



Health aspects of peanuts as an outcome of its chemical composition

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ABSTRACT

Peanut is an energy dense food item and it contains a substantial amount of fat, proteins, carbohydrate, both fat soluble and water soluble vitamins, minerals and phytochemicals. Peanuts are consumed worldwide due to its high nutritional value and pleasant or unique flavor after roasting or boiling. The lipid, protein and carbohydrate not only provide energy, but also provide essential nutrients for normal body functions such as body fat and muscle buildup. Vitamins are needed for normal cell function, growth, development, disease prevention and act as coenzymes during the production of energy. Due to the high nutrient contents of peanuts, they have been used to combat malnutrition in most developing countries. Epidemiologic studies have associated nut consumption with a reduced incidence of cardiovascular heart diseases and gallstones in both genders and diabetes in women. Limited evidence also suggests beneficial effects on hypertension, cancer, and inflammation. The health risk associated with peanut consumption is allergy in developed countries. The review discusses the health aspects, including allergy, of peanut consumption as they related to the chemical composition of peanuts using literatures published in past two decades with exceptions of a few older articles.

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1. Introduction

Peanuts (*Arachis hypogaea*) also known as groundnuts from the family of legumes, is an important crop in the United States and all over the world. Asia is the major producer of peanut which accounts for 60% of the world production [1]. There are many different peanut cultivars available, however, four major types (Runner, Virginia, Spanish and Valencia) have been accepted by the market due to flavor, oil content, size, shape, and disease resistance [2]. Peanuts are very rich in proteins, oils, fiber, vitamins, carbohydrate and are consumed all over the world due to its availability and affordability compared to other types of nuts [3]. In general, peanuts are used to produce oil, consumed as snack, peanut butter and as an ingredient for confectionery products in the developed countries. In the United

State, the largest portion of this crop is processed into peanut butter, salted peanuts and snack bars for consumption. The by-product of the oil extraction is the meal which is rich in proteins, dietary fiber, antioxidants, vitamins, and minerals, and is utilized as animal feed or processed further for human consumption [4]. Epidemiologic studies have associated peanut consumption with a reduced incidence of coronary heart disease and gallstones in both genders and diabetes [5,6]. Other beneficial effects of peanuts consumption with limited evidence are the reduced incidence of obesity, hypertension, cancer, and inflammation [7,8].

2. Health benefits of peanut consumption

2.1. Peanut consumption and mortality

Some cohort studies with large populations and long follow up time have shown that consumption of nuts (including peanuts) was inversely associated with total and cause-specific mortality regardless race and gender [9–12]. Specifically, nut consumption has been reported to be significantly associated with reduced risk of cancer, cardiovascular, respiratory, infectious, renal and liver disease mortality but not with diabetes or Alzheimer's disease mortality. However, no significant associations between peanut butter

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consumption and all-cause and cause-specific mortality has been observed [13].

2.2. Peanut consumption and cardiovascular diseases

A 12-week clinical study conducted with 151 participants found that moderate daily peanut consumption (42 g/day) resulted in significant reduction of blood pressure, blood cholesterol and blood triglyceride in participants with elevated serum lipids and blood pressure. The participants at greater risk of cardiovascular disease had significantly greater mean reductions in diastolic blood pressure (-5.0 ± 1.7 mm Hg), cholesterol (-12.1 ± 8.5 mg/dL), and triglycerides (-31.7 ± 15.8 mg/dL) ($n = 27, 24$, and 15 , respectively; $P < 0.01$) than those at lower risk [14]. Nut consumption was inversely associated with risk of myocardial infarction, heart failure, atrial fibrillation and abdominal aortic aneurysm in the age-adjusted and sex-adjusted study with 61, 364 Swedish adults who had completed a Food Frequency Questionnaire and were followed up for 17 years [15]. Consumption of peanuts, tree nuts (2 or more times/week) and walnuts (1 or more times/week) was associated with a 13%–19% lower risk of total cardiovascular disease and 15%–23% lower risk of coronary heart disease [16]. A systematic review and meta-analysis of the results of 13 randomized controlled trials revealed that consumption of peanuts, especially peanut oil, high-oleic peanut and peanut sprout, for more than 12 weeks has a positive significant effect on HDL of healthy subjects, but has no significant effect on other CVD risk factors [17]. Two prospective cohort studies in the U.S. found that men and women consuming 5 or more units of nuts per week (frequent consumption) had a significantly lower risk of gallstone disease than those who never ate or who ate less than 1 unit per month after adjustment for age and other known or suspected risk factors [18,19].

