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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.

The highlights of these studies have been summarized in a review by St. Angelo and Mann (1973). These studies showed that arachin, precipitated by dilution from a NaCl solution and then acidified, produced during ultracentrifugation 2 sedimenting components that had sedimentation coefficients (S_{20}) of 14.6 S and 9.5 S. It was also shown that only the 14.6 S protein or arachin was precipitated out of the NaCl solution with 0.20 ionic strength $(NH_4)_2SO_4$. These data suggested that, under certain extracting conditions, the parent molecule of arachin, molecular weight 330,000, dissociates into 2 half-molecules each having molecular weight 180,000.

The development of newer techniques to isolate, fractionate and characterize proteins brought on a second series of investigations on peanut seed proteins. In general, these studies confirmed the earlier investigations that most of the proteins of peanut seed are easily extractable (Altschul et al., 1961, 1964a,b; Dechary et al., 1961; Dechary and Altschul, 1966; Dawson, 1971) and can be separated into 2 major fractions, arachin and conarachin (Dechary et al., 1961; Evans et al., 1962; Daussant et al., 1969a,b). More extensive purification of these 2 fractions (Evans et al., 1962; Tombs, 1965; Tombs and Lowe, 1967; Neucere, 1969; Dawson, 1971; Singh and Dieckert, 1973a,b; Cherry et al., 1973; Cherry and Ory, 1973; Shetty and Rao, 1974; Basha and Cherry, 1976) has revealed that they are composed of complex large molecular weight globulins (labeled in the pure form as α-arachin, α-conarachin), plus some closely related compounds not completely separated by the usual techniques.

The complexity of the proteins in $NaH_2PO_4 \cdot H_20\text{-}Na_2HPO_4$ buffer (pH 7.9; I = 0.01) extracts of peanut seed is summarized in the DEAE-cellulose chromatographic and polyacrylamide gel electrophoretic patterns of Figures 1 and 2 (Cherry et al., 1973). This total extract contains albumins (Fraction I) and a mixture of globulins (Fractions II, III , and IV) that can be assigned to the 2 classical groups of proteins, α-arachin (Fraction IV--insoluble after dialysis against 0.9% NaCl or precipitated by 40% $[NH_4]_2SO_4$) and conarachin (Fraction I + II + III--soluble after dialysis against 0.9% NaCl or precipitated by 85% $[NH_4]_2SO_4$ after removal of α-arachin) (Dechary et al., 1961; Cherry et al., 1973). The conarachin can be separated by DEAE-cellulose chromatog- II + raphy into 3 groups including Fraction I (albumins), Fraction II + III (heterogeneous globulin and enzyme mixture), and Fraction III (α-conarachin). Further chromatography of Fraction IV (α-arachin) yields Fractions V and VI. An α-arachin with similar properties as Fraction IV can also be fractionated from the other proteins of peanut seed by cryoprecipitation at 2 C (Neucere, 1969).

Gel electrophoresis of DEAE-cellulose chromatographed α-arachin showed an increased number of bands in 0-2.0 cm region and 3.5-5.0 cm region compared to the pattern exhibited by arachin prior to chromatography (Figure 2; Cherry et al., 1973). This change in gel patterns became more evident upon further DEAE-cellulose chromatographic purification of α-arachin (Fraction IV) into Fraction V and VI. An increased number of smaller proteins was observed in the lower half of the gel for Fraction VI. Also, the large molecular weight proteins in region 0-3.0 cm were further dissociated into distinct major and minor bands. The minor protein band in region 3.0-3.5 cm of Fraction IV

