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Chapter 17

COMPOSITION, QUALITY, AND FLAVOR OF PEANUTS

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Peanuts (*Arachis hypogaea* L.) are characterized by high oil and protein contents and a low percentage of carbohydrates and ash. The oil from these seed is of high quality, and a large percentage of the world production of peanuts is utilized as an edible oil source. In the USA, generally, about 60% of the production goes into domestic food use, the end products being peanut butter, salted products, confections, and roasting stock. As with many other foods, interest in the composition and chemistry of peanuts is largely a result of their use as human food. Peanuts are continually utilized for preparation of new and improved products; thus, a more complete knowledge of their composition and flavor properties is desirable.

Since an extensive coverage of the literature through 1970 on the physicochemical properties of peanuts was made by Cobb and Johnson (1973), the main thrust of this chapter is to focus primarily on the literature published in the past decade on the composition, quality and flavor of peanuts.

COMPOSITION

Proteins

Crude protein content of whole seed peanuts ranges between 22 and 30% (Altschul, 1964; Pancholy et al., 1978). Total protein can be separated into albumins, arachin, nonarachin or conarachin (Johns and Jones, 1916; Jones and Horn, 1930; Johnson and Shooter, 1950; Johnson et al., 1950; Evans et al., 1962; Johnson and Naismith, 1963; Dawson, 1968, 1971; Daussant et al., 1969a, b; Cherry et al., 1973). The arachin and conarachin fractions were quantified and their properties were determined (Johns and Jones, 1916; Evans et al., 1962; Tombs, 1965; Dawson, 1968,1971; Neucere, 1969, 1974; Ory et al., 1970; Dawson and McIntosh, 1973; Shetty and Rao, 1974). Arachin represents about 63% of the total protein and contains 2 components in the ratio of about 3 to 1 while conarachin represents about 33% of the total protein and contains 2 components in the ratio of about 4 to 1 (Fontaine et al., 1945). The major difference between these 2 globulins was found in their sulfur content, 0.40% for the arachin fraction, and 1.09% for the conarachin fraction (Johns and Jones, 1916). The arachin fraction was rich in threonine and proline and poor in lysine and methionine, while the conarachin fraction was poor in phenylalanine and tyrosine (Kaneko and Ishii, 1978). In addition, the antigenic structure of the major reserve protein, α-arachin, was unchanged by 1 hour heating at 145 C (Ory et al., 1970). This protein component should be intact in peanut products which are heated during processing.

The arachin and conarachin protein fractions are complex in composition and structure. Gel electrophoresis of sodium dodecyl sulfate dissociated proteins showed that these 2 fractions each contained 5 different components having molecular weights between 20,000 and 84,000 (Basha and Cherry, 1976). In addition, these fractions were found to be glycoproteins containing both neutral and amino sugars. The conarachin fraction contained approximately twice as much serine (7.5 g/100 g of protein), 1/2-cystine (2.7), methionine (2.0) and lysine (5.6) as compared to arachin (Basha and Cherry, 1976). Two-dimensional polyacrylamide gel electrophoresis was employed to separate and characterize peanut seed polypeptides. The use of this technique resulted in the detection of at least 74 major and between 100 and 125 minor peptides among several peanut cultivars and breeding lines (Basha, 1979). The majority of these polypeptides had isoelectric points between pH 4.4 and 8.0 and molecular weights between 16,000 and 75,000. Considerable variation existed among the major polypeptides of the cultivars examined (Basha, 1979). Characterization of peanut protein polypeptides by 2-dimensional gel electrophoresis should provide valuable information for the selection of cultivars and breeding lines with a particular storage protein makeup and for following compositional changes during peanut seed development and germination (Basha, 1979). Basha et al. (1980) found the presence of genetic variability in the mechanism for peanut protein synthesis, indicating that there is a potential for the development of peanut cultivars possessing nutritionally desirable proteins by manipulating protein synthesis. Although peanut proteins have been traditionally classified into arachin and conarachin proteins, at present their identity and protein composition are questionable. In order to distinguish and identify the 2 protein fractions, Basha and Pancholy (1981a) have separated arachin from nonarachin proteins and constructed composite 2-dimensional polypeptide maps.

Peanut proteins undergo changes due to heating or roasting of the seed and removal of the oil from the seed by solvent extraction. Neucere et al. (1969) and Ory et al. (1970) summarized the effects of dry roasting (145 C for 60 minutes) on peanut protein preparations and found that: a) solubility of the proteins was reduced by about 50%; b) the major protein, α-arachin, maintained its antigenic structure, but had an increased electrophoretic mobility; and c) other peanut proteins showed altered physical and chemical properties. These authors concluded that α-arachin remains intact after exposure of peanut seed to heat or dry roasting. Removal of oil from peanut seed by mechanical means did not result in any adverse effects on protein properties in the pressed cake (Ory et al., 1970). However, oil extraction by organic solvents resulted in drastic changes in the physical and chemical properties of the albumin and conarachin fractions (Ory et al., 1970). Acetone extraction of oil from peanut seed resulted in the formation of 2 closely related components in the arachin fraction (Ory et al., 1970).

The amino acid composition of peanut proteins is shown in Table 1. The major protein fractions are arachin and conarachin. Manganin was extracted from conarachin, it has a molecular weight of 56,300, and contains less 1/2-cystine, tryptophan and arginine than conarachin as shown in Table 1 (Dieckert and Rozacky, 1969). α-arachin contained more aspartic acid, glutamic acid, phenylalanine and arginine than α-conarachin. The latter protein contains more lysine, 1/2-cystine, methionine and tryptophan than α-arachin. Manganin contains more glycine than the other protein fractions.

Table 1. Amino acid composition of α-arachin and α-conarachin (g/100 g protein) and manganin (mol %) of peanut protein.(Adapted from Altschul, 1964; Dickert and Rozacky, 1969; Neucere, 1969).

Amino Acid	α-arachin	α-conarachin	manganin
Aspartic acid	12.1	10.5	10.5
Threonine	2.5	2.2	4.4
Serine	4.1	4.1	7.7
Glutamic acid	19.5	16.0	10.2
Proline	2.4	2.7	5.6
Isoleucine	3.3	3.7	4.1
Leucine	6.2	5.6	5.9
Tyrosine	3.3	1.1	2.8
Phenylalanine	5.3	4.6	3.2
Lysine	2.1	4.9	5.2
Glycine	3.5	2.8	20.0
Alanine	3.8	3.0	6.3
1/2-Cystine	0.0	0.7	0.7
Valine	4.0	4.5	6.1
Methionine	0.1	1.1	1.0
Histidine	2.0	2.4	1.7
Arginine	9.4	8.6	4.3
Tryptophan	-	1.0	0.4

Amino Acids

Two general methods are used in determining the amino acid composition of peanut proteins; the ion-exchange chromatography technique (Spackman et al., 1958) and the gas-chromatography technique (Conkerton, 1974). Amino acids analysis by these 2 methods are comparable (Conkerton, 1974).

The contents of amino acids in peanut seed vary according to type of peanuts, cultivar, location, year and during maturation of the seed. Amounts of free amino acids decreased while protein content increased with advancing maturity of peanut seed (Basha et al., 1976, 1980). Arginine undergoes the greatest reduction in content upon maturation (Young and Mason, 1972; Young et al., 1973, 1974a, b; Basha et al., 1976); thus it was proposed that arginine content could be used to determine the degree of maturity of peanut seed (Young and Mason, 1972). It was suggested that free amino acids are incorporated into protein at different rates (Basha et al., 1976, 1980). Thus high-protein cultivars contained higher amounts of free amino acids than the low-protein cultivars during seed maturation. This implies that certain polypeptides or proteins with a specific amino acid composition are selectively deposited in the maturing seed at different time intervals and at different rates among the various peanut cultivars (Basha et al., 1976; Basha and Pancholy, 1981a). Conarachin proteins that are high in essential amino acids were observed to be deposited during early stages of maturity of peanut seed while the arachin proteins that are low in essential amino acids were deposited during the later stages of maturation (Cherry, 1974; Basha et al., 1980). Young (1979) determined amino acid contents in seed of peanuts obtained from the uniform pea-

nut performance tests. Peanut samples were grown by breeders in 3 major USA growing areas, representing 11 locations and 31 entries. Statistical analysis of the data showed significant year, location, cultivar and cultivar-environmental interaction effects (Young, 1979; Oupadissakoon et al., 1980). In another study, Young et al. (1973) determined the amino acid levels in 16 varieties that had 24-30% protein content in the seed. These authors found nearly 2-fold variations in the limiting essential amino acids (lysine, isoleucine, methionine, threonine and valine). Aspartic acid, glutamic acid and arginine accounted for about 45% of total amino acid present (Young et al., 1973). The types of amino acids and their amounts present in 16 cultivars of peanuts are shown in Table 2. Pancholy et al. (1978) studied amino acid composition of 19 cultivars and breeding lines of peanuts ranging in protein content from 23 to 28%. They concluded that the deficient amino acids were lysine, methionine and threonine with ranges of 2.14 to 3.83, 0.35 to 0.99 and 3.83 to 4.97 as % of total protein, respectively. The ranges for these acids as reported by Young et al. (1973) were 2.88-4.45% for lysine, 0.71-1.21% for methionine and 2.01-2.73% for threonine. Differences in these limiting amino acids as reported by these 2 group of investigators reflect differences due to cultivars and environmental conditions. The content of amino acids present in Nigerian peanut defatted meals (Mba et al., 1974) was generally similar to that found for USA defatted peanut meal (Young et al., 1973). Boiling peanut seed for 90 minutes, autoclaving the defatted peanut meal at 121 C for 15 minutes or heating peanut seed for 30 minutes prior to defatting did not exert any appreciable influence on amino acid contents as reported by Mba et al. (1974) and shown in Table 3.

Table 2. Amino acid composition of meal from 16 cultivars of peanuts. (Young et al., 1973).

	Cultivar number[1]								
Amino Acid	1	23	25	27	28	33	41	45	50
	% of Total (by wt)								
Aspartic acid	15.43	11.67	13.15	15.03	13.08	12.35	13.28	13.76	8.83
Threonine	2.73	2.46	2.69	2.66	2.57	2.37	2.50	2.60	2.01
Serine	5.89	2.31	5.71	5.38	5.27	5.74	5.60	5.69	5.52
Glutamic acid	20.16	19.26	21.59	19.15	21.60	19.59	20.60	21.18	22.39
Proline	4.77	4.28	4.85	4.73	4.75	4.60	4.90	4.89	4.96
Glycine	6.41	6.03	6.69	7.83	7.51	6.69	5.85	7.22	7.29
Alanine	4.02	3.55	3.92	3.91	3.98	4.16	3.73	3.82	4.04
1/2-Cystine	2.45	2.62	3.31	2.64	2.77	2.44	2.41	2.42	2.22
Valine	3.04	2.85	3.36	3.11	2.79	2.99	3.78	3.19	3.99
Methionine	1.12	1.12	1.21	0.96	1.03	1.08	1.17	0.98	0.92
Isoleucine	2.26	2.07	2.34	2.41	2.12	1.81	2.52	2.43	3.33
Leucine	6.15	5.93	6.70	6.17	6.32	5.77	6.73	6.40	6.79
Tyrosine	3.64	3.58	3.79	3.80	3.80	3.72	3.96	3.70	3.53
Phenylalanine	4.91	4.64	5.06	4.91	5.19	4.89	5.19	5.00	5.16
Lysine	2.88	4.38	2.96	3.35	3.07	3.79	2.94	2.81	3.41
Histidine	1.97	2.94	2.05	2.28	2.06	2.59	2.13	2.15	2.22
Ammonia	1.73	1.77	1.30	1.50	1.59	2.60	1.61	1.26	2.06
Arginine	10.40	15.49	10.35	11.13	10.44	12.82	11.07	10.50	11.33

Table 2 (continued)