2.3. Peanut consumption and obesity and diabetes

A prospective cohort study of 83,818 women from 11 states has shown that nut consumption was inversely associated with risk of type 2 diabetes after adjustment for age, body mass index (BMI), family history of diabetes, physical activity, smoking, alcohol use, and total energy intake. Consumption of peanut butter was also inversely associated with type 2 diabetes, especially, in women consuming peanut butter 5 times or more a week (≥ 140 g of peanuts/week) compared with those who never/almost never ate peanut butter [20]. A randomized control trial with 32 patients who had type-2 diabetes mellitus (T2DM) found that incorporated into a low carbohydrate diet, almonds and peanuts had a similar effect on improving fasting and postprandial blood glucose among patients with T2DM [21]. A study with 262 sixth-grade Mexican American children revealed that children in the peanut consumer group were less likely to be overweight or obese than children in the non-peanut consumer group ($\chi^2 = 13.9$, $P = 0.001$), had significantly higher intakes of several vitamins and micronutrients (i.e., magnesium, vitamin E), and had lower low-density lipoprotein and total cholesterol levels [22]. Several cross-sectional analyses have shown an inverse association between long-term high nut consumption between peanut consumption and lung/prostate cancers [28,29]. The increased consumption of peanut especially was associated with a lower C-reactive protein CRP and tumor necrosis factor receptor 2 (TNFR2) [30].

In addition to the health benefits of direct peanut consumption, some *in vitro* studies [31,32] and limited *in vivo* animal studies [33,34] indicates that enzymatic hydrolysis of peanut protein resulted in peanut protein hydrolysates and peptides with antihypertensive activities. These may explain the blood pressure lower effects of regular peanut consumption reported by Jones and colleagues [14] because hydrolysis of peanut protein in gas-

trointestinal system after peanut intake produces antihypertensive peptides which could inhibit the activity of angiotensin converting enzyme, one of the key enzymes in blood pressure regulation. The peanut protein hydrolysates also exhibit different antioxidant properties such as DPPH free radical scavenging, hydroxyl radical scavenging, metal chelation and reducing power [31,35]. These antioxidant activities may also contribute to the reduced cancer and CVD risks among populations frequently consuming peanuts.

3. Nutritional composition of peanuts

The health benefits of peanuts are attributed to their balanced nutrient composition. The B vitamins, vitamin E, MUFA, PUFA, fiber, and phytochemicals in peanuts are the components claimed to be responsible for the protective effects [38]. Compared to other nuts, peanuts are more affordable, particularly for the populations with low socioeconomic status. Due to the high nutrient contents and affordability, peanuts have been used to combat malnutrition in most developing countries [36,37]. Due to the important health benefits described above, it is necessary to look into the nutritional composition of peanuts in detail.

3.1. Proximate composition of peanuts

Similar to other nuts, peanut is an excellent source of nutrients with a substantial amount of lipid, protein and fiber content along with some amount of carbohydrate, vitamins, and minerals. The proximate composition of peanut kernels was reported to be 5%–10% moisture, 44%–56% fat, 22%–34% protein, and 6%–24% carbohydrate in 1973 [39], and updated by other researchers due to the advancement in analytical technologies. The ranges of peanut nutrient constituents recently reported were protein 20.7%–25.3%, crude fat 31%–46%, ash 1.2%–2.3%, crude fiber 1.4%–3.9%, carbohydrate 21%–37%, and moisture 4.9%–6.8% [40]. The constituents of Indian raw peanut kernel were stated as 47.27% fat, 25.48% protein, 5.25% moisture, 17.43% carbohydrate, and 1.84% ash [41]. The macronutrient compositions of peanuts are comparable or better than tree nuts as shown in Table 1. Because soybean is another important oil seeds and protein source, the proximate composition of soybean is also given in Table 1.