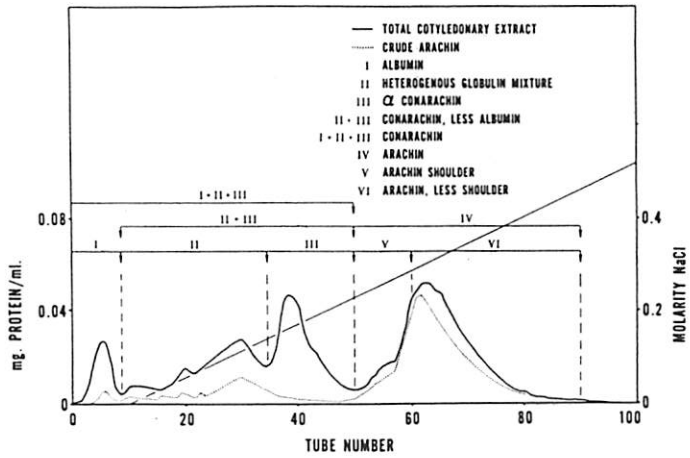

Fig. 1. Chromatographic elution patterns of peanut seed proteins fractionated on DEAE-cellulose. The straight line indicates the NaCl gradient from 0 to 0.5 M. Reprinted from J. Agric. Food Chem. 21:652 (1973). Copyright 1973 by Amer. Chem. Soc.

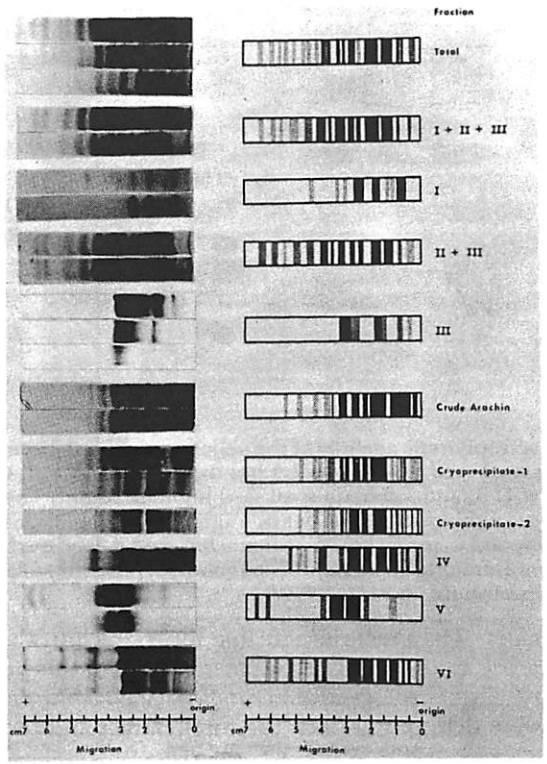

Fig. 2. Polyacrylamide gel electrophoretic and diagramatic patterns of peanut seed proteins fractionated on DEAE-cellulose and by cryoprecipitation. Identification of fractions is shown in Figure 1. Reprinted from J. Agric. Food Chem. 21:652 (1973). Copyright 1973 by Amer. Chem. Soc.

was greater in Fraction V but was absent in Fraction VI. Proteins in region 2.5-3.0 cm were common to all 3 fractions.

Immunoelectrophoretic analysis of 4 DEAE-cellulose fractionated groups of peanut seed proteins, albumins, a heterogeneous protein fraction, α-conarachin, and α-arachin (Dechary et al., 1961; Cherry et al., 1973) showed that at least 14 antigenic proteins could be detected with immune serum made against a total extract of peanut cotyledons (Figure 3; Daussant et al., 1969a; Neucere, 1977). The α-arachin fraction contained 1 major component and 3