	Cultivar number								
Amino Acid	52	61	70	75	84	85	86	Range	FAO[2]
	% of Total (by wt)								
Aspartic acid	12.37	12.72	12.77	13.19	12.73	13.95	12.87	8.83-15.43	12.09
Threonine	2.35	2.30	2.43	2.44	2.35	2.43	2.43	2.01-2.73	2.77
Serine	4.74	5.11	4.85	5.07	5.26	6.04	5.30	4.74-6.04	5.08
Glutamic acid	17.20	20.78	20.34	20.99	20.30	21.91	22.46	17.20-22.46	19.38
Proline	4.79	5.57	5.20	5.45	5.38	6.24	6.36	4.28-6.36	4.62
Glycine	5.42	6.08	5.33	6.91	6.38	7.25	6.77	5.33-7.83	5.92
Alanine	3.54	3.67	3.54	3.62	3.56	3.81	3.41	3.41-4.16	4.13
1/2-Cystine	2.12	2.29	2.73	1.97	2.90	2.21	2.41	1.97-3.31	1.32
Valine	3.32	3.76	3.14	2.74	2.65	2.39	2.55	2.39-3.99	4.43
Methionine	0.73	0.71	1.12	1.18	1.18	1.03	1.18	0.71-1.12	1.22
Isoleucine	2.44	2.86	2.47	2.15	1.70	1.64	1.86	1.64-3.33	3.58
Leucine	6.10	6.45	6.16	6.06	5.60	6.08	6.12	5.60-6.79	6.79
Tyrosine	3.50	3.45	3.60	3.39	3.36	3.69	3.57	3.36-3.96	4.14
Phenylalanine	4.61	5.06	4.82	5.50	5.54	4.56	4.62	4.56-5.54	5.28
Lysine	4.45	3.23	3.73	3.72	3.66	3.17	3.53	2.88-4.45	3.75
Histidine	3.17	2.45	2.68	2.49	2.51	1.94	2.20	1.94-3.17	2.51
Ammonia	1.98	1.62	1.88	1.48	2.03	1.35	1.41	1.26-2.60	1.69
Arginine	17.17	11.89	13.21	11.66	12.91	10.31	10.95	10.31-17.17	11.84

[1]Cultivar no. 1 is Dixie Spanish, 23 Tennessee Red, 25 Ga. 61-42, 27 Nambyquarae, 28 Virginia Bunch 67, 33 Argentine, 41 Jenkins Jumbo, 45 Early Runner, 50 Conagin Macrocarpa, 52 Florida Jumbo, 61 McEachern Jumbo, 70 Bynum Runner, 75 NC-5, 84 Tarapota, 85 F334 A-B-14 and 86 Ba. 186-28.
[2]Calculated from data tabulated by Food and Agriculture Organization of the United Nations.

Table 3. Mean[1] composition of amino acid (g/16 gN) of Nigerian groundnuts. (Mba et al., 1974.)

	Commercial groundnut cake	Laboratory prepared groundnut meals	
		Dry heated[2]	Cooked and autoclaved[3]
Arg	11.07 ± 0.185	11.95 ± 0.170	11.06 ± 0.180
Cys	1.20 ± 0.004	1.35 ± 0.002	1.40 ± 0.003
Met	0.85 ± 0.000	1.40 ± 0.001	0.94 ± 0.000
Met + Cys	2.05 ± 0.002	2.75 ± 0.001	2.34 ± 0.001
Lys	3.04 ± 0.085	4.02 ± 0.086	3.42 ± 0.085
Leu	6.30 ± 0.075	7.17 ± 0.070	6.78 ± 0.072
Ile	3.12 ± 0.085	3.50 ± 0.820	3.44 ± 0.080
His	2.13 ± 0.000	2.58 ± 0.002	1.89 ± 0.001
Phe	4.69 ± 0.085	5.57 ± 0.087	5.20 ± 0.086
Tyr	4.16 ± 0.010	4.74 ± 0.008	4.30 ± 0.006
Thr	2.58 ± 0.040	2.98 ± 0.042	2.67 ± 0.040
Val	4.00 ± 0.030	4.35 ± 0.025	4.30 ± 0.020
Gly	6.10 ± 0.040	5.94 ± 0.034	5.97 ± 0.034
Try	1.82 ± 0.020	1.58 ± 0.008	1.74 ± 0.014
Asp	11.98 ± 0.115	12.79 ± 0.110	12.28 ± 0.108
Ser	4.90 ± 0.160	5.43 ± 0.140	5.06 ± 0.150
Glu	19.50 ± 0.680	19.32 ± 0.600	20.28 ± 0.608
Ala	3.54 ± 0.030	4.27 ± 0.020	4.31 ± 0.025
Pro	2.46 ± 0.470	3.64 ± 0.450	Trace

[1]Mean of 4 runs.
[2]Heated meal prepared by heating peanut seed for 30 minutes, defatted and ground.
[3]Cooked meal prepared by boiling seed for 90 minutes, sundried, defatted and ground. Autoclaved meal prepared by heating the defatted meal at 121 C for 15 minutes.

Oil

Peanut seed may range in oil content from 44% to 56% with an average of 50% (Cobb and Johnson, 1973). The chemical and physical properties of peanut oil as compiled by Cobb and Johnson are shown in Table 4. Peanut oil is light yellow with a slightly nut-like flavor, and it is a low viscosity type fluid. Peanut oil is an unsaturated lipid susceptible to oxidation as indicated by its relatively high iodine value and refractive index. The low values of the Reichert-Meissl and Polenske value indicate the presence of small amounts of fatty acids with 10 carbons or less. The saponification value is inversely proportional to the mean molecular weight of the glycerides of fats (Cobb and Johnson, 1973). The saponification value for peanut oil was lower than coconut oil. About 84% of coconut triglycerides are composed of caprylic, capric, lauric and myristic acids. About 96% of peanut triglycerides are composed of palmitic, stearic, oleic and linoleic acids (Koman and Kotuc, 1976). The titer value of oils represents solidification temperature of the free fatty acids present. The titer value for peanut oil was reported as a range of 26-32 C (Cobb and Johnson, 1973) and as 29.7 C (Koman and Kotuc, 1976). These values were higher than coconut, corn, linseed, rapeseed, and sunflower oils and lower than cottonseed oil and lard (Cobb and Johnson, 1973; Koman and Kotuc, 1976). The acid value or % free fatty acids of a lipid is a measure of the extent of hydrolysis that has occurred in a fat. The % free fatty acids in peanut oil was found to range between 0.02 and 0.6% (Cobb and Johnson, 1973). These values fall within the range of 0.25 to 1.5% for the common oleic-linoleic oils. Koman and Kotuc (1976) developed a computer program to calculate 50 physiochemical characteristics of a lipid from its fatty acid composition, acid value and titer.

Table 4. General Properties of Peanut Oil. (Cobb and Johnson, 1973.)

Melting point	0-3 C
Iodine value	82-106
Thiocyanogen value	58-75.5
Saponification value	188-195
Acetyl value	8.5-9.5
Reichert-Meissl value	0.5
Polenske value	0.5
Free fatty acids	0.02-0.6%
Unsaponifiable matter	0.3-0.7%
Refractive index (ND^{20})	1.4697-1.4719
Density at 15 C	0.917-0.921
Density at 25 C	0.910-0.915
Mean viscosity, 20 C	71.07-86.15 centipoise
Titer	26-32 C
Heat of fusion	21.7 cal/g (unhydrogenated) 24.7 cal/g (hydrogenated)
Color: Visual	Light yellow
Lovibond, 1 in.	Yellow: 16-25; Red: 1-2
Taste and odor	Slightly nut-like

Fatty acid composition of peanut oil as influenced by cultivar, maturity stage and environmental conditions was investigated by several workers (Iverson et al., 1963; Worthington and Holley, 1967; Worthington et al., 1972; Sekhon et al., 1972b, 1973; Young et al., 1972, 1974c; Holaday and Pearson, 1974; Brown et al., 1975). Fatty acid composition of 7 cultivars of peanuts are shown in Table 5.

Table 5. Fatty acid composition of oil obtained from seven cultivars of peanuts[1]. Worthington and Holley, 1967.)

	Fatty Acid Composition (%)							
Fatty acid	S. E. Runner	Dixie Spanish	Va. Bunch	Bynum Runner	Florida 393-7-1	Bleckley	Valencia	CV[2](%)
Palmitic	9.60	12.45	9.24	8.19	7.51	7.48	10.35	2.25
Palmitolic	0.14	0.09	0.11	0.11	0.08	0.09	0.09	9.61
Heptadecylic	0.11	0.06	0.08	0.06	0.07	0.05	0.06	9.91
Heptadecenoic	0.07	0.01	0.06	0.03	0.04	0.03	0.02	19.90
Stearic	2.83	3.43	2.77	3.91	3.11	4.92	3.57	3.72
Oleic	46.91	41.35	52.33	64.97	61.99	67.44	42.82	0.67
Linoleic	34.76	35.13	28.49	16.22	19.11	13.90	35.13	2.08
Linolenic	0.04	0.02	0.04	0.02	0.02	0.02	0.03	14.78
Arachidic	1.25	1.58	1.38	1.66	1.65	1.88	1.59	3.47
Eicoseonic	0.94	0.89	1.25	1.01	1.45	0.84	1.09	3.54
Behenic	2.16	3.59	2.73	2.65	3.42	2.34	3.45	4.71
Nervonic	1.14	1.39	1.45	1.15	1.52	0.98	1.67	9.95

[1]Values given are averages of three determinations.
[2]Coefficient of variation.

All the cultivars contained 12 fatty acids, 3 of which are present in amounts exceeding 5% of the fatty acid composition: palmitic, oleic and linoleic. These acids comprised about 90% of fatty acid composition. The remainder of the fatty acids, about 10% of the fatty acid composition, ranged in concentrations from 0.02% to 3.59%. Oleic and linoleic acids are unsaturated acids and both comprised about 80% of fatty acid composition (Table 5). Peanut cultivars varied in their fatty acid composition. S.E. Runner, Dixie Spanish, Va. Bunch and Valencia contained less oleic acid and more linoleic acid than Bynum Runner, Florida 393-7-1 and Bleckley. The last 3 cultivars contained less palmitic acid than the remainder of the cultivars examined. Similar varietal differences in their fatty acid composition were found for newer cultivars of peanuts as shown by Brown et al. (1975). Differences in fatty acid composition due to the effect of the geographic location were observed (Table 6). However, the differences in fatty acid composition due to cultivars were greater than those due to geographic location. Spanhoma peanuts grown in Yoakum, TX and Tifton, GA contained 45.5% and 46.6% of oleic acid, respectively (a difference of 1.1%) while the differences in the content of this acid between Spanhoma and Va. 72R varieties grown at the same location were 16% and 14%, respectively (Table 6). Florigiant and Va. 72R contained the highest oleic acid and lowest linoleic acid content regardless of having been grown at Yoakum, TX or Tifton, GA. Similar conclusions can be drawn if one considers the palmitic and stearic acids present in the Starr and Florunner cultivars grown at the 3 geographic locations.

Table 6. Fatty acid composition of peanuts from three locations in the national regional peanut cultivar trials in 1972 (normalized to 100%). (Brown et al., 1975.)

Cultivar	Palmitic	Stearic	Oleic	Linoleic	Arachidic	Eicosenoic	Behenic
				Yoakum, Texas			
Spanhoma	11.8	2.9	45.5	34.7	1.5	0.9	2.8
Comet	11.9	2.4	44.7	36.0	1.4	1.0	2.5
Starr	12.2	2.4	45.6	35.1	1.4	1.0	2.3
TP716-2-1	12.0	3.2	45.6	34.0	1.5	0.8	2.9
TP931	11.8	2.0	47.7	34.7	0.9	0.7	2.1
Wilco I	11.5	1.7	49.1	33.6	1.3	1.1	1.8
Florunner	9.6	1.5	59.1	25.8	1.0	1.1	1.8
F439-16-6	11.2	1.9	45.1	38.2	0.8	1.1	2.4
Florigiant	9.1	2.2	60.3	24.2	1.1	1.0	1.8
Va. 72R	9.0	2.1	61.7	23.4	1.4	1.0	1.5
				Tifton, Georgia			
Spanhoma	10.7	2.8	46.6	34.9	1.3	0.8	2.6
Comet	11.3	2.3	46.5	35.0	1.4	0.9	2.5
Starr	11.4	2.0	46.4	36.0	1.8	1.6	2.8
TP716-2-1	11.3	2.6	46.6	35.0	1.4	0.9	2.3
TP931	11.4	2.6	47.9	33.3	1.4	0.7	2.6
Wilco I	11.1	1.4	46.7	36.6	0.4	1.4	2.2
Florunner	9.6	1.3	55.5	28.8	1.2	1.3	2.2
F439-16-6	10.8	1.7	41.3	41.9	0.7	1.1	2.4
Florigiant	9.0	2.4	56.4	26.8	1.8	1.1	2.4
Va. 72R	8.8	1.6	60.0	26.2	0.8	0.9	1.6
				Ft. Cobb, Oklahoma[1]			
Spanhoma	11.0	2.2	42.7	38.7	0.9	0.8	2.9
Comet	11.5	2.6	42.5	37.5	1.8	1.1	3.0
Starr	11.3	2.3	45.0	36.7	1.0	1.1	3.0
TP716-2-1	10.8	2.4	43.3	38.2	1.2	1.2	3.0
TP931	10.8	2.6	43.0	37.1	2.0	1.3	3.1
Wilco I	10.5	1.6	41.1	40.1	1.7	1.2	2.6
Florunner	9.0	1.4	48.0	36.5	1.1	1.8	2.3

[1]Florigiant, Va. 72R and F 439-16-6 not tested at Ft. Cobb.