Peanut contains higher amount of oil compared to soybean; on the other hand, soybean contains higher amount of protein than peanut. Compared with commonly consumed tree nuts, the protein content of peanuts is the highest, the lipid content of peanuts is slightly higher than cashew and pistachio but significantly lower than other nuts (Table 1). Nuts including peanuts provide over 10% of the recommended dietary allowance of nutrients (protein, iron, thiamin and vitamin E) for adult males [43]. However, the price of peanuts is much lower than the tree nuts. For example, the retail price of roasted peanuts is about \$2.69/lb (WalMart.com), while the average price of tree nuts in the U.S. amounts to \$6.07/lb (<https://www.statista.com/statistics/682860/us-average-price-of-nuts-us/>). Peanut is an excellent source of protein and lipid for both human and animal. The crude protein and lipid contents of peanuts are about 25% and 50%, respectively (Table 1). After oil extraction, the protein content in the peanut meal/flour reaches 50% [42]. According to Karkanis and colleagues [44], the chemical compositions of peanuts are very much affected by cultivar, maturity, year, location, season, agriculture practice, processing and storage, but not always by a statistically significant amount. Proximate analysis of peanut varieties resulted in significantly different composition, however, there was no significant difference in the protein content [40]. The energy dense nature, high protein content and affordability make peanuts a suitable crop to combat malnutrition in many developing countries where majority of the

Table 1
Macronutrient compositions of peanuts, other nuts and grains (USDA, 2018) [42].

	Almond	Cashew	Peanuts	Pecan	Pecan	Pistachio	Walnuts	Soybean	Soybean
Energy (kcal)	607	579	587	679	691	571	654	449	469
Moisture (%)	–	–	1.81	–	3.52	–	4.07	0.8	1.95
Protein (%)	21.43	18.42	24.35	7.14	9.17	21.43	15.23	43.32	38.55
Total lipid (fat) (%)	53.57	47.37	49.66	67.86	71.97	46.43	65.21	21.62	25.4
Carbohydrate (%)	17.86	28.95	21.26	21.43	13.86	28.57	13.71	28.98	30.22
Total Dietary Fiber(%)	10.70	2.60	8.40	7.10	9.60	10.70	6.70	8.10	17.70
Total Sugars (%)	3.57	5.26	4.90	10.71	3.97	7.14	2.61	0	0

Source: USDA Food Composition Database Release, April 2018.

population is under poverty line and animal-based products are too expensive them.

3.2. Nutritional value of peanut protein

The nutritional value of a food protein is determined by its essential amino acid contents and its digestibility. Animal proteins contain all the essential amino acid including the Sulphur-containing amino acids and highly-digestible. However, individuals such as vegans and vegetarians who are unable to eat animal products depend on alternative plant sources that are high in protein such as peanut and soybean. Although the amino acid composition of peanuts varies greatly with variety and plant location, peanuts contain all the 20 amino acids in variable proportions and is the richest source of arginine [45,46,43]. The common limiting amino acids of peanuts are sulfur containing amino acids such as methionine and cysteine [45]. However, these can be complemented by consuming peanut products together with cereal grains because the proteins in cereal grains are rich in methionine and cysteine [47–49].

It is important to select the types of plant products that are digestible to provide the body with the required amino acids needed by the cells, muscles and organs to function properly. The Protein Digestibility Corrected Amino Acid Score (PDCAAS) for peanut is 81% [50] and that of soybean is 72% [51]. A nutritional bar made from peanut and soybean were reported to have an *in vitro* protein digestibility of 42.28% and 35.34% respectively [52]. The *in vitro* protein digestibility was reported to be 92.65% for raw peanut [53]. This indicates that even though soybean contains a higher amount of protein than peanut, peanut protein is more bioavailable than the soy protein.

3.3. Fatty acid composition of peanut oil and its health benefits

Although peanuts and tree nuts have high lipid contents, peanut oil is rich in unsaturated fat, predominantly, monounsaturated fats (MUFA) (Table 2) which have been associated with lower cardiovascular risk [54]. The MUFA of regular US peanuts is 49%–57%, and medium and high oleic peanuts have 66%–69% and 78%–80% of MUFA, respectively [55]. The consumption of monounsaturated fats promotes artery-clearing which keeps the blood flowing well and lowers the risk of atherosclerosis, heart attack or stroke [56]. Clinical studies demonstrated that intakes of MUFAs and PUFAs were associated with a lower risk of cardiovascular diseases (CVD) and death, whereas saturated fat and trans-fat intakes were associated with a higher risk of CVD [54,57]. A 4-week randomized clinical trial included 43 males with BMI of (29.7 ± 2.4) kg/m² and aged between 18 and 50 years found that regular consumption of high-oleic peanut within a hypocaloric-diet increased fat oxidation and reduced body fatness in overweight and obese men [58], and attenuated glucose homeostasis disruption and inflammation related to obesity by strong moderation of postprandial glucose, insulin, and TNF- α concentrations [59]. Some observational studies also show that high consumption of monounsaturated fat was significantly associated with a decreased risk of basal cell carcinoma (BCC), but high level of polyunsaturated fat intake was potentially positively associated with squamous cell carcinoma (SCC) [60]. A clear reduction of risk of cognitive decline has been found in a population sample with a high intake of PUFA and MUFA. A prospective population-based study on older nondemented subjects with a typical Mediterranean diet found that high MUFA and PUFA energy intakes and total energy intake were significantly associated with a better cognitive performance in an 8.5-year follow-up [61]. An observational study also found positive association between high intake of MUFA intake reduced cognitive decline in aged women population (≥ 60) [62]. Therefore, regular consumption of peanuts can

