: Botanical description of Peanuts

Figure 2: Overview of Peanut Processing

Figure 3: Functional compounds present in peanut oil

TABLE CAPITATION

Table 1: World Wide Peanut Production (Million metric tons)

Table 2: Physicochemical Parameters of Peanut oil

Table 3: Fatty acids composition of peanut oil (%)

Table 4: Overview and composition of sterols present in peanut oil

Table 5: Comparison of peanut phytosterol content with other oils

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Kingdom	**Plantae**
Division	Tracheophyta
Class	Magnoliophyhta
Order	Fabales
Family	Fabaceae
Subfamily	Faboideae
Tribe	Aeschynomenaceae
Genus	Arachis
Species	*A. hyogaea*

Figure 1. Botanical description of Peanuts (Bertioli et al. 2011)

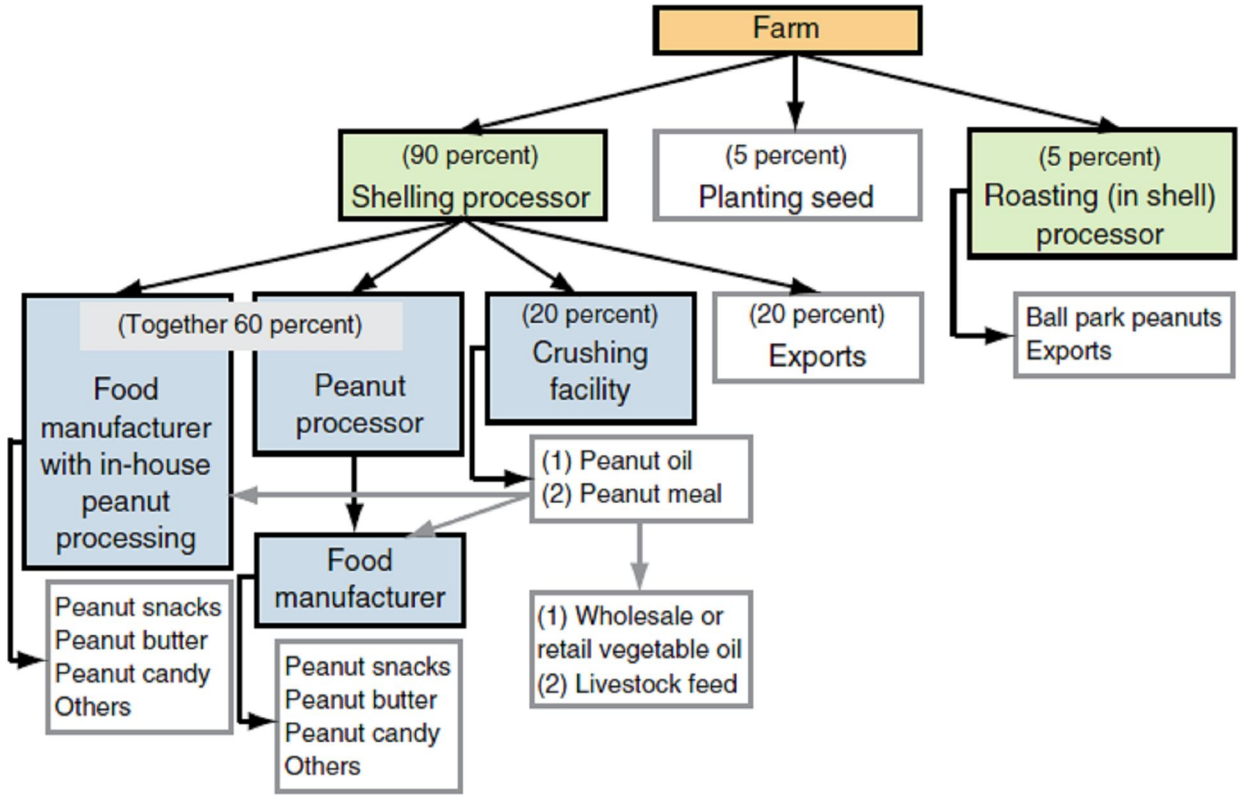

Figure 2. Overview of Peanut Processing

Source: USDA, Economic Research Service, *Oil Crops Outlook*; USDA, National Agricultural. Statistics Service, *Peanut Stocks and Processing*; USDA, Foreign Agricultural Service, Global Agricultural Trade System