Fatty acid contents change as peanut seed advance in maturity (Young et al., 1972). These authors determined fatty acid composition as a function of maturity stage for 8 cultivars of peanuts. Fatty acid composition for 2 of these cultivars is shown in Table 7. Mature seed contained more stearic, oleic and less arachidic, behenic and lignoceric acid than the immature seed. Mature seed of the Argentine cultivar contained less linoleic acid than the immature seed, but the amount of this acid remained unchanged during maturation of the Spanhoma cultivar. However, the amounts of both oleic and linoleic acids increased as the seed of both cultivars advanced in maturity.

Sekhon et al. (1972b, 1973) determined oil content and fatty acid composition in peanut seed of 100 peanut cultivars obtained from the world germplasm collection grown at the Punjab Agricultural University Farm, Ludhiana, India. These cultivars originated at Bihan, Madhya Pradesh, Maharashkra, Tamil Nadu and Punjab states of India; Israel; East, Central and South Africa; Australia; China; and Sudan. Oil content ranged from 47.5% to 52.1%. The major fatty acids present were palmitic (7.9-23.1 mol%), oleic 38.5-61.6 mol%) and linoleic 20.5-42.9 mol%). The mean values for these acids were 11.8, 47.2 and 34.1 mol %, respectively. The amount of linoleic acid present

Table 7. Fatty acid composition of peanuts grown at Perkins, OK, 1968.

Fatty Acid	Maturity	Days to Harvest 113	127	141	155	169
		Percent of Total				
				Argentine		
Palmitic	Mature	13.06	13.16	13.07	12.56	11.87
	Low int.[1]	12.92	12.29	13.14	12.08	11.81
	Immature	13.65	13.29	13.66	13.00	12.60
Stearic	Mature	2.74	2.47	2.63	2.86	2.76
	Low int.	2.48	2.24	2.51	2.88	2.31
	Immature	2.03	2.10	2.40	2.55	1.75
Oleic	Mature	40.48	41.19	41.44	41.40	40.67
	Low int.	38.28	38.44	39.78	41.08	40.30
	Immature	36.03	35.97	37.54	37.14	35.47
Linoleic	Mature	39.56	38.49	38.31	38.51	39.23
	Low int.	39.87	41.08	39.65	39.13	40.72
	Immature	40.57	41.32	40.14	40.86	42.74
Arachidic	Mature	.98	1.15	1.02	1.12	.94
	Low int.	1.24	1.05	.95	1.05	1.08
	Immature	1.13	1.04	1.10	1.10	.88
Linolenic +	Mature	.72	1.07	.82	.77	.90
eicoseonic	Low int.	1.09	1.15	.76	.83	1.02
	Immature	1.46	1.44	1.24	1.51	1.87
Behenic	Mature	1.84	2.14	2.10	2.27	2.45
	Low int.	3.30	2.70	2.61	2.14	2.18
	Immature	4.16	3.44	3.18	2.84	3.43
Lignoceric	Mature	.51	.27	.62	.61	.78
	Low int.	.82	.82	.60	.68	.53
	Immature	.87	1.16	.86	.92	1.25
Oleic +	Mature	80.04	79.68	79.75	79.91	79.90
linoleic	Low int.	78.15	79.52	79.43	80.21	81.02
	Immature	76.60	77.29	77.68	78.00	78.21
Oleic-linoleic	Mature	1.02	1.07	1.08	1.08	1.04
ratio	Low int.	.96	.94	1.00	1.05	.99
	Immature	.89	.87	.94	.91	.83
				Spanhoma		
Palmitic	Mature	12.88	12.81	12.15	12.06	12.37
	Low int.	12.70	11.68	11.64	11.40	11.33
	Immature	12.78	13.59	13.38	12.88	12.04
Stearic	Mature	2.79	2.90	2.58	2.36	2.34
	Low int.	2.96	2.86	2.92	2.89	3.28
	Immature	2.66	2.44	2.06	2.21	2.53
Oleic	Mature	41.85	42.23	41.46	41.02	41.03
	Low int.	38.09	38.58	38.49	39.02	39.86
	Immature	36.56	35.14	35.20	35.30	37.09
Linoleic	Mature	38.08	37.10	38.94	39.66	39.84
	Low int.	37.52	38.79	38.96	39.20	38.14
	Immature	37.81	38.52	38.93	39.76	39.87
Arachidic	Mature	1.15	1.18	1.07	1.18	1.09
	Low int.	1.57	1.50	1.51	1.46	1.61
	Immature	1.60	1.48	1.30	1.36	1.39
Linolenic +	Mature	.71	.73	.89	1.09	.95
eicoseonic	Low int.	1.24	1.31	1.33	1.25	1.23
	Immature	1.66	1.68	2.18	2.19	1.69
Behenic	Mature	1.82	2.28	2.02	2.23	2.27
	Low int.	4.23	3.80	3.67	3.22	3.23

Table 7 (continued)

	Immature	5.32	5.24	4.97	4.59	3.95
Lignoceric	Mature	.51	.60	.62	.55	+
	Low int.	1.67	1.47	1.47	1.56	1.31
	Immature	1.71	1.90	1.99	1.72	1.43
Oleic +	Mature	79.93	79.33	80.40	80.68	80.87
linoleic	Low int.	75.61	77.37	77.45	78.22	78.00
	Immature	74.27	73.66	74.13	75.06	76.96
Oleic-linoleic	Mature	1.10	1.14	1.06	1.03	1.03
ratio	Low int.	1.02	.99	.99	1.00	1.05
	Immature	.96	.91	.90	.89	.93

[1]Low intermediate.

or the ratio of oleic to linoleic fatty acids in peanut oil was considered by several investigators as an indicator of oil stability. Holly and Hammons (1968) reported a correlation coefficient of -0.92 between linoleic acid content and oil stability. Worthington et al. (1972), Young et al. (1972) and Brown et al. (1975) considered wider oleic/linoleic ratios (O/L) as an indicator of more stable oils. The O/L ratio increases with advanced maturity of peanut seed as shown in Table 7 (Young et al., 1972). Cultivar and locations influenced the O/L ratio as was found by Brown et al. (1975) and shown in Table 8. The O/L ratio changed from 1.38 to 2.63 for different cultivars of peanuts grown at Yoakum, TX. The corresponding ratios for the Tifton, GA and Marianna, FL locations were 1.28 to 2.29 and 1.44 to 2.32, respectively. Changes in O/L ratios for Florunner, Florigiant and Va. 72R cultivars grown at Yoakum and Bryan, TX, Marianna, FL and Tifton, GA contained about twice as much oleic acid as compared to linoleic acid. Peanuts grown at Stephenville, TX, Ft. Cobb, OK and Holland, VA exhibited narrower O/L ratios than those grown at other locations. Holaday and Pearson (1974) found that higher temperatures during the last 4 weeks before harvest resulted in higher oleic acid content and correspondingly higher O/L ratios. These authors postulated that this temperature-O/L relationship may provide at least partial explanation for observed problems with oxidative stability in peanuts grown in colder climates or with colder temperatures during the latter weeks of the growing season.

Table 8. Oleate/linoleate ratios of peanuts grown in the national regional peanut cultivar trials in 1972. (Brown et al., 1975.)

Cultivar	Yoakum TX	Bryan TX	Marianna FL	Tifton GA	Stephen-ville TX.	Ft. Cobb OK[1]	Holland VA[1]
Spanhoma	1.31	1.27	1.44	1.34	1.10	1.10	1.15
Comet	1.24	1.29	1.43	1.33	1.17	1.13	1.08
Starr	1.30	1.31	1.51	1.29	1.14	1.23	1.17
TP716-2-1	1.34	1.32	1.54	1.33	1.16	1.13	1.17
TP931	1.38	1.39	1.44	1.44	1.15	1.16	-
Wilco I	1.46	1.38	1.38	1.28	1.02	1.02	-
Florunner	2.29	1.92	1.98	1.93	1.40	1.31	-
F439-16-6	1.18	1.03	1.14	0.99	0.84	-	-
Florigiant	2.49	2.25	2.33	2.10	1.55	-	-
Va. 72R	2.63	2.24	2.32	2.29	1.57	-	-

[1]Not available from Ft. Cobb, OK; lost in heavy rains at Holland, VA.

The oleic/linoleic ratio as an indicator of oil stability (oven keeping time at 60 C) was postulated by several investigators. However, the correlation coefficients obtained were quite variable from year to year. Worthington et al. (1972) were able to account for 10-73% of the variation and Brown et al. (1975) were able to account for 39% of the variation in oil stability on the basis of O/L ratios. These variations could be due to differences in climatic conditions, soil moisture and air temperature during maturation and temperatures during curing of peanut seed (Worthington and Hammons, 1971; Holaday and Pearson, 1974). The relative linolenic acid content of peanut oil was found to be among the major factors affecting oil stability (Fore et al., 1953). Tocopherol composition of the peanut oils did not vary significantly either in the distribution of α- and γ-tocopherols or in total tocopherol contents. The enhanced stability of oils obtained from runner type peanuts may be due to their higher linoleic acid and slightly higher tocopherol contents (Fore et al., 1953). These authors suggested that there is some evidence that crude peanut oils contain some non-tocopherol antioxidant and/or synergist. Shewfelt and Young (1977) suggested that stability of oil in peanut-based foods may be increased by low temperature and humidity storage, packaging under vacuum or inert gas and addition of antioxidants to these foods. They also suggested that the selection or development of raw peanuts with low levels of linolenic acid is also a means of extending product shelf-life. Sekhon et al. (1972a) reported that peanut cultivars high in oleic acid and low in linoleic acid content are preferred for the achievement of better oil stability.

Senn (1969) determined the fatty acid distribution of triglycerides and phosphatides of cold pressed peanut oil (Table 9). It is of interest to note the relatively high concentration of palmitate found in the phosphatidylethanolamines and phosphatidyl serines fractions with relatively low concentration of oleate and linoleate. Senn (1969) attributed the variance in his results from

Table 9. Fatty acid composition of triglycerides and phosphatides of cold-pressed peanut oil. (Senn, 1969.)

Fatty Acid	Fatty Acid Methyl Esters, Percent of Total G3[1]	Eth[1]	Ser[1]	Chol[1]
Palmitic	8.1	24.7	33.9	12.9
Palmitolic	Trace	.1	.2	Trace
Heptadecylic	Trace	.2	-	Trace
Stearic	1.5	2.6	4.7	2.8
Oleic	49.9	39.5	30.9	47.0
Linoleic	35.4	28.2	27.5	35.6
Linolenic	Trace	.1	Trace	Trace
Arachidic	1.1	.1	.2	.3
Eicoseonic	.9	1.0	.2	.4
Behenic	2.1	.5	.5	.3
Erucic	-	-	-	.1
Lignoceric	1.0	3.0	2.0	.5
Nervonic	-	-	-	.1

[1]Abbreviations: G3, triglycerides; Eth, phosphatidylethanolamines; Ser, phosphatidylserines; Col, phosphatidylcholines.

Worthington and Holley's (1967) data to differences in cultivar used, cultural curing, and storage conditions. Carter et al. (1958) isolated a new complex lipid, phytoglycolipid, from peanut and other plant seed. This phytoglycolipid was the first sphingolipid of plant origin to be isolated, and it possesses the structural features of a glycolipid and of a phosphatid. Analysis of peanut seed unsaponifiable lipids indicated that sterols constituted about 17.5% of this fraction (Fedeli et al., 1968). Eisner and Firestone (1963) found the sterol fraction to be composed of 84% β-sitosterol, 12% camposterol, 3% stigmasterol and less than 1% of minor components. These findings were in agreement with those of Zuercher and Hadron (1976), who reported that sitosterol is the dominant sterol present, campsterol is present in small amounts, and stigmasterol in trace amounts.