Table 2
Fatty acid compositions of peanuts, other nuts and grains.

Fatty acids	Numerical Abbreviation	Almond	Cashew	Peanut	Pecan	Pistachio	Walnut	Soybean
Palmitic	C16:0	6.8	10.3	10.46	6.17	8.89	6.80	13.58
Palmitoleic	C16:1	0.53	0.37	N/A	N/A	0.53	N/A	0.24
Stearic	C18:0	2.3	8.8	3.37	N/A	1.52	2.00	4.94
Oleic (n-9)	C18:1	67.2	61.8	53.77	23.70	64.59	19.60	26.09
Linoleic (n-6)	C18:2	22.8	17.3	26.96	68.03	23.50	60.40	46.70
Linoleic (n-3)	C18:3	N/A	0.14	1.42	1.78	0.29	11.40	6.31
Arachidic	C20:0	0.09	0.62	N/A	0.29	0.16	N/A	0.56
Palmitic	C20:1	0.16	0.16	2.73	N/A	0.52	N/A	0.59
Docosanoic	C22:0	N/A	0.13	1.29	N/A	N/A	N/A	N/A
Lignoceric	C24:0	N/A	0.14	N/A	N/A	N/A	N/A	N/A
Total MUFA		67.9	62.36	53.77	23.70	65.64	19.60	22.78
Total PUFA		22.8	17.44	26.96	69.81	23.79	71.80	57.74
Total SFA		9.3	19.99	19.27	6.46	10.57	8.80	15.65
Others		0.21	0.26	0.00	0.03	0.00	0.10	0.99
Total FA		100.09	100.05	100.00	99.97	100.00	99.90	99.01
References		[63]	[64]	[65]	[66]	[67]	[68]	[69]

MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid and SFA: saturated fatty acid.

provide sufficient PUFA and MUFA to protect against CVD, some types of cancer and age related cognitive decline.

3.4. Dietary fiber content of peanuts

Dietary fiber is mainly found in fruits, vegetable, whole grain and legumes. There are soluble and insoluble dietary fibers which have health benefits such as lowering the risk of heart disease, diabetes and maintenance of a healthy weight [70]. Other health benefits are lowering of blood cholesterol and improvement of bowel movement [71]. Recent studies also show that dietary fiber intake is associated with lower risk of metabolic syndrome [72]. The dietary fiber content of dry roasted peanut is 8.4 g per 100 g of peanut similar to that of soybean (9.3 g per 100 g), and the total dietary fiber of defatted peanut flour is 15.8% which is comparable to that of defatted soybean flour (17.5%) [42,73,74]. This is a substantial amount of dietary fiber that can help individuals reach their recommended daily allowance which is 38 g for men and 25 g for women. The peanut dietary fiber consisting of insoluble polysaccharides (cellulose and hemicellulose) and soluble oligosaccharides (raffinose, stachiose and verbascose). Defatted peanut flour has been shown to contain approximately 38% total carbohydrates [42] which includes 12.5% starch, 4.0% hemicellulose, 4.5% cellulose, approximately 13.90% sucrose, 0.89% raffinose, 1.56% stachiose, and 0.41% verbascose [75]. Peanuts also contains significant amount of glucosamine [76] which is chondroprotective against osteoarthritis [77]. An important property of insoluble fibers is their ability to bind with carcinogens, mutagens, and other toxic chemicals formed during digestion of food, allowing their subsequent removal through the feces; whereas soluble fibers can be fermented in the colon by gut microbiota to produce short-chain fatty acids, such as butyrate, propionate, and acetate [78]. Specific short-chain fatty acids, particularly, butyrate, may reduce the risk of developing gastrointestinal disorders, cancer, and cardiovascular disease [79]. Thereby, the combined properties of insoluble and soluble dietary fiber are likely led to reduce the incidence of colorectal cancer and other malignancies as well as non-neoplastic diseases, such as diabetes, cardiovascular disease and immune disorders [78,79].