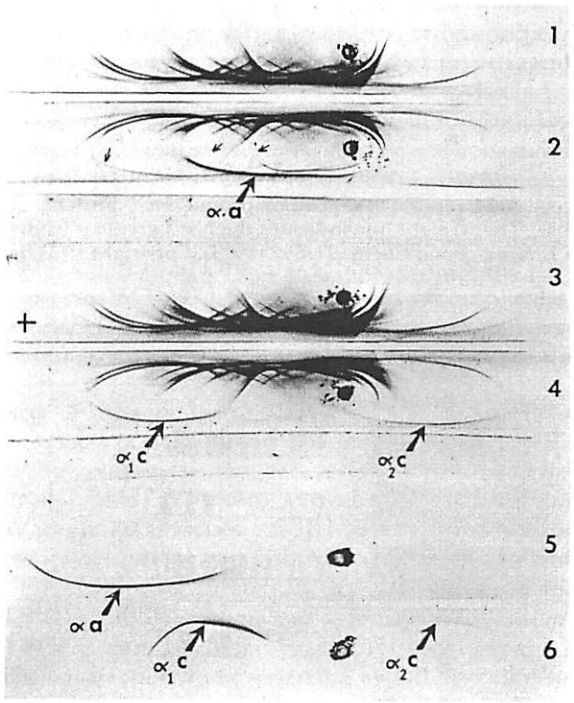

Fig. 3. Immunoelectrophoretic analysis of the major peanut seed proteins. Wells 1,2,3, and 4 contain total seed extracts, well 5 has α-arachin, and well 6, α-conarachin. Troughs below 1, 3, and 5 contain total seed immune serum. The trough below 2 contains anti-α-arachin and the one below 4 anti-α-conarachin. The labels α-a, α_1-c, and α_2-c correspond to α-arachin, α_1-conarachin, and α_2-conarachin, respectively. Reprinted from Immunological Aspects of Foods, N. Catsimpoolas, ed. Copyright 1977 by AVI Publishing Co., Inc.

minor contaminants. The precipitation line for α-arachin was an elongated double arc indicating the presence of polymeric forms of this protein with the same antigenicity. Two serologically distinct α-conarachin proteins (α_1-and α_2-conarachin) were detected in both the total extract and the purified fraction.

Purification of arachin and conarachin by DEAE-cellulose chromatography, then analysis by polyacrylamide or immuno-gel electrophoresis (Tombs, 1963, 1965; Tombs and Lowe, 1967; Dawson, 1971) demonstrates the com-

plexity of the different proteins in peanut seeds. Both α-arachin and α-conarachin are shifted in mobility; i.e., α-arachin, instead of moving toward the cathodic pole, migrated to the anodic pole, and α-conarachin, vice versa. Chromatography of arachin and conarachin over DEAE-cellulose apparently either allows proteolysis to occur, or the chromatographic process itself alters the surface charge(s) of the intact molecules, resulting in a gradual release or fragmentation of subunits and/or molecular reorientation. These factors could account for the variations in gel electrophoretic patterns of total protein extracts compared to the corresponding proteins in separated or purified fractions. Solubilizing the chromatographically separated proteins of peanut seed (Cherry et al., 1973) in the presence of thiol-reducing reagents (dithiothreitol, β-mercaptoethanol) and then examining them by polyacrylamide gel electrophoresis also produced significant changes in their mobilities when compared to those that were untreated (Cherry and Ory, 1973). Frozen storage altered the solubility characteristics and electrophoretic patterns of these proteins, especially when the samples contained high concentrations of a reducing reagent. Thiol-reducing compounds and/or frozen storage promote many *in vitro* changes (e.g., molecular weight, conformation, structural, steric hindrance, and functionality) in these constituents.

Different amounts of protein can be recovered from defatted peanut meal depending on the type and amount of extraction medium used (Figure 4; Basha and Cherry, 1976). The ratio of meal to extracting medium was important in determining the amount of soluble protein recovered. Protein recovery im-

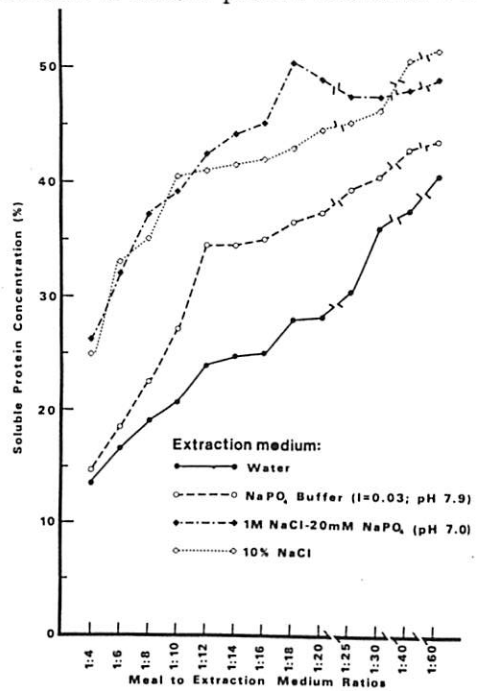

Fig. 4. Percentage protein of fat-free meal solubilized relative to various ratios of meal and different extraction media (1:4-1:60, w/v). Reprinted from J. Agric. Food Chem. 24:359 (1976). Copyright 1976 by Amer. Chem. Soc.