No noticeable chemical changes were observed in peanut oil (Hoffpauir, 1953) or changes in the fatty acid composition of the extracted oil due to roasting (Haffpauir, 1953; Iverson et al., 1963; Sekhon et al., 1971). Fatty acid compositions of oils extracted from roasted and unroasted peanut seed are shown in Table 10. Roasting did not affect the contents of fatty acids.

Table 10. Comparison of fatty acid composition of oil from roasted and unroasted peanuts (%). (Iverson et al., 1963.)

Fatty acid	Unroasted	Roasted		
		Light	Medium	Heavy
Palmitic	8.4	8.2	8.5	8.6
Stearic	2.0	1.9	2.2	2.2
Oleic	47.4	48.3	48.2	47.9
Linoleic	37.5	37.1	36.2	36.4
Arachidic	1.2	1.4	1.5	1.4
Eicoseonic	1.1	1.0	1.0	1.1
Behenic	1.6	1.5	1.7	1.7
Nervonic	0.7	0.7	0.8	0.8

Carbohydrates

Pattee et al. (1974) followed the development of starch and sugars during maturation of NC 2 peanuts. These authors found starch to reach a maximum just beyond middle maturity stage of the seed and then remain constant. Sugar content increased throughout maturation reaching a maximum at full maturity. Sucrose was found to be the major sugar. Holley and Hammons (1968) found sucrose to vary from 2.86 to 6.35% among different cultivars of peanuts. The overall levels of sucrose, glucose and fructose found by Cobb and Swaisgood (1971) were considerably lower than those found by Holley and Hammons (1968), Mason et al. (1969) and Newell et al. (1967). This was probably due to the difference in peanut cultivars used by these investigators. Additional sugars were identified among the carbohydrate fraction of peanuts. Cegla and Bell (1977) identified the presence of glucose, sucrose and raffinose in peanut defatted flour. Oupadissakoon et al. (1980) identified and quantified the presence of 6 sugars and 1 unknown sugar in the defatted flour of 5 cultivars and breeding lines of peanuts grown at 4 different locations (Table 11). Statistical differences in sugar contents were found due to the genotype and due to

the growing location. The most abundant sugar, in all genotypes studied, was sucrose followed by stachyose and raffinose. Glucose was present at the lowest concentration, not considering the unknown sugar concentration. Summation of the amounts of free sugars to represent total free sugar content showed that NC 6 breeding line had the highest amount (42.5 mg/g) among genotypes, and peanuts grown at Northampton County had the highest total free sugar content (37.8 mg/g) among growing locations. Glucose, fructose, arabinose and galactose were the major monosaccharides found in the acid hydrolysates of the defatted flour of Tennessee Red and Virginia Bunch 67 peanuts (Amaya-Farfan et al., 1978). Concentration of fructose, arabinose and galactose remained almost unchanged as peanut seeds advanced in maturity. However, glucose content decreased considerably with advanced maturation.

Tharonathan et al. (1975) reported that total carbohydrates in a peanut defatted flour of unknown variety amounted to about 38% of the flour. Mono- and oligosaccharides accounted for 18% of the total carbohydrate moiety. The major oligosaccharide was sucrose which was present at 13.9% while fructose

Table 11. Mean comparison of free sugars (mg/g of peanuts), AMI value and calcium content g) of virginia type peanuts among cultivars and locations.[1] (Oupadissakoon et al., 198(

Sugars	Cultivars					Location			
	Florigiant	NC6	NC17921	NC17922	NC18976	Martin	N'hampton	Sussex	Suff
Unknown	0.080	0.034	0.069	0.071	0.055	0.094	0.038	0.061	0.05
	0.067a	0.029b	0.065a	0.057a	0.049ab	0.134a	0.021b	0.029b	0.03
	0.074a	0.032c	0.067ab	0.064ab	0.052b	0.114a	0.030b	0.045b	0.04
Fructose	0.247a	0.231a	0.257a	0.226ab	0.192b	0.226	0.216	0.232	0.24
	0.198	0.207	0.194	0.196	0.182	0.241a	0.185b	0.173b	0.18
	0.222a	0.219a	0.226a	0.211a	0.187b	0.233a	0.200b	0.202b	0.21
Glucose	0.102	0.102	0.103	0.098	0.085	0.098	0.090	0.104	0.10
	0.105b	0.125a	0.099b	0.096b	0.092b	0.096	0.095	0.106	0.11
	0.103ab	0.114a	0.101b	0.097bc	0.088c	0.097	0.092	0.105	0.10
Inositol	0.143	0.107	0.135	0.116	0.129	0.057c	0.178a	0.138b	0.13
	0.157a	0.121b	0.155a	0.120b	0.131b	0.038b	0.151a	0.174a	0.18
	0.150a	0.114c	0.145a	0.118bc	0.130b	0.048b	0.164a	0.156a	0.15
Sucrose	30.742b	37.435a	29.141bc	28.170c	28.499c	27.984b	32.582a	30.828a	31.79
	28.331bc	37.40a	28.051bc	29.312b	27.038c	30.023ab	32.199a	30.347	27.29
	29.536b	37.453a	28.596bc	28.741bc	27.769c	29.003b	32.391a	30.588b	29.69
Raffinose	0.376a	0.313b	0.369a	0.384a	0.387a	0.326c	0.359bc	0.406a	0.37
	0.344	0.312	0.334	0.317	0.346	0.319b	0.282b	0.299b	0.42
	0.360a	0.313b	0.352a	0.350a	0.366a	0.322b	0.320b	0.353b	0.39
Stachyose	3.548b	4.339a	4.298a	4.108a	4.208a	2.649c	5.086a	3.878b	4.78
	3.837ab	4.147a	3.895ab	3.617b	3.788ab	2.723b	4.166a	4.160a	4.37
	3.692c	4.243a	4.097ab	3.863bc	3.998ab	2.686c	4.626a	4.019b	4.58
AMI value	37.50	34.92	38.08	34.00	33.92	22.00c	39.93ab	45.47a	39.33
	36.58	30.92	34.67	34.33	34.75	24.47c	40.80a	34.20b	37.53
	37.04	32.92	36.38	34.17	34.33	23.23b	30.37a	39.83a	36.43
Calcium	0.303b	0.259c	0.324ab	0.328a	0.343a	0.293b	0.301b	0.373a	0.27
	0.356a	0.267b	0.340a	0.338a	0.359a	0.293c	0.326b	0.386a	0.32
	0.329b	0.263c	0.332b	0.333b	0.351a	0.293c	0.313b	0.380a	0.30

[1]The comparison is made across the row. Means which have the same letter show non-significant differences accordi the Waller-Duncan multiple range test. Means which are down the column represent digging 1, digging 2, and bined results, respectively.

and glucose represented 0.80 and 0.41%, respectively. Other oligosaccharides present were raffinose 0.89%, stachyose 1.56% and verbascose 0.41%. The remainder of the carbohydrate fraction was composed of starch 12.5%, hemicelluloses 4.0% and cellulose 4.5%. The chemical composition of 70% ethanol-soluble and 70% ethanol insoluble materials from defatted peanut flour (HG-4 and Nambyquarae varieties) is shown in Table 12. In contrast to other published literature about sugar contents in peanut defatted flour, sucrose content was less than glucose or fructose content, and the presence of verbascose, xylose and ajugose sugars was established (Table 12). This is the first report indicating the presence of the latter 3 sugars in peanuts.

Table 12. Chemical composition[1] of ethanol-soluble and ethanol-insoluble materials from defatted groundnut flour. (Tharanathan et al., 1975.)

	HG-4 Groundnut		Nambyquarae Groundnut	
	Soluble Material	Insoluble Material	Soluble Material	Insoluble Material
Yield[2]	9.88	89.66	9.98	90.00
Total sugar[3]	89.20	24.00	90.00	25.50
Protein (N X 6.25)[3]	3.06	61.25	2.19	62.50
Moisture[3]	6.26	6.65	4.26	4.68
Ash[3]	0.31	5.26	0.20	4.88
Sugars detected[4]	Glu, 2.89	GalA, 1.70	Glu, 2.88	GalA, 1.88
	Fru, 2.19	Gal, 3.04	Fru, 2.11	Gal, 3.26
	Suc, 0.91	Glu, 8.60	Suc, 0.95	Glu, 5.20
	Raf, 0.94	Ara, 4.30	Raf, 1.06	Ara, 6.17
	Berb, 0.20	Xyl, 2.51	Sta, 0.51	Xyl, 4.29
	Unk, 0.14		Verb, 0.38	
			Aju, 0.48	

[1]Figures are averages of results of triplicate experiments in all cases.
[2]Percentage of dry solids extracted from dry defatted groundnut flour.
[3]Figures represent the percentage composition of ethanol-soluble and ethanol-insoluble material.
[4]Glu, Glucose; Gal, Galactose; Fru, Fructose; Ara, Arabinose; Xyl, Xylose; Suc, Sucrose; Raf, Raffinose; Sta, Stachyose; Verb, Verbascose; Aju, Ajugose; GalA, Galacturonic acid; Unk, unidentified. (The figures represent the percentages (on moisture-free basis) of defatted groundnut flour, average values in triplicate).

Slight losses in sugar contents (Mason et al., 1969) were found upon roasting of spanish peanuts as shown in Table 13. There was about 15% loss in sucrose and inositol and about 33% loss in glucose and fructose upon roasting. Fructose and glucose occur in small concentrations, but it was found that sucrose undergoes hydrolysis to the 2 monosaccharides, fructose and glucose, which in turn react with some free amino acids to form the characteristic flavor of roasted peanuts.

Minerals

Hoffpauir (1953) and Woodroof (1969) summarized many of earlier investigations on the mineral composition of raw peanuts. Some of these earlier investigations reported an apparent 10-fold error in the upper limit of zinc, manganese, copper, iron and boron (Gaines and Hammons, 1981). Derise et al. (1974) studied the mineral content of raw and roasted virginia type peanuts and measured the changes occurring with roasting. Cultivar differences in

Table 13. Effect of roasting on sugar content (mg/g fat-free peanut meal) in spanish peanuts. (Mason et al., 1969.)

	Mean values and ranges for five samples			
	Raw		Roasted	
Sugar	Mean	Range	Mean	Range
Fructose and/or Mannose	2.7	1.6-3.3	1.8	1.4-2.0
Glucose	1.9	1.7-2.1	1.3	0.9-1.5
Inositol	1.3	1.0-1.6	1.1	0.7-1.6
Sucrose	149.0	109.0-197.0	125.3	107.0-161.0

mineral contents were observed for the raw and roasted peanuts (Table 14). Virginia 70 raw peanuts contained more sodium and potassium than NC 2 and Florigiant. Raw Florigiant peanuts contained more calcium and phosphorous than the other 2 cultivars. Roasted NC 2 contained more calcium and iron than Virginia 70 and Florigiant. Roasted peanuts contained more minerals than raw peanuts. Results obtained by Derise et al. (1974) were in general agreement with some of the earlier findings and those obtained by Gaines and Hammons (1981). Peanuts contain much more potassium than sodium, and they are good sources for potassium, phosphorous and magnesium.

Table 14. Mineral element content (mg/100g) of three cultivars of raw and roasted peanuts. (Derise et al., 1974.)