4. Vitamins in peanuts

In addition to macronutrients, peanut is an excellent source of some important vitamins including B vitamins and vitamin E. Vitamins are essential micronutrients required by the body to performs numerous functions such as boosting the immune system, energy production and digestion of food. Among 14 vitamins, human body can synthesize vitamin D3 and niacin; the rest of vitamins must be supplies from diets for the normal performance of chemical and physiological functions of the body [80]. Vitamins can be categorized into water-soluble and fat-soluble vitamins according to their solubility in water and in non-polar organic solvents. Fat-soluble vitamins include vitamins A, D, E, and K, while water-soluble vitamins include vitamin C and 8 B vitamins [81]. Fat soluble vitamins can be stored in the liver and fatty tissues, while water-soluble vitamins need regular replacement in the body due to their fast removal from the body [82]. Deficiency of vitamins in a human body can cause the following avitaminosis: gastrointestinal problems, night blindness, scurvy, cardiovascular, nervous disorders, and growth retardation [83]. Hypervitaminosis occurs when there is an overdose of vitamins (fat-soluble) since they can be stored in the liver and fatty tissues of the body compared to the water-soluble vitamins.

4.1. Water-soluble vitamins in peanuts

The water-soluble vitamins are responsible for the formation of coenzymes during biochemical processes in the body. The B vitamins include B₁ (thiamine), B₂ (riboflavin), B₃ (niacin), B₅ (pantothenic acid), B₆ (pyridoxine), B₈ (biotin), B₉ (folic acid), B₁₂ (cyanocobalamine), and B₄ (choline). Dietary sources of B vitamins are nuts, seeds, peanuts, soy beans, pork, leafy green vegetables, honey, and milk products [82]. However, they can be easily lost through food preparation and processing.

Thiamine (B₁) is a portion of an enzyme that is required for energy metabolism, and it is important for nerve and brain function [84,85]. Riboflavin (vitamin B₂) plays a major role in the metabolism of fats, carbohydrates, and proteins, and is required for skin health and normal vision. The riboflavin in the form of flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD), participate in electron transfer and hydrogen transfer reactions into the electron transport chain during ATP production in the human body [86]. Niacin (B₃) and thiamin are responsible for the normal functioning of the digestive system, skin, nerve and the food conversion to energy and for the functioning of the heart, muscles, and nervous system respectively [81]. Research indicates that dietary niacin may protect against Alzheimer's disease and cognitive decline [84]. Folate is important especially in infancy and pregnancy because it aids in the production and maintenance of cells [82]. Studies show that individuals who have adequate amount of folate are at lower risk of cardiovascular diseases [87]. Pantothenic acid helps in the metabolism and synthesis of fatty acids [89]. Choline is critical for normal membrane structure and function. It is also important for lung function and memory development in infants [90,91].

Peanut has been noted as a great source of thiamin, niacin and choline. The literature about the B vitamins in peanut is very limited because the analysis of B vitamins in an oilseed is technically difficult: the extraction and purification procedure of B vitamins from cereal grains and oil seeds are time consuming, and different B vitamins needs to be analyzed by different methods [92]. The major challenge is the loss of vitamins at the end of extraction due to exposure to light and air. The comparison of B vitamin contents of peanuts, soybean, and other nuts is given in Table 3.

Table 3 shows that peanuts grown in the United States are very rich in niacin and choline, and contains moderate amount of thiamin, riboflavin, folate and pyridoxine, compared to other nuts and soybean. The choline content of peanuts is about the same as Almonds but obviously higher than other nuts. The peanuts grown in other locations have similar B vitamin composition to those grown in the United States: 0.6 mg/100 g thiamin, 0.1 mg/100 g riboflavin, 12.1 mg/100 g niacin, 0.24 mg/100 g and soybean, 2.7 mg/100 g thiamin, 0.2 mg/100 g riboflavin, 27.3 mg/100 g niacin by [93,94], but differ from those reported in USDA nutrient database. A recent study warns that individuals who favor plant-based and vegan diets may be lacking in choline, a nutrient essential for brain health [95]. Because cereal grains, fruits, vegetables and most legumes are low in choline [96,97], peanuts and peanut derived products can be valuable source of choline for vegetarians, particularly, vegans. As a fact, it was reported that peanut consumers had adequate amount of B vitamins such as niacin, thiamine, riboflavin [98].