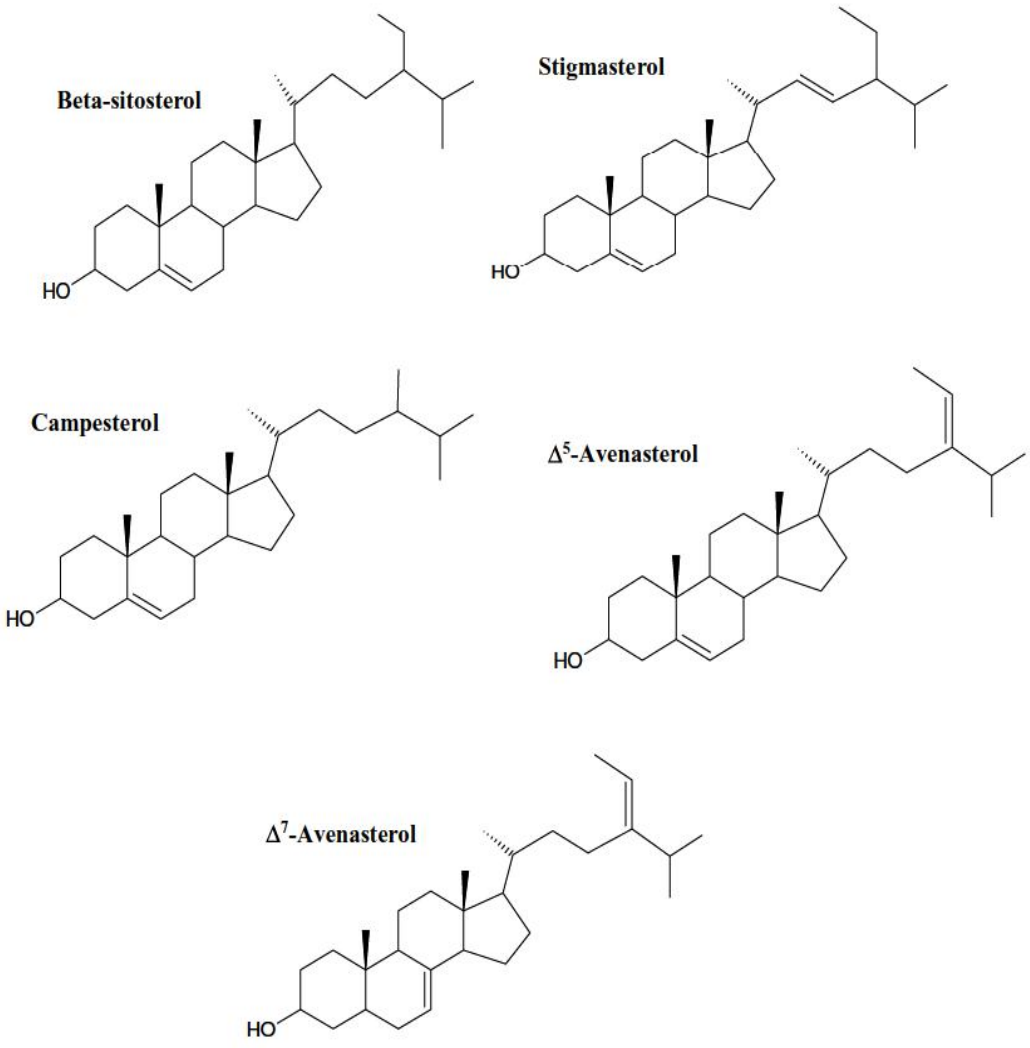

Figure 3. Functional compounds present in peanut oil

(Francisico and Resucrrecion, 2008)

Table 1. World Wide Peanut Production (Million metric tons)

Rank	Country	Production
1	China	13,420,000
2	India	7,700,000
3	United State	1,880,000
4	Nigeria	1,510,000
5	Indonesia	1,130,000
6	Burma	710,000
7	Chad	450,000
8	Senegal	450,000
9	Ghana	440,000
10	Argentina	420,000
	Total	30,470,000

Source: USDA Foreign Agricultural Service: Table 13, Peanut Area, Yield and Production