Cultivar and Physical State	Calcium	Magnesium	Phosphorus	Sodium	Potassium
Raw:					
Virginia-70	74.2 ± 0.46a	174.4 ± 2.31b	414.9 ± 7.98a	6.98 ± 0.08c	634.0 ± 2.02c
North Carolina-2	85.8 ± 0.34b	182.8 ± 1.59c	429.0 ± 3.11b	6.16 ± 0.07b	618.2 ± 2.13a
Florigiant	87.8 ± 1.98c	165.2 ± 0.42a	470.3 ± 0.76c	5.79 ± 0.08a	626.6 ± 1.31b
Roasted:					
Virginia-70	80.5 ± 0.42x	180.0 ± 0.68x	510.4 ± 1.60y	6.18 ± 0.07z	657.6 ± 0.99y
North Carolina-2	91.7 ± 0.25z	195.9 ± 2.10y	501.1 ± 0.55x	4.97 ± 0.03x	647.1 ± 1.05x
Florigiant	91.3 ± 0.75y	178.8 ± 0.27x	538.2 ± 0.99z	5.53 ± 0.10y	647.8 ± 1.05x
Overall mean:					
Raw	82.6	174.1	438.1	6.31	626.3
Roasted	87.8	184.9	516.6	5.56	650.8

Cultivar and Physical State	Iron	Copper	Zinc	Manganese
Raw:				
Virginia-70	1.43 ± 0.03a	1.14 ± 0.05a	6.13 ± 0.05a	1.75 ± 0.01a
North Carolina-2	1.76 ± 0.02c	1.27 ± 0.01b	6.15 ± 0.03a	1.77 ± 0.01a
Florigiant	1.58 ± 0.01b	1.26 ± 0.01b	6.09 ± 0.06a	2.01 ± 0.03a
Roasted:				
Virginia-70	1.54 ± 0.08x	1.25 ± 0.02x	6.69 ± 0.03x	2.08 ± 0.03y
North Carolina-2	1.79 ± 0.02z	1.30 ± 0.02x	6.56 ± 0.02y	1.94 ± 0.03x
Florigiant	1.70 ± 0.01y	1.36 ± 0.02y	6.64 ± 0.02xy	2.17 ± 0.02y
Overall mean:				
Raw	1.59	1.22	6.12	1.84
Roasted	1.68	1.30	6.63	2.06

Vitamins

Vitamin content of peanut seed are shown in Table 15. Peanuts have little or no vitamin A activity. Three forms of tocopherol (α, γ, δ) were found, with γ-tocopherol as the highest and δ-tocopherol as the lowest. The total tocopherol range was found to be 26.3-59.4 mg/100 g oil. Three forms of vitamin B_1 exist in peanuts; thiamine, thiamine monophosphate and thiamine pyrophosphate (Dougherty and Cobb, 1970a). Thiamine occurs in peanut seed at a concentration of about 1.0 mg/100 g. The content of this vitamin in peanut testa is considerably higher, in excess of 3.8 mg/100 g (Dougherty and Cobb, 1970b). Engel (1943) determined choline content in different peanut products (mg/100 g dry weight); spanish peanuts 174, runner peanuts 165, peanut meal 252 and peanut butter 148.

Table 15. Vitamin content of peanuts, units per 100 g dry weight. (Cobb and Johnson, 1973.)

	Coytledons	Defatted Flour
Fat-Soluble:		
Vitamin A	26 I.U.	
Carotene (provitamin A)	Trace (< 1 μg)	
Vitamin D	(2)	
Vitamin E[1]	26.3-59.4 mg (avg 41.6)	
α-tocopherol	11.9-25.3 mg (avg 17.1)	
γ-tocopherol	10.4-34.2 mg (avg 22.9)	
δ-tocopherol	0.58-2.50 mg (avg 1.62)	
Vitamin K	(2)	
Water-Soluble:		
B-Complex		
Vitamin B_1-Thiamine	0.99 mg	0.75 mg
Vitamin B_2-Riboflavin	0.13 mg	0.35 mg
Vitamin B_6-Pyridoxine	0.30 mg	
Vitamin B_{12}-Cyanocobalamine	(2)	
Niacin - Nicotinic Acid	12.8-16.7 mg	2.5 mg
Choline	165-174 mg	252 mg
Folic Acid	0.28 mg	
Inositol	180 mg	
Biotin	0.034 mg	
Pantothenic Acid	2.715 mg	
Vitamin C	5.8 mg	

[1]Results expressed as mg/100 g oil.[2] No evidence for presence.

SENSORY QUALITY

Sensory quality is the summation of all physical and chemical characteristics of edible peanut seed or their products that influence human senses and result in acceptability judgments by the consumer.

Color

Color of raw peanut seed is attributed to both the testa and the oil. Tannins and catechol-type compounds are responsible for the testa color. The seed color is due primarily to the oil color present. Pattee and Purcell (1967) and Pattee et al. (1969) found that the major carotenoid pigments present in oil were β-carotene and lutein. Maximum concentration of these pigments occur in the immature seed: 60 μg of β-carotene and 138 μg of lutein per liter of oil (Pattee and Purcell, 1967). The carotenoid concentration diminishes as the peanuts advance in maturity. The total carotenoid concentration in oil from mature peanuts was less than 1.0 μg per liter of oil (Pattee and Purcell, 1967).

The characteristic color of roasted peanuts is due primarily to the sugar-amino acid reactions with subsequent production of melanins (Hodge, 1953). The brown color development intensifies as temperature of roasting increases or as roasting time increases. Caramelization of sugars may contribute to brown coloration of roasted peanuts. However, sugar degradation products were found in much smaller quantities as compared to sugar amine reaction products (Mason et al., 1966). In addition, the heat of activation for sugar-amino acid reactions in model systems is lower than for caramelization reactions (Hodge, 1953). These findings indicate that Maillard type reactions are primarily responsible for the browning of roasted peanuts and Amadori rearrangements play a minor role in the coloration of heated peanut seed. Color of raw and roasted peanuts could be assessed instrumentally using the techniques of tristimulus colorimetry or reflectance spectrophotometry.

Texture

Texture plays an important role in food acceptance by the consumer. Roasted peanuts should possess a firm and crisp texture. Soft or mushy roasted peanuts will be rejected by the consumer even though they exhibit attractive color and good flavor. Instrumental techniques are available that might be used to assess the degree of crispness of roasted peanuts. These techniques are based on measuring the force required to break or crush a food material. These forces should be correlated with consumer ratings of roasted peanuts, texture to select the optimum forces reflecting consumer preference of acceptable texture. Apparent viscosities of peanut butter range from about 23 to 7 pa-s at 25C and about 9 to 3 pa-s at 40C for a moderate shear rate of 100 sec^{-1} (Hamann and Young, unpublished data).

Flavor

Roasted peanut seed are a desirable food product with a pleasant and unique flavor. Consumption of peanuts as nuts and in the manufacture of peanut butter is based on the use of roasted peanut seed. Buckholtz et al. (1980) found that roasting time had a significant influence on the strength of the odor and flavor of roasted peanuts. Pickett and Holley (1952) suggested that amino acids and carbohydrates were the precursors of roasted peanut flavor. This observation was further verified by Newell et al. (1967) who stated that some specific amino acids and monosaccharides are the precursors of roasted flavor. These authors also indicated that aspartic acid, glutamic acid, glutamine, aspargine, histidine and phenylalanine were associated with the production of typical roasted flavor while threonine, tyrosine, lysine and an unknown amino acid were considered the precursors of atypical flavor.

Monosaccharides are more reactive than sucrose in the formation of brown-

ing reactions in the presence of amino acids (Elode et al., 1966; Newell et al., 1967). Browning reactions in model systems, comprised of monosaccharides and amino acids, revealed the formation of pyrazines, pyrroles, furans and other low molecular weight products (Koehler et al., 1969; Koehler and Odell, 1970; Shaw and Berry, 1977; Shibamato and Bernard, 1977; Ledl and Severin, 1978). Mixtures of volatile components from roasted peanuts were isolated, separated and identified by physical methods. Mason et al. (1966) identified the presence of 5 pyrazines and a pyrrole among the flavor constituents of roasted spanish peanuts: methylpyrazine, 2,5-dimethylpyrazine, trimethylpyrazine, methylethylpyrazine, dimethylethylpyrazine and N-methylpyrrole. Koehler et al. (1971) identified the presence of 2-methylpyrazine (6 ppm) and dimethylpyrazine (11 ppm) among the volatile components of roasted peanuts (unidentified variety). Waller et al. (1979) identified the presence of 2,5- and 2,6-dimethylpyrazine in the volatile components of the basic fraction obtained from roasted spanish, virginia, valencia and runner type peanuts. Newell et al. (1967) postulated a mechanism for the conversion of amino acids and sugars to volatile compounds associated with peanut flavor (Figure 1). The mechanism involves the initial addition of an amino acid to the anomeric carbon atom of an aldose followed by dehydration to the 1,2-eneaminol (I) and elimination of hydroxyl ion to give the Schiff base cation (II). The Schiff base cation can undergo hydrolysis to an α-dicarbonyl compound (III) which is converted to browning pigments by a series of steps. Alternatively, the Schiff base cation could decarboxylate to the imine (IV) which would rapidly hydrolyze to yield an aldehyde and a dieneamine (V). Enolization of the 1,2 double bond and migration of the 3,4 double bond yields the unsaturated ketoamine (VI). This compound then could undergo retro-aldol condensation to yield amino acetone and glyceraldehyde. Condensation of 2 molecules of amino acetone yields 2,5-dimethylpyrazine (VII), which was one of the major pyrazine compounds found in roasted peanuts (Mason et al., 1966; Koehler et al., 1971).

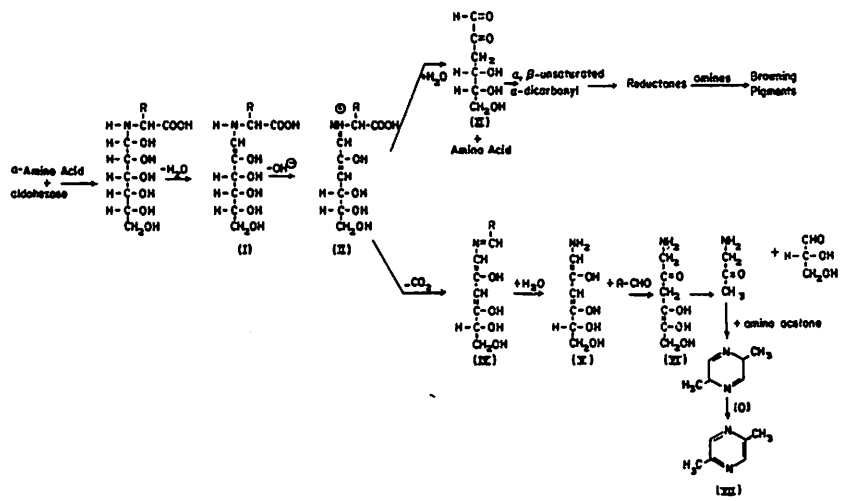

Fig. 1. Postulated mechanism for conversion of amino acids and sugars to volatile compounds. Reprinted from J. Agr. Food Chem. 15:767 (1967). Copyright 1967 by Amer. Chem. Soc.

The volatile components of roasted peanuts were extensively studied and identified by several investigators. The various components were isolated by solvent extraction, vacuum distillation and other methods; separated by thin-layer, column and gas chromatographic techniques; and identified by retention indices, mass spectroscopy and infrared and ultraviolet spectrophotometric methods. The basic fraction of the vacuum distillate of the oil expressed from roasted peanuts contained 19 alkylpyrazines compounds (Johnson et al., 1971a; Shu and Waller, 1971). Twenty-four compounds were identified in the neutral fraction of the vacuum distillate of the oil expressed from roasted spanish peanuts (Johnson et al., 1971b). The identified compounds included 7 furans, 6 pyrroles, 3 of the 2-phenyl-2-alkenals, 2 thiophenes, and some miscellaneous compounds. Carbonyl compounds present in oil cold pressed from raw and roasted runner and spanish peanuts were identified and quantified (Brown et al., 1972, 1973). Hexanal, octanal, nonanal, decanal and pentanal were the major carbonyl compounds in raw peanuts while roasted peanuts contained high concentrations of 2-methylpropanal, 2-methylbutanal and 3-methylbutanal (Brown et al., 1972, 1973). The average concentrations of carbonyls in raw and roasted runner and spanish peanuts are shown in Table 16. It is apparent from this data that total carbonyls increased 4-5 times upon roasting of the raw peanuts. It is also apparent that total carbonyls in spanish peanuts were higher than those in the runner peanuts. Brown et al. (1973) attributed these high values to the higher linoleate content of the spanish peanuts and to lower stability of the linoleate to autooxidation. Walradt et al. (1971) reported the results of an extensive study on flavor components present in the steam distillate of roasted (medium brown) spanish peanuts, Starr cultivar (Table 17). These authors identified 187 compounds; 142 of them including 17 pyrazines were reported for the first time. Ho et al. (1982) studied the volatile flavor components isolated from roasted (Neotec color reflection of 25.0 ± 0.3) runner peanuts. These investigators identified 131 components, 67 of which were reported as new to roasted peanut flavor (Table 18). The findings of Walradt et al. (1971) and Ho et al. (1982) provide valuable information on the complex nature of peanut flavor. However, they do not provide the information about which of these chemicals contribute more to roasted peanut flavor or which one correlates best with consumer perception of roasted peanut flavor. Several attempts were conducted to relate the contribution of specific volatile components to the aroma and flavor of roasted peanuts. The concentration of dimethylpyrazine in roasted peanuts was found to be 11 ppm, and the odor detection threshold levels of 2,5-dimethylpyrazine and 2,6-dimethylpyrazine in oil were 17 and 8 ppm, respectively (Koehler et al., 1971). It was suggested that monocarbonyls contribute to the overall flavor of roasted peanuts. Removal of phenylacetaldehyde and low molecular weight aldehydes from the volatile condensate of roasted peanuts resulted in the disappearance of the "bouquet" and "harsh" aroma, respectively, usually associated with the warm freshly roasted peanuts (Mason et al., 1967). Several volatile components isolated from roasted peanuts were described as contributors to "nutty" odor or a "nut-like" note, some of which are 2-crotolactone, 3-methyl-2-crotolactone, 5-hydroxy-4-nonenoic acid, pyrazines, 2-isopropyl-4,5-dimethylthiazole and 2-propyl-4,5 diethylthiazole (Ho et al., 1982). Seven oxazoles were identified in the flavor of roasted peanuts, most of them were characterized as having a green nutty aroma (Ho et al., 1982).