4.2. Fat soluble vitamins in peanuts

Fat-soluble vitamins include A, D, E and K. Vitamin A promotes good vision, vitamin D aids in calcium absorption, vitamin E functions as an antioxidant for cell membrane protection and vitamin K promotes blood clotting/coagulation [99,86]. Vitamin E is not a single compound, but a group of eight compounds which act as antioxidants maintaining the stability of cell membranes

Table 3
Contents of B-Vitamins in Peanuts, Soybean and Other Nuts (USDA, 2018) [42].

Water-soluble vitamins	Almond (mg/100 g)	Cashew (mg/100 g)	Peanut (mg/ 100 g)	Pecan (mg/100 g)	Pistachio (mg/ 100 g)	Walnut (mg/100 g)	Soybean (mg/100 g)
Thiamine (B1)	0.21	0.42	0.6	0.66	0.87	0.34	0.87
Riboflavin (B2)	1.14	0.06	0.1	0.13	0.16	0.15	0.87
Niacin	3.62	1.06	12.1	1.17	1.30	0.57	1.62
Pyridoxine (B6)	0.14	0.42	0.35	0.21	1.70	0.54	0.377
Folic acid	0.04	0.25	0.24	0.22	51.00	0.98	N/A
Choline	52.10	N/A	52.5	40.5	N/A	39.20	N/A

Source: USDA National Food Composition Database, April, 2018.

Table 4
Contents of Tocopherols in Peanuts, soybean and Other Nuts.

Nut Type	Total Tocopherol (mg/100 g)	α -T (mg/100 g)	β -T (mg/100 g)	γ -T (mg/100 g)	δ -T (mg/100 g)	References
Almond nut	26.57	25.63	0.23	0.64	0.07	[42]
Cashew	6.60	0.90	0.03	5.31	0.36	[42]
Peanut	44.45	20.21	0.40	22.23	1.63	[102]
Pecan	26.7	1.4	0.39	24.44	0.47	[42]
Pistachio	24.49	2.86	N/A	20.44	0.80	[42]
Walnut	23.57	0.70	0.15	20.83	1.89	[42]
Soybean	12.37	0.96	N/A	6.93	4.90	[103]

against oxidative stress [82]. These compounds are α -, β -, γ -, and δ -tocopherols and α -, β -, γ -, and δ -tocotrienols, collectively known as tocopherols. Potential health benefits of tocopherols include antioxidant activity, prevention of certain types of cancer, heart disease, and other chronic ailments [100]. Deficiency of vitamin E may increase the risk of coronary heart disease [101]. Foods with the highest vitamin E content are oil seeds. Table 4 shows the tocopherol contents of peanuts, tree nuts and soybeans. Peanuts is an excellent dietary source of vitamin E because it can be consumed in different forms: peanut butter, snacks and cooking oils. Compared with other nuts, peanuts contain highest total tocopherols and rich in all other tocopherols. The α -tocopherol content of peanuts is 20.21 mg/100 g peanuts, slightly lower than that of almonds (25.65 mg/100 g), but much higher than other nuts. The α -tocopherol has a high bioavailability than alpha tocotrienols, thus vitamin E in food products are quantified based on the content of α -tocopherol. Table 4 gives the contents of different tocopherols in peanuts, tree nuts and soybean. Obviously, peanut is a better source of vitamin E than other nuts, and it cost much less to obtain.

4.3. Effects of processing on vitamins in peanuts

Peanut processing aims at presenting a wholesome and safer product to consumers. It improves the flavor, color and texture of the peanut. One disadvantage of peanut processing is the decrease in shelf stability due to an increase in oxidation after processing. Generally, in the United State peanuts are processed into peanut butter and roasted peanuts. Commercial peanut processing involves blanching, roasting and peanut butter making. Peanut are blanched after shelling to simply remove the reddish skin covering the kernels. It helps to extent shelf life by reducing quality loss over time because it stops enzymatic reaction that disrupts the development of flavor. As reported by Nkafamiya and colleagues, fat-soluble vitamins such as vitamin E was not lost during blanching [104].