proved with increasing volumes of water, $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer (I = 0.03; pH 7.9), or 10% NaCl, but maximum solubilization of 95% of the protein in the meal was achieved with 1 M NaCl-20 mM $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer (pH 7.0) at a ratio of 1:18. Gel electrophoresis showed that

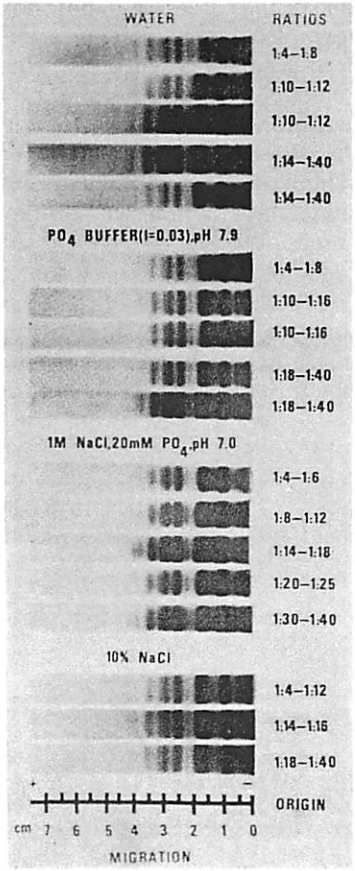

Fig. 5. Polyacrylamide disc gel electrophoretic patterns of proteins solublized in extracts of various ratios of fat-free meal and different extraction media. Some gel patterns containing two levels of protein from various extraction ratios are shown for clarity of all possible bands. Reprinted from J. Agric. Chem. 24:359 (1976). Copyright 1976 by Amer. Chem. Soc.

only the 1 M NaCl-20 mM $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer uniformly solubilized the proteins both quantitatively and qualitatively, regardless of the meal to extraction ratio (Figure 5); select bands appeared quantitatively lower in gel patterns of the more dilute preparations.

Solubility properties varied among proteins prepared with different extraction media (Figure 6; Basha and Cherry, 1976). Proteins from extraction media containing NaCl had isoelectric points between pH 3.0 and 3.5, while those of $NaH_2PO_4 \cdot H_2O$-Na_2PO_4 buffer and water were approximately pH 4.5 and 5.0, respectively. The protein solubility levels at these isoelectric points differed, being approximately 1.3, 1.2, 0.6, and < 0.1 mg/ml for me-

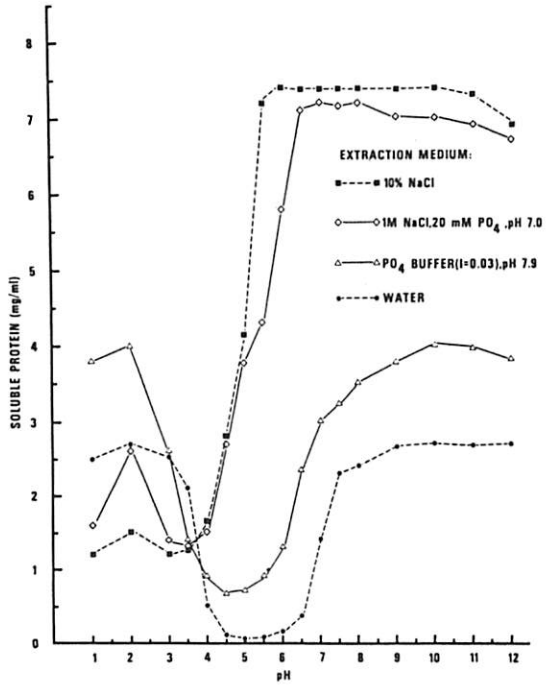

Fig. 6. The influence of pH and extraction medium on the solubility of peanut seed proteins. Reprinted from J. Agric. Food Chem. 24:359 (1976). Copyright 1976 by Amer. Chem. Soc.

dia containing 1 M NaCl-20 mM $NaH_2PO_4 \cdot H_2O$-Na_2PO_4 buffer, 10% NaCl, $NaH_2PO_4 \cdot H_2O$-Na_2PO_4 buffer and water, respectively.

Protein levels in extraction media containing NaCl increased from 1.3 to 7.5 mg/ml between pH 3.5 and 6.5. Proteins were most soluble in water and $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer at above pH 9.0 and 10.0, respectively. At pH 2.0, solubilities of protein in all extraction media were higher than at the isoelectric point, but solubility decreased again at pH 1.0. The highest solubility in the acid pH range was noted for the proteins extracted with $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer.

Characterization

Tombs (1965) classified the principle components of α-conarachin and α-arachin on the basis of their behavior in agar and polyacrylamide gels as follows (Figure 7):

(1) Region δ--2 components of high molecular weights (>500,000) that are high polymers of α-arachin.
(2) Region γ-- contains most of the monomer and dimer α-arachin components, and a component believed to be α-conarachin.
(3) Region β-- yellow-colored α-conarachin compounds.
(4) Region α-- low molecular weight (<30,000) subunits of α-arachin.

α-Arachin was shown to contain 4 different kinds of polypeptide chains (α, β,

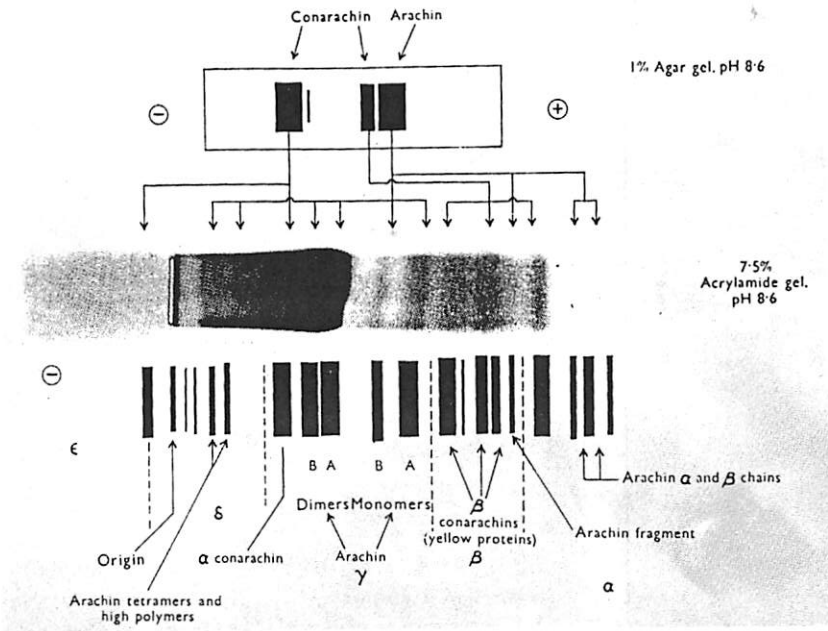

Fig. 7. Electrophoretic classification of groundnut proteins. At the top is the result of agar-gel electrophoresis; these zones are connected to the zones corresponding to α-arachin and α-conarachin in the acrylamide gel shown below. Below this is shown a diagram of the gel, for clarity, with identification of some of the components. The gel has been split into five areas; α, β, δ, and ε. Reprinted from Biochem. J. 96:119 (1965). Copyright 1965 by Biochem. Soc.

γ, and δ). Further studies by Tombs (1965) showed the presence, in certain seed, of a variant form B of α-arachin which contained only β, γ, and δ chains.

The structure of α-arachin was postulated to be composed of 4α, 4β, 2γ, and 2δ polypeptides; α-arachin B did not have the 4 α chains. The α and β chains have molecular weights of about 35,000, and the γ and δ chains are about 10,000; the molecular weight of α-arachin totaled approximately 320,000. Further experiments by gel electrophoresis showed that α-arachin dissociated into fragments when exposed to 8 M urea that appeared to be dimers of the type α-S-S-β, and β-S-S-β, held together by disulfide bonds (Tombs and Lowe, 1967).

Singh and Dieckert (1973a) demonstrated with sodium dodecyl sulfate-polyacrylamide gel electrophoresis that an arachin-P6 isolated from a 10% NaCl extract of fat-free peanut meal by a method that included steps of slow heating at 85 C, dilution with water, and saturation with $(NH_4)_2SO_4$ to 40% (Singh and Dieckert, 1973b) contained 9 types of subunits (Figure 8). The subunits ranged in molecular weight from 15,069 to 43,104 (Table 1). This observation was qualitatively comparable to the results of electrophoresis of arachin-P6 in the presence of 8 M urea. These results are in contrast to those of Tombs and Lowe (1967), who observed only 4 types of subunits; Singh and Dieckert (1973a) indicated that their arachin-P6 was similar to the major α-arachin component isolated by Tombs and Lowe (1967).

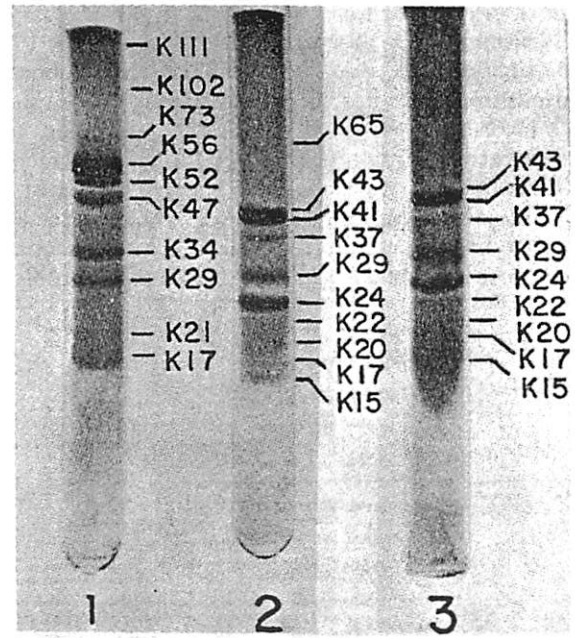

Fig. 8. Pattern of SDS-PAGE of arachin-P6 in a pH 7.1, 0.01 M sodium phosphate buffer containing 0.1% SDS (gel 1), 0.1% SDS and 0.1% β-mercaptoethanol (gel 2) or 1% SDS and 1% β-mercaptoethanol (gel 3). Direction of migration, top (-) to bottom (+). Reprinted from Prep. Biochem. 3:73 (1973). Copyright 1973 by Marcel Dekker, Inc.

Table 1. Molecular weights of subunits of arachin-P6. (Singh and Dieckert, 1973b.)

Subunit[a]	Molecular Weight[a]	Subunit[d]	Molecular Weight[b]
K17	17,125 ± 1.7%	K15	15,069 ± 1.3%
K21	20,875 ± 2.4%	K17	17,334 ± 3.2%
K29	28,750 ± 1.9%	K20	20,000 ± 1.4%
K34	34,000 ± 1.4%	K22	21,750 ± 0.8%
K47[c]	47,000	K24	23,557 ± 1.2%
K52	52,000 ± 1.6%	K29	29,019 ± 1.2%
K56	56,375 ± 0.4%	K37	37,161 ± 1.3%
K73	73,500 ± 4.5%	K41	41,326 ± 1.9%
K102	102,500 ± 5.8%	K43	43,104 ± 2.2%
K111	111,500 ± 6.6%	K65[e]	65,165 ± 4.3%

[a]As marked on gel 1 (Figure 8).
[b]The figures following the ± sign represent the coefficient of variation (in %) for the molecular weight.
[c]No measurable variation was found in its molecular weight.
[d]As shown on gels 2 and 3 (Figure 8).
[e]Present in gel 2 but not in gel 3 (Figure 8).

Although numerous methods have been reported for fractionation of peanut seed proteins, most of them are either complex or inefficient in separating arachin, conarachin, and other nonarachin components into highly purified ex-

tracts (Johns and Jones, 1916; Jones and Horn, 1930; Dechary et al., 1961; Tombs, 1965; Neucere, 1969; Dawson, 1971; Cherry et al., 1973; Singh and Dieckert, 1973a,b; Shetty and Rao, 1974). By gel electrophoresis of the proteins during various isolation steps, Basha and Cherry (1976) showed that water, $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 (I = 0.03; pH 7.9) buffer, and 10% NaCl neither completely extracted nor separated arachin and conarachin, or nonarachin proteins. Fractionation of peanut seed proteins with 1 M NaCl-20 mM $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer, on the other hand, yielded α-arachin (region 0.5-2.0 cm) and α-conarachin (region 2.0-4.5 cm; fractions on electrophoretic gels (compare separation of these 2 fractions in solubles and precipi-