Table 16. Concentration of carbonyl fractions and ketoglyceride fraction in raw and medium roasted runner and spanish peanuts (μmol/100 g oil). Adapted from Brown et al., 1972 and Brown et al., 1973.

Fraction	runner		spanish	
	Raw	Roasted	Raw	Roasted
Total carbonyl	62	324	116	447
Dicarbonyl	30	198	36	261
Ketoglyceride	24	99	69	121
Monocarbonyl	8	26	10	65

Table 17. Volatile compounds identified in roasted spanish cv. Starr peanut flavor. (Walradt et al., 1971.)

	First Report in Roasted Peanut	Retention index gc-ms	Retention index Authentic
A. Pyrazines			
Pyrazine		5.87	5.87
Methylpyrazine		6.42	6.42
2,5-Dimethylpyrazine		6.86	6.86
2,6-Dimethylpyrazine		6.98	6.98
Ethylpyrazine		7.06	7.03
2,3-Dimethylpyrazine		7.18	7.18
Isopropylpyrazine	X	7.32	7.34
2-Ethyl-6-methylpyrazine		7.58	7.53
2-Ethyl-5-methylpyrazine		7.60	7.62
Trimethylpyrazine		7.73	7.73
2-Ethyl-3-methylpyrazine		7.73	7.72
Methylisopropylpyrazine	X	7.82	
Propylpyrazine	X	7.90	7.85
Vinylpyrazine	X	8.06	7.80
2-Ethyl-3,6-dimethylpyrazine		8.14	8.14
2-Ethyl-3,5-dimethylpyrazine		8.31	8.27
Methylpropylpyrazine		8.39	
Diethylpyrazine	X	8.40	
Tetramethylpyrazine	X	8.43	8.41
Isopropenylpyrazine	X	8.54	8.56
2-Methyl-6-vinylpyrazine	X	8.58	
2-Methyl-5-vinylpyrazine	X	8.63	8.63
2,3-Diethyl-5-methylpyrazine		8.65	8.60
Diethyl methylpyrazine		8.87	
Methyl propenylpyrazine	X	9.12	
Diethyl dimethylpyrazine	X	9.19	
Acetylpyrazine	X	9.94	9.92
5-Methyl-6,7-dihydro-5H-cyclopentapyrazine	X	9.95	9.94
6,7-Dihydro-5H-cyclopenta pyrazine	X	10.15	10.25
2(or 3),5-Dimethyl-6,7-di-hydro-5H-cyclopentapyrazine	X	10.42	10.34
6-Acetyl-2-methyl-pyrazine[1]	X	10.54	

	First Report in Roasted Peanut	Retention index gc-ms	Retention index Authentic
I. Phenols			
o-sec-Butylphenol	X	11.92	12.65
2,6-Di-tert-butyl-p-cresol	X	12.74	13.14
o-Methoxyphenol	X	12.71	13.46
Phenol	X	13.86	13.46
p-Ethylphenol	X	15.4	15.05
2-Methoxy-4-vinylphenol (4-vinylguaiacol)	X	16.4	15.32
4-Vinylphenol	X	17.5	16.91
J. Pyridines			
Pyridine	X	5.55	5.74
2-Methylpyridine	X	5.85	5.78
2-Pentylpyridine	X	9.45	
Methyl 2-pyridyl ketone	X	9.73	9.65
Methyl nicotinate	X	11.42	11.51
K. Ketones			
Acetone	X	1.00	1.00
2-Butanone		2.22	2.22
2-3-Butanedione	X	3.17	3.17
2-Pentanone	X	3.27	3.27
4-Methyl-2-pentanone	X	3.61	3.66
2,3-Pentanedione	X	4.13	4.16
4-Heptanone	X	4.82	
4-Methyl-3-penten-2-one		4.95	5.02
3-Penten-2-one	X	5.10	5.06
2-Heptanone	X	5.47	5.49
Cyclopentanoe	X	5.55	5.59
2-Octanone	X	6.55	6.55
Cyclohexanone	X	6.74	6.76
Cyclopentenone	X	7.27	
2-Undecanone	X	9.67	9.62
Acetophenone	X	10.17	10.18
Ethyl phenyl ketone	X	10.93	10.85
Benzyl methyl ketone	X	10.97	
2-Hydroxy-3-methyl-2-cyclopenten-1-one	X		11.71

Table 17 (continued)

5-Acetyl-2-methyl-pyrazine[1]	X	10.64	
2-Methyl-6,7-dihydro-5HX cyclo pentapyrazine		10.75	10.73
6-Acetyl-2-ethylpyrazine	X	10.99	
5,6,7,8-Tetrahydroquin-oxaline	X	11.12	11.14
Quinoxaline	X	12.64	12.70
B. Pyrroles			
1-Methylpyrrole		5.07	5.09
Pyrrole	X	8.79	8.73
Methyl 1-pyrrolyl ketone (1-acetylpyrrole)	X	8.76	9.06
2-Methylpyrrole	X	9.23	
Pyrrole-1-carboxaldehyde	X	9.60	
1-Ethylpyrrole-2-car-boxaldehyde		9.78	9.84
2-Methylpyrrole-1-car-boxaldehyde	X	9.84	
1-Methylpyrrole-2-car-boxaldehyde	X	9.85	9.86
5-Methylpyrrole-2-car-boxaldehyde		11.45	11.81
1-Furfurylpyrrole		11.88	11.89
Methyl 2-pyrrolyl ketone (2-acetyl-pyrrole)		13.26	13.69
Pyrrole-2-carboxaldehyde		13.69	13.69
2-Propionylpyrrole	X	13.52	13.66
1-Furfurylpyrrole-2-car-boxaldehyde		16.1	
C. Thiazoles			
Thiazole	X	6.08	6.07
4-Methylthiazole	X	6.53	6.55
Benzothiazole	X	12.92	12.91
p-Mentha-1,8-diene			
D. Sulfur compounds			
Methyl disulfide		4.49	4.48
Propyl disulfide	X	7.55	7.55
3-Methylthiopropionalde-hyde	X	8.22	8.14
2-Methyldihydro-2H-thi-ophen-3-one	X	9.05	9.05
Dihydro-2H-thiophen-3-one	X	9.31	9.30
Methyl 2-thienyl ketone (2-acetylthiophene)		11.36	11.37
5-Methylthiophene-2-carboxaldehyde	X	11.45	11.43
Benzyl methyl disulfide	X	13.62	13.60
E. Furans			
2-Pentylfuran		6.11	5.93
2-Furaldehyde		8.31	8.31
Furyl methyl ketone		8.71	8.71
Furfuryl alcohol acetate	X	9.05	
5-Methylfurfural		9.41	9.41
L. Aldehydes			
Acetaldehyde			0.44
Isobutyraldehyde		0.94	1.00
2-Methylbutanal		2.43	2.43
Pentanal	X	3.33	3.33
Hexanal		4.49	4.49
2-Methyl-2-butenal	X	4.61	4.61
2-Methyl-2-pentenal	X	5.31	5.34
Heptanal	X	5.51	5.55
Octanal	X	6.57	6.59
Nonanal	X	7.64	7.74
Benzaldehyde		8.97	8.96
o-Tolualdehyde	X	9.90	10.00
Phenylacetaldehyde		10.15	10.15
o-Ethylbenzaldehyde	X	10.25	10.44
p-Ethylbenzaldehyde	X	10.95	11.00
trans-2,tran-4-Decadienal		11.67	11.69
2-Phenyl-2-butenal		12.90	12.90
Cinnamaldehyde	X	14.00	14.00
5-Methyl-2-phenyl-2-hexenal		13.78	14.19
M. Terpenes			
2(10)-Pinene(β-pinene)	X	4.85	4.85
4(10)-Thujene(sabinene)	X	4.95	5.00
Myrcene	X	5.28	5.28
p-Mentha-18-dicue (limonene)	X	5.72	5.75
1-Isopropyl-4-methylben-zene-r-terpinene)	X	6.24	6.23
p-Mentha-1,4-diene (p-cymene)	X	6.45	6.45
4,8-Epoxy-p-menth-2-ene (4-herpinol)	X	9.65	9.65
p-1-Menthen-8-ol (α-terpineol)	X	10.65	10.54
p-Mentha-6,8-dien-2-one (carvone)		11.04	11.02
N. Alcohols			
Hexyl alcohol	X	7.15	7.11
3-Hexen-1-ol	X	7.45	7.35
Cyclohexanol	X	7.66	
Heptyl alcohol	X	8.01	8.00
α-Methylbenzyl alcohol	X	11.61	11.51
Benzylalcohol	X	12.32	12.32
Phenethyl alcohol	X	12.55	12.55
O. Aromatic Hydrocarbons			
Benzene	X	2.92	2.42
Toluene		4.14	4.14
Ethylbenzene	X	5.00	5.00
p-Xylene	X	5.10	5.10
m-Xylene	X	5.15	5.17
o-Xylene	X	5.60	5.61
Propylbenzene	X	5.86	5.83
Mesitylene	X	6.25	6.24
Styrene	X	6.32	6.32

Table 17 (continued)

Furoic acid, methyl ester	X	9.44	9.42	1,2,4-Trimethylbenzene	X	6.59	6.61
Furoic acid, ethyl ester	X	9.61	9.79	Butylbenzene	X	6.90	6.91
Methyl 5-methylfuryl ketone	X	10.04	9.84	Indene	X	8.61	8.61
				Methyl-2,3-dihydroinden	X	8.76	
Furfurylalcohol		10.17	10.17	1,2,3,4-Tetrahydronlene	X	9.05	
3-Phenylfuran		11.99		Naphthalene		11.12	11.12
α-Methylfuranacrolein	X	12.31	11.99	Methylnaphthalene	X	11.99	
				Ethylnaphthalene	X	13.08	
F. Esters				Dimethylnaphthalene	X	13.48	
Acetic acid, ethylester	X	2.00	2.00	Biphenyl	X	13.46	13.54
Butyric acid, ethyl ester	X	4.00	4.00	Dimethylnaphthalene (isomer)	X	13.48	
Acetic acid, butyl ester	X	4.30	4.34				
Acetic acid, isopentyl ester	X	4.87	4.86				
Acetic acid, 2-ethyoxy ethyl-ester	X	6.58		P. Miscellaneous			
				Pentane	X		
Acetic acid, phenyl ester	X	9.92		Acetaldehy,dedibutylacet	X	5.90	5.96
Acetic acid, methylphentyl ester	X	11.72	11.23	1-Chloro-2-methylbenzene	X	6.87	
				Hexadecane	X	9.71	9.72
Propionic acid, phenethyl ester	X	12.40	12.44	$C_{17}H_{36}$	X	10.72	
				Tolunitrile	X	12.80	
				Benzonitrile	X		9.70
G. Lactone							
4-Hydroxyvaleric acid, (γ-lactone)	X	9.77	9.77				
4-Hydroxybutyric acid, (γ-lactone)	X	9.96	9.96				
4-Hydroxyoctanoic acid, (γ-lactone)	X	12.82	12.88				
H. Alcohols							
Isopropyl alcohol		2.30	2.30				
Isobutyl alcohol	X	4.35	4.37				
2-Pentanol	X	4.35					
3-Pentanol	X	4.50	4.51				
Butyl alcohol		4.91	4.91				
1-Penten-3-ol	X	5.07	5.00				
4-Methyl-2-pentanol	X	5.14	5.14				
2-Methyl-1-butanol	X	5.58	5.54				
2-Hexanol	X	5.72	5.66				
Pentyl alcohol	X	6.00	6.00				

Table 18. Volatile compounds identified in roasted runner peanut flavor. (Ho et al., 1982.)