Generally, peanuts are roasted to enhance their color, flavor, taste, aroma and crunchy texture [105,106]. Roasting of peanut also reduces the bacteria load and aflatoxin-producing fungi of the raw peanut [107]. Vitamin E and B vitamins are very sensitive to heat and might be lost during roasting. In hazelnuts, roasting significantly decreased α -, β -, and γ -tocopherols by 34%, 40%, and 70%, respectively [108]. However, the extent of nutrient loss are largely dependent on the nut variety, the roasting temperature and time. Roasting had a diminishing effect on thiamine, carotenoids and tocopherols especially in almonds and walnuts, but not in hazelnuts and pistachios [109]. Thiamin is stable in slightly acidic water up to its boiling point however unstable in alkaline solution, and it can be lost through rapid boiling (high temperature) and ultraviolet irradiation [92]. The loss of thiamin during roasting is anticipated to be less compared to the loss through rapid boiling. Vitamin B₂ (riboflavin) on the other hand is stable at high temperature and in acid solutions but sensitive to UV light and alkaline solutions [92]. Thus, riboflavin may not be destroyed by peanut roasting, however it can be lost when exposed to air and light for long period. Vitamin B₃ (niacin) is the most sta-

ble among vitamins in the peanuts. Niacin is heat resistant but can be destroyed by air and light [110]. Pyridoxine (vitamin B₆) is stable in acid solution and can also be quickly destroyed by light.

Peanut butter has made a mark in several countries, especially in American cuisine. It is high in calories and contains fiber, vitamins, minerals, protein, fat, and phytochemicals. Peanut butter production has little or no effect on the vitamin content of the end-product because peanut butter is made from roasted peanuts by grinding the peanuts into a paste while incorporating other ingredients (<http://www.fao.org/3/y1390e/y1390e0m.htm>). Blanching and roasting are the main processes that may result in vitamin loss during peanut butter production.

5. Other phytochemicals of peanuts

Recent studies have also indicated that peanuts contain polyphenols (phenolic acids, flavonoids, A-type procyanidins, p-Coumaric acid), isoflavones, phytosterols, resveratrol [111–113]. These compounds are strong antioxidants which neutralize free radicals and the unstable molecules that can cause oxidative damage to the cells. Excessive free radical activity has been associated with possible mechanism which leads to the formation of cancerous cells. The supply of antioxidants to the body may lower the risk of cancer [114]. Phytosterols are the equivalent of animal cholesterol in the body. The main difference is the lower rate of absorption of phytosterol 5%–10% compared to cholesterol at a rate of 50% [115,116]. In a placebo-controlled, crossover study, treatment of hypercholesterolaemic subjects with in the PS-SM and PS-VFM at dose of 2 g/day for 4 weeks resulted in a decrease in the low density lipoprotein (LDL) cholesterol by 8.0 and 7.4 %, respectively [117]. Phytosterols reduce blood cholesterol by enhancing excretion of cholesterol, interfering with cholesterol production, and competing for cholesterol acceptor sites in the intestinal wall [118,119].

Peanut oil contains a substantial amount of phytosterols, which impair the absorption of cholesterol from the digestive tract [120,121]. The three most common forms of phytosterols in foods are beta-sitosterol, campesterol, and stigmasterol. Roasted peanuts contains 61–114 mg/100 g of phytosterol depending on the peanut variety of which 78%–83% is in the form of beta-sitosterol. The phytosterol (PS) content of unrefined peanut oil is 207 mg/100 g which is higher than that of unrefined olive oil. Peanut butter, which represents 50% of the peanuts consumed in the United States, contains 144–157 mg PS/100 g. Peanut flour, which results from partial removal of oil from peanuts, contains 55–60 mg PS/100 g [122]. A study that focused on evaluating the phytosterol composition in seed components showed that the sum of β -sitosterol, campesterol and stigmasterol comprised 82.29%, 86.39 % and 94.25% of total phytosterols in seed hearts, kernels and seed coats, respectively [123]. Phytosterols especially β -sitosterol have exhibited protective roles against colon and breast cancers [124,125]. The relationship between peanut consumption and lower risk of gallstone disease has been considered as a result of

the presence of phytochemicals and rich in monounsaturated fat [126].