Table 2. Physicochemical Parameters of Peanut oil

Characteristic	Value	Reference
Acid value (Refined)	0.6 mg KOH/ g oil 0.99mg KOH/g oil	CEC, 2005 Özcan, 2010
Hehner value	95-96	Jacobs, 1973
Iodine value (Wijs)	86-107	CEC, 2005
Peroxide value	1.0 meq peroxides O_2/kg oil 1.01 meq peroxides O_2/kg oil	CEC, 2005 Özcan, 2010
Polenske value	0.5	Cobbs and Johnson, 1973
Viscosity (21.1^{0}C)	7o.7 mPaS	Goodrum and law, 1987
Melting Point	0-3 ^{0}C	McMicheal and Bailey, 1951
Melting Point of fatty acids	22-30 ^{0}C	McMicheal and Bailey, 1951
Moisture and volatiles	0.23%	McMicheal and Bailey, 1951
Refractive Index 40 ^{0}C	1.46-1.465 1.456	Jacobs, 1973 Özcan, 2010
Sponification number	187-196	Jacobs, 1973
Smoke point	226.4 ^{o}C	Woodroof, 1983
Surface Tension	35.6 Nm/m	Cobbs and Johnson, 1973
Color (Lovibond, Maximum)	Yellow 16-25; 2.0 Red	Cobbs and Johnson, 1973
Color (Visual)	Light Yellow	Cobbs and Johnson, 1973

Fatty acid	Özcan, 2010	Misuna et al. 2008	Özcan and Seven, 2003	Sander et al. 1995	Hashmi et al. 1993	Worthington et al. 1975
Palmitic acid	7.63-11.41	8.39-15.63	0.31-10.83	8.0-14.0	7.4-12.5	5.3-10.4
Stearic acid	2.14-4.13	3.56-4.76	0.1-4.23	1.0-4.5	2.7-4.9	2.2-4.4
Oleic acid	48.4-57.3	40.96-63.47	0.30-48.40	35.0-69.0	41.3-67.4	52.8-82.2
Linoleic acid	27.3-38.3	17.35-34.78	0.21-31.93	12.0-43.0	13.9-35.4	2.9-27.1
Arahidic acid	1.44-2.36	0.50-0.89	0.15-1.67	1.0-2.0	1.2-1.9	1.1-1.8
Eicosenoic acid	-	0.28-0.64	-	0.7-1.7	0.7-1.4	0.7-2.4
Behenic acid	-	1.75-2.33	0.31-2.43	1.5-4.5	2.1-3.6	2.2-3.9
Lignoceric acid	-	0.55-1.11	-	0.5-2.5	0.9-1.7	1.0-1.9

Table 3. Fatty acids composition of peanut oil (%)

Table 4. Overview and composition of sterols present in peanut oil

Compounds	Peanut oil
Total unsaponifiable compounds (g/kg)	≤10
Sterols (mg/kg)	900–4344
Cholesterol	ND–3.8
Brassicasterol	ND–0.4
Campesterol	11.4–19.8
Stigmasterol	4.8–13.3
β-Sitosterol	47.4–69.0
Δ -5-Avenasterol	5.0–19.0
Δ -7-Stigmasterol	ND-5.2
Δ -7-Avenasterol	ND–6.6

Others	ND–1.4
4-Monomethylsterols (mg/kg)	157
Triterpene alcohols (mg/kg)	360
Squalene (mg/kg)	270–1296
Total Tocopherols (mg/kg)	137–934
% of total tocopherols	
α – Tocopherol	18–57
β – Tocopherol	ND–2
γ – Tocopherol	36–78
δ – Tocopherol	ND–6
Tocotrienols (mg/kg)	ND–474
Chlorophylls (mg/kg)	1.4–1.6

β-Carotene (mg/kg)	0.1

N.D=Non detectable at (≤0.05%)

(CEC, 2005; Padley et al., 1992; O'Brien, 2004; Tuberoso et al., 2007)

Table 5. Comparison of peanut phytosterol content with other oils (Awad et al., 2000)

Oil Type	β-Sitosterol	Campesterol	Sigmasterol	Phytosterols
Unrefined peanut oil	190.7	14.3	13.4	206.8
Refined peanut oil	153.1	23.1	13.0	189.2
Extra virgin olive oil	144.5	5.3	ND	144.5
Pure olive oil	117.3	4.8	ND	117.3
Sesame oil	367.4	76.6	28.4	472.9
Soybean oil	220.6	58.1	66.8	345.5