Identification	New to roasted peanut flavor	Identification	New to roasted peanut flavor
A. Aliphatic hydrocarbons		H. Pyrroles	
n-pentane		pyrrole	
isopentane	+	N-methylpyrrole	
n-nonane	+	N-ethylpyrrole	
3-methylnonane	+	2-acetylpyrrole	
4-methylnonane	+	N-methyl-2-formylpyrrole	
undecane		1,2,5-trimethylpyrrole	+
tridecane		3-methyl-4-ethylpyrrole	+
2-methyltetradecane	+		

Table 18 (continued)

4-ethyltetradecane	+	I. Pyridines	
2-methylhexadecane	+		
isobutylcyclopentane	+	pyridine	
n-hexylcyclopentane	+	2-methylpyridine	+
		3-methoxypyridine	+
B. Aromatic hydrocarbons		2-acetylpyridine	
		2-(n-pentyl)pyridine	
toluene		methyl nicotinate	
ethylbenzene		nicotinylacetone	+
p-xylene			
n-butylbenzene	+	J. Sulfides	
n-hexylbenzene	+		
n-heptylbenzene	+	2-thia-3-hexene	+
l-methylnaphthalene		5-methyl-2-thiahexane	+
		3,3-dimethyl-2-thiapentane	
C. Alcohols		propylbutylsulfide	+
		dimethyldisulfide	+
ethanol		methylpropyldisulfide	+
n-butanol		1,1-di-(methylthio)ethane	+
n-pentanol		methylbutyldisulfide	+
2,4-dimethyl-3-pentanol	+	dipropyldisulfide	
2-phenylethanol		propylbutyldisulfide	+
benzyl alcohol		di-sec-butyldisulfide	+
4-vinylphenol		dimethyltrisulfide	+
		methylethyltrisulfide	+
D. Aldehydes and Ketones		dipropyltrisulfide	+
		dibutyltrisulfide	+
isobutylaldehyde			
benzaldehyde		K. Thiazoles	
2-hexanone			
4-methyl-3-penten-2-one		2-methylthiazole	+
cyclopentanone		4-methylthiazole	+
2-methylcyclopentanone	+	5-methylthiazole	+
acetophenone		5-butylthiazole	+
		2-isopropyl-4,5-dimethylthiazole	+
E. Acids		4-butyl-2,5-dimethylthiazole	+
		2-propyl-4,5-diethylthiazole	+
isobutanoic acid		2,4-dimethyl-5-ethylthiazole	+
propionic acid			
pentanoic acid		L. Thiophenes	
2-methylbutanoic acid	+		
2,2-dimethyl-3-butenoic acid	+	2-ethylthiophene	+
		2-acetylthiophene	
F. Esters and Lactones		2-acetyltetrahydrothiophene	+
methyl acetate	+	M. Furans	
ethyl acetate			
trimethyl orthoacetate	+	furfural	
γ-butyrolactone		furfuryl alcohol	
γ-crotolactone	+	2-methyl-3(2H) furanone	+
3-methyl-γ-butyrolactone	+	5-methyl-3(2H) furanone	+
3-methyl-γ-crotolactone	+	2-methyltetrahydrofuran-3-one	
5-hydroxypentanoic acid, lactone	+	3-hydroxy-2-methyltetrahydrofuran	+
5-hydroxy-4-nonenic acid, lactone	+	2-acetyl-5-methylfuran	
		5-methylfurfuryl alcohol	3
G. Pyrazines		2-acetylfuran	
		2-(n-butyl)furan	
pyrazine		2-(n-pentyl)furan	+
methylpyrazine			

Table 18 (continued)

2,3-dimethylpyrazine		N. Oxazoles and Oxazolines	
2,5-dimethylpyrazine			
2,6-dimethylpyrazine		4,5-dimethyloxazole	
2-acetylpyrazine		2,4,5-trimethyloxazole	
trimethylpyrazine		2-acetyloxazole	+
2-methyl-5-ethylpyrazine		2-methyl-5-propyloxazole	+
isopropylpyrazine		2-pentyloxazole	+
2-methyl-5-vinylpyrazine		2-ethyl-5-butyloxazole	+
2,3-dimethyl-5-ethylpyrazine		2,4-diethyl-5-propyloxazole	+
2,5-dimethyl-3-ethylpyrazine		2-methyl-3-oxazoline	+
2,5-dimethyl-3-vinylpyrazine	+	2,4-dimethyl-3-oxazoline	+
2,5-dimethyl-3-propylpyrazine	+	2,4,5-trimethyl-3-oxazoline	+
2,5-dimethyl-3-isopropylpyrazine	+		
2-methyl-5,6-diethylpyrazine	+	O. Miscellaneous	
2-methyl-6-propenylpyrazine			
2-methyl-6,7-dihydro-5H-cyclo-pentapyrazine		2-acetoxy-2-butene	+
		maltol	+
5-methyl-6,7-dihydro-5H-cyclo-pentapyrazine			
3,5-dimethyl-6,7-dihydro-5H-cyclo-pentapyrazine	+		
5,6,7,8-tetrahydroquinoxaline			

Sensory flavor evaluation relies on the use of human subjects as the detectors of sensors of food flavor. For roasted peanuts, the Quality Committee of APREA (1971) has adopted the CLER flavor score method. In this procedure, 20 roasted half-seed are tasted individually and a score is assigned to each seed. The total of these scores will represent the treatment flavor score. Tiemstra (1973) pointed out the disadvantages of this method: a) a panelist's perception saturation point may be reached often before 1 treatment is evaluated, thus only a limited number of treatments can be tasted at 1 sitting; b) sampling becomes an acute problem since the number of "bad" seed in a lot may be fairly small, and the incidence of their occurrence in samples submitted to the panel judges may be quite variable; and c) the standard deviation between samples rated on a 100 basis (using 5, 4, 2, 0 rating scale) was 10; thus a significant difference exists between samples if 5 people were asked to run each sample in duplicate, and the average difference between the 2 lots is 6 or greater.

It is suggested to use the standardized sensory methodology used for other food products to evaluate the flavor or other sensory quality parameter of roasted peanuts. Such methodology is outlined in several publications (Amerine et al., 1965; ASTM, 1968; Rodriguez, 1976; Larmond, 1977).

Wholesomeness

Raw and roasted peanuts have to be free of foreign material, unadulterated with toxic or noxious substances such as pesticides and mycotoxins, not infested with insects or rodents, and free of spoilage and pathogenic microorganisms (Tiemstra, 1973). The Food and Drug Administration (1969) issued guidelines for food manufacturers who produce wholesome food items including peanuts and peanut products. The "Official Methods of the AOAC" gives methods (36.020 to 36.024) for the determination of adulterants in foods. The Food and Drug Administration (Federal Register 37, No. 62, March 30, 1972) published guideline limits for insects, insect parts, rodent hairs and water-insoluble inorganic residue in peanuts and peanut products. The USDA has established standards for domestically produced peanuts (1956, 1959a,b).

NUTRITIONAL QUALITY

Peanut seed contain relatively large quantities of protein (25-34%) and oil (44-56%) and have high energy value (average 564 calories/100 g seed), as compiled by Cobb and Johnson (1973).

Protein

There is a growing demand throughout the world for more protein supplies and for balanced dietary sources of protein. Since peanuts are a rich source of protein, a considerable interest was developed to determine their amino acid composition, with special attention to the essential amino acids.

The limiting amino acids of blanched but unroasted peanut and roasted peanut protein were lysine, threonine and methionine (McOsker, 1962; Pancholy et al., 1978). Roasting was accomplished by heating peanut seed to an end point temperature of 170 C. Roasting caused a decrease in the amount of lysine, threonine and methionine in the order of 15, 11 and 10% of the total, respectively. A feed efficiency equal to or better than that of a 15% casein diet could be obtained by supplementing roasted peanut protein with at least 0.31% of L-lysine, 0.19% of DL-threonine and 0.21% of DL-methionine (McOsker, 1962).

Young et al. (1973) compared the amino acid content to 16 cultivars of peanuts with FAO (1965) recommended levels. They concluded that in addition to lysine, methionine and threonine, isoleucine and valine might also be limiting. Conkerton et al. (1978) found new white-testa peanut genotypes contain relatively larger amounts of the sulfur-containing amino acids— methionine and 1/2-cystine 2.5-2.7 g/16 g N. Recently, Basha and Pancholy (1981b) isolated a methionine-rich polypeptide from peanut seed containing 2.9 g methionine and 10.7 g 1/2-cystine per 100 g protein.

The nutritional quality of peanut meals prepared from Virginia 56-R peanuts that were wet and dry heated at different temperatures was determined (Neucere et al., 1972). Total amino acid composition of the total proteins was not affected by the heat treatments. Rat feeding studies were conducted using diets containing 10% protein. The highest rat body weight, available lysine, and protein efficiency ratio (PER) values occurred for peanut seeds wet heated at 110 C and dry heated at 120 C (Table 19). Casein was used as the reference protein and its PER was 2.50 as compared to 1.81 and 1.94 for the wet- and dry-heated seeds, respectively. Heating peanut seeds at 145 and 155 C resulted in peanut meals with lower PER values than other heat treatments and unheated seeds (Table 19).

Methods used to assess the nutritional quality of a protein, whether evaluated by the slope-ratio technique (Hegsted et al., 1972) or by protein efficiency ratio (PER) (Neucere et al., 1972), assess the growth promoting effects of pro-

Table 19. Effect of wet and dry heat on nutritional quality of peanut meals. (Neucere et al., 1972.)

Heat treatment, C	Body weight, g[1]	Digestibility[2]	PER[3]	AVL[4]
None	99.0 ± 7.3[5]	93.7	1.41	1.95
110 wet heat	112.6 ± 16.8	94.8	1.81	3.08
120	103.6 ± 12.6	94.9	1.55	2.78
130	107.0 ± 19.1	94.6	1.54	2.40
145	91.0 ± 5.1	94.7	1.25	2.03
155	86.4 ± 8.2	95.0	1.09	2.03
110 dry heat	100.6 ± 13.3	94.4	1.50	2.48
120	128.4 ± 16.1	93.6	1.94	3.08
130	106.0 ± 10.5	94.9	1.64	2.63
145	88.2 ± 7.7	94.8	1.23	2.33
155	84.2 ± 7.9	94.3	1.00	2.18
Casein	140.6 ± 21.9	96.1	2.50	

[1]Initial weight 56.5 g.
[2]Feed intake minus moisture-free fecal weight divided by feed intake x 100 for 1 week.
[3]Body weight gain (g) per g protein eaten, 10% protein diet.
[4]Determined as E-DNP-L-Lysine percent in protein.
[5]Standard deviation.

teins present in the diet in growth limiting concentrations. Carpenter and Muelenaere (1965) concluded that, under certain conditions, higher levels of poor proteins would result in nearly as good growth as with practical diets containing good-quality proteins. The nutritional quality of peanut protein is considered low since some of its essential amino acids are present in suboptimum amounts in comparison to good quality proteins such as casein. Miller and Young (1977), in their extensive study of the nutritional quality of defatted peanut meal prepared from Florunner peanuts, found that growth of rats fed 16.7% peanut protein was essentially equivalent to that of animals fed 12% to 24% casein protein (Figure 2). In addition, Miller et al. (1978) found that a concentration of 16% peanut protein resulted in a better growth in weanling rats than 12% protein in all peanut cultivars tested. Increasing protein to 20% of the diet further improved growth of rats fed meal prepared from some, but not all, cultivars of peanuts. These authors concluded that peanut meal is potentially a good source of protein for animal production if the peanuts and meal are properly handled after harvest to maintain the nutritional quality of the product.

Werle (1969), Neucere et al. (1972), Camuse et al. (1973) and Ellenrieder et al. (1980) reported the presence of trypsin inhibitors in peanut meal, soybean meal, hard and soft wheats and kidney bean meal. Trypsin inhibitors could be inactivated by heat treatments or enzymatic treatment of the seeds. The tryptic proteolysis of peanut meal was increased by either roasting or by treatment of the peanut seed with pepsin prior to preparation of the meal (Camus et al., 1973). The tryptic proteolysis of peanut seed resulted in a meal which had a higher proteolysis rate, approaching those found for animal proteins, than other vegetable proteins (Camus et al., 1973). Heat treatment resulted in the inactivation of tryspin inhibitors in peanut and soybean and other legumes (Werle, 1969; Neucere et al., 1972; Ellenrieder et al., 1980). Wet heat is more effective than dry heat in inactivating the trypsin inhibitor found in peanuts (Neucere et al., 1972). Inactivation of the trypsin inhibitor in peanuts occurred at a wet heat with a temperature of 110 C treatment and at 130 C dry heat treatment. Neucere et al. (1972) stated that there is no correlation between trypsin inhibitor activity and protein quality in the dry heated peanuts since highest PER value occurred at 120 C and inactivation occurred at 130 C. They also stated that for wet heat treatment, the loss of nutritional quality of peanut protein is directly related to heat since the inhibitor is inactivated at 110 C.

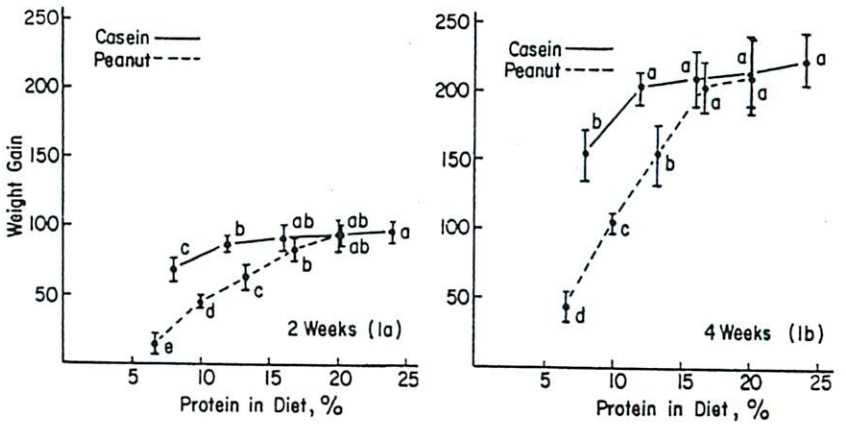

Fig. 2. Weight gain of rats fed several dietary concentrations of either defattd peanut meal or casein as a protein source for (a) 2 weeks or (b) 4 weeks. The vertical lines above and below each point represent ± 1 standard deviation of the mean. The lowercase letters following each point indicate statistical difference of means according to Duncan's (1955) multiple range test. Means not followed by a common letter are different at $P<0.05$. Reprinted with permission from J. Agr. Food Chem. 25:653 (1977). Copyright 1977 by Amer. Chem. Soc.

The essential amino acid content of peanut cultivars (Young et al., 1973), the white testa breeding line WP-3 (Conkerton et al., 1978), and the methionine-rich polypeptide in peanut seed (Basha and Pancholy, 1981b) exceed the recommended dietary allowances (RDA) (1980), assuming 100 g of peanut protein will be consumed by 70 kg man (Table 20). Some of the essential amino acids in peanuts are present in amounts less than the pattern for high quality protein, weight for weight basis. However, 200 g of peanut protein will supply the adult man with essential amino acids at least equivalent to 100 g of the suggested high quality protein (Table 20). Unfortunately, tryptophan was not determined for the peanut cultivars and breeding line mentioned in Table 20; however, it was found that the amount of tryptophan in Nigerian peanuts ranged from 1.58 to 1.82/16 g N (Mba et al., 1974), from 1.05 to 1.41 g/100 g protein in commercially grown American peanuts (Amaya-Farfan et al., 1977) and from 0.85 to 1.66 g/100 g protein in South American wild types of peanuts (Amaya-Farfan et al., 1977). Thus these peanuts are richer sources for tryptophan than the suggested high quality protein.

Table 20. Essential amino acid requirements of man and EAA contents in peanuts. Adapted from recommended dietary allowances, 1980; Young et al., 1973; Conkerton et al., 1978; Basha and Pancholy, 1981b.)

Amino Acid	Requirement mg/kg body weight/day Infant 4-6 mo	Child 10-12 yr	Adult --	Pattern for high quality protein mg/protein	Peanuts (mg/g protein) Methionine-rich Red testa	White-testa	polypeptide
Histidine	33	?	?	17	26	19	16
Isoleucine	83	28	12	42	25	16	18
Leucine	135	42	16	70	62	57	62
Lysine	99	44	12	51	37	26	24
Total S-containing	49	22	10	26	36	27	137
Total aromatic	141	22	16	73	87	85	50
Threonine	68	28	8	35	24	20	17
Tryptophan	21	4	3	11	-	-	-
Valine	92	25	14	48	32	23	17

[1]Tryptophan not determined.

Oil

Peanut oil contains about 80% unsaturated fatty acids with more of oleic acid (47%) than linoleic acid (33.2%) as reported by Carpenter et al. (1976). These authors calculated the ratio of the sum of all polyunsaturated fatty acids to the sum of all saturated acids (P/S) for several commercial oil samples. The P/S ratio for peanut oil was 1.8 as compared to 2.9 for soybean oil, 4.3 for corn oil and 8.7 for safflower oil. These oils contained more polyunsaturated fatty acids (principally linoleic acid) than peanut oil. The contents of linoleic acid and other polyunsaturates are inversely proprotional to the keeping quality of an oil. Accordingly, peanut oil has a better keeping quality than soybean, corn and safflower oils. Sometimes, the ratio of the content of linoleic acid to the sum of palmitic and stearic acids (L/P + S) is used instead of the P/S ratio as an indicator of dietary value of the oil. The L/P + S ratios for peanut oil and soybean oil were 2.6 and 2.7, respectively (Carpenter et al., 1976). The corresponding ratios were 4.3 for corn oil and 9.1 for safflower oil.

The primary dietary essential fatty acid for man is linoleic acid. The amount of dietary linoleic acid found to prevent both biochemical and clinical evidence of deficiency in several animal species and also in man is 1-2% of dietary calories. This requirement is more than adequately satisfied by the relatively high intake of vegetable oils in the USA. The USDA estimates that about 23 g of linoleic acid, about 6% of total dietary energy, are available per person per day in the current USA food supply (Rizek et al., 1974). The Committee on Dietary Allowances (1980) believes that, in view of the possible hazards of high intakes of polyunsaturated oils (FAO, 1977), an upper limit of 10% of dietary energy as polyunsaturated fatty acids is advisable. Peanut oil, due to its lower linoleic acid content (33.2% of total fatty acids) than corn oil (58%), safflower oil (79.5%) or mixtures of soybean oil and cottonseed oil (46.7%), as reported by Carpenter et al. (1976), satisfies the recommendation of the Committee on Dietary Allowances.

Harris and Embree (1963) suggested that the ratio of α-tocopherol to polyunsaturated fatty acids could be used as a measure of the adequacy of dietary

vitamin E and that ratio should be 0.6 or higher. Of the 14 oils evaluated by Carpenter et al. (1976), only peanut, safflower and olive oils had the recommended ratios of 0.6 or higher (Table 21). Soybean, soybean-cottonseed and corn oil, which constitute the bulk of oils consumed in the USA, had ratios much lower than 0.6. Recently, a ratio of 0.2 was suggested to be a satisfactory indicator of vitamin E adequacy (Bieri and Evarts, 1973). Accordingly, most of the oils shown in Table 21 are good sources of vitamin E, with the exception of apricot kernel oil and 2 of the soybean oils.

Table 21. Tocopherol composition and alpha tocopherol to polyunsaturated fatty acid (PUFA) ratios. (Carpenter et al., 1976.)

Brand[a]	Tocopherols alpha (mg/kg)	gamma (mg/kg)	Alpha-T delta (mg/kg)	PUFA (mg/g)
Wesson SBO/CSO	13	63	20	0.26
Nu-Made SBO/CSO	11	81	18	0.23
Giant SBO	10	80	22	0.23
Crisco SBO	14	102	37	0.36
Kraft SBO	5	42	11	0.13
Hollywood SBO	9	68	23	0.15
Ann Page CO	12	46	4	0.23
Nu-Made CO	22	66	5	0.38
Mazola CO	18	75	-	0.30
Saffola SFO	48	-	-	0.61
Hollywood SFO	60	-	-	0.75
Planters PO	21	15	-	0.63
Progresso OO	14	-	-	2.26
Golden Harvest AKO	1	17	2	0.03

[1]Soybean oil = SBO; Cottonseed oil = CSO; Corn oil = CO; Safflower oil = SFO; Peanut oil = PO; Olive oil = OO; Apricot kernel oil = AKO.

Weanling rats fed for 8 weeks with 20% protein diets containing 5, 10, 20 or 40% peanut oil showed increased deposition of cholesterol in the animal's liver as the dietary fat level increased (Landes and Miller, 1974). However, the serum cholesterol levels remained constant. Lipid accumulated in the animal's livers receiving the 20 and 40% oil diets, with this accumulation occurring in the "neutral" and "cephalin" fractions of the liver lipid (Landes and Miller, 1974). These authors did not include other oilseed oils in comparison with peanut oil in their study. No differences were observed when used frying oils (peanut or soybean) were fed to rats in the same amount and over the same period as compared to the unheated oils. The concentration of plasma lipids, including total cholesterol content, electrophoretic patterns of plasma lipoproteins and the fatty acid composition of plasma lipids and adipose tissue, were similar in both the heated and nonheated oil (Fuehr et al., 1975). Kritchevsky et al. (1973) concluded that the triglyceride structure of a fat, as well as its fatty acid composition, are determining factors in its atherogenic potency. Peanut oil was more atherogenic than corn oil when fed to rabbits in a diet containing 2% cholesterol and 6% oil. The average atheromata (arch plus thoracic/2) was 1.59 for peanut oil and 1.20 for corn oil (Kritchevsky et al., 1973). Data presented by Landes and Miller (1974) and Kritchevsky et al. (1973) lack adequate proof to substantiate their findings, due either to lack of inclusion of oth-

er vegetable oils for comparison reasons or lack of adequate data for a sound statistical treatment.

Carbohydrates

Carbohydrates and fats are the dominant sources of food energy. Peanuts contain about 20% carbohydrate and 50% oil, so they are an excellent source of food energy; 100 g of peanut seed contribute 585 calories.

Minerals and Vitamins

The mineral content of raw and roasted peanut kernels (Table 14) does not meet the RDA requirements (1980). However, the vitamin E content of peanuts (Table 15) exceeds the RDA requirements, and there are adequate amounts of thiamine, niacin and folic acid in peanuts to approach the recommendations of the RDA (1980).

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Chapter 18

POTENTIAL FOOD USES OF PEANUT SEED PROTEINS

KAY H. MCWATTERS AND JOHN P. CHERRY

Peanut-containing foods such as peanut butter, salted seed, candies, and snack-type crackers and cookies enjoy widespread popularity because of their unique roasted peanut flavor. On a worldwide scale, however, peanuts are grown primarily for the seed oil which is favored for cooking and as a salad oil. Oil extraction also produces a protein-rich coproduct which may be used for human consumption if processed from edible-grade peanuts and by commercially accepted food processes. This material is available as flakes, grits, or flours and may be further processed to high protein concentrates and isolates. These products contribute to the physicochemical, functional, and nutritional characteristics of foods in which they are incorporated.

PHYSICOCHEMICAL PROPERTIES

Extraction and Fractionation

Because their potential as food supplements has been known for many years, peanut seed proteins have been the subject of numerous investigations. These studies date back to Ritthausen (1880) who showed that proteins in peanut seed meal could be extracted with various salt and alkaline solutions and precipitated by dilution with water, or by adjusting the protein-containing extract to an acid pH. Water and various salt solutions were used to selectively isolate albumins and globulins, respectively, from peanut seed by Lichnikov (1913). By extracting defatted peanut meal with NaCl solution and precipitating the solubilized proteins with various percentages of $(NH_4)_2SO_4$, Johns and Jones (1916) were able to isolate 2 major globulins, arachin and conarachin. These names are still used today to describe these proteins. Arachin was precipitated from a 10% NaCl extract by dilution with water, by making the salt extract 20% saturated with $(NH_4)_2SO_4$, or by saturating the salt extract with CO_2. Conarachin was precipitated by dialyzing the filtrate from the arachin precipitate against water, or by saturating it with $(NH_4)_2SO_4$. Jones and Horn (1930) studied the chemical composition, precipitation properties with $(NH_4)_2SO_4$, specific rotation, and coagulation temperature of arachin and conarachin. These authors showed that conarachin content was about a third that of the arachin, and that these proteins amounted to 8 and 25%, respectively, of defatted peanut seed.

Between 1935 and 1950, different versions of the techniques that use salt and various pH and ionic strength solutions were studied to confirm the earlier results, prepare optimum quantities of highly purified globulins, and determine certain of the physical and chemical properties of the isolated proteins.