5.1. Peanut allergy

Although peanut proteins represent significant nutrition and health benefit, they also trigger severe, even fatal allergenic reaction to individuals who consume it. Peanut allergy is known to be the most severe food allergies due to its prevalence, persistency, and extent of severity of the allergic reaction [127]. About 2.5% children and 1.8% of adults in the U.S. are allergic to peanut [128,129]. The prevalence of peanut allergy in Europe is 2.2% [130]. The peanut allergy contributes to approximately 59% deaths caused by food allergy [131]. Ingestion of a little amount can cause allergic reactions such as gastrointestinal discomfort, allergic dermatitis and other diseases in some cases severe or even allergic shock and anaphylactic death [132]. Thermal processing (roasting) of peanut was reported to increase the allergenic properties which results from protein modification during Maillard reaction [133].

Many studies have been conducted to characterize the specific proteins responsible for peanut allergy. So far, 17 allergenic proteins in the peanuts have been identified [134,135]. Among these proteins, Ara h 2, and Ara h 6 have been considered as most potent peanut allergens in the United States [136,137]. It has been reported that all known peanut allergens comprise 85% of the total protein content of peanut while Ara h 1, Ara h 2, and Ara h 3 together account for 75% [138]. Research also shows that peanut allergy has different clinical and immunologic patterns in different geographical areas of the world. Swedish patients frequently had IgE antibodies to Ara h 1 Ara h 3 and often presented with severe symptoms; while Spanish patients were more sensitized to the lipid transfer protein Ara h 8 and Ara h 9 (60.0%) [140]. So far, the best protection method for those allergic to peanuts is avoidance. To protect from accidental exposure to peanuts or peanut containing products, patients with potentially life-threatening food allergy require an epinephrine autoinjector, as well as training on its use [141].

Agricultural and food scientists have conducted many studies to reduce the allergenicity of peanuts and peanut-derived products either through genetic breeding [142–144] and post-harvest technologies [145–152]. Our studies have shown that treating peanut kernels with proteases such as chymotrypsin and trypsin effectively eliminate Ara h1 and reduce Ara h2 in roasted peanuts [148] and ultrasound pretreatment of peanuts enhanced the allergen reducing efficiency of these enzymes [152]. The proteases break down allergenic proteins and peptides in the peanuts thus reduce the allergenicity. However, some allergens are resistant to the hydrolysis by digestive proteases, particularly in the raw peanuts. None specific proteases were more effective in reducing resistant allergens Ara h 2 and Ara h 6 in both raw and roasted peanuts [150,151]. Some studies mixing peanut butter flour with plant phenolics to form non-digestible protein-polyphenol complexes which showed reduced allergenicity due to the reduced IgE-binding sites and change in secondary structure of allergens [153–155]. Clinical researchers have made great progress in oral immunotherapy by feeding an allergic individual an increasing amount of an allergen with the goal of increasing the threshold that triggers a reaction. A clinical study with 40 peanut-allergic infants and preschoolers 9–36 months shows that 32 subjects had evaluable outcomes, 81% were desensitized (low dose: 76%, high dose: 85%), and 78% achieved 4-SU (low dose: 85%, high dose: 76%, $P < 5\%$) over a median treatment period of 29 months [156]. However, A systematic review of 12 trials concluded with high certainty that available peanut oral immunotherapy regimens considerably increase allergic and anaphylactic reactions over avoidance or

placebo, despite effectively inducing desensitization [157]. Consequently, safer approaches for mitigating peanut allergy and more clinical studies are needed.

6. Conclusion

Peanut has well balanced nutritional composition but much more affordable than other nuts. Regular consumption of peanuts has been associated with reduced risks of coronary heart disease (CVD), hypertension, inflammation, cancer, gallstones, age related cognitive decline and increased life expectancy. These health benefits are closely associated with the high contents of protein, monounsaturated fatty acid, important vitamins and other phytochemicals, but lack of trans fat. However, the majority of proteins in peanuts are highly allergenic and individuals who are allergic to peanuts should avoid peanuts or possible peanut containing food products. In addition, peanut protein is low in sulfur-containing essential amino acids. More research is needed to increase these essential amino acids and to reduce or eliminate the allergenicity of peanut proteins, which are made possible by the advancement in genetic modification/editing technology. Post-harvest technologies such as nutrient fortification, chemical, physical and enzymatic modification will also contribute to the improvement of nutrition value and the reduced allergenicity of peanuts.

Declaration of Competing Interest

All authors declare no conflict of interest in regard to this paper. All authors agree to publish this paper in Food Science and Human Wellness.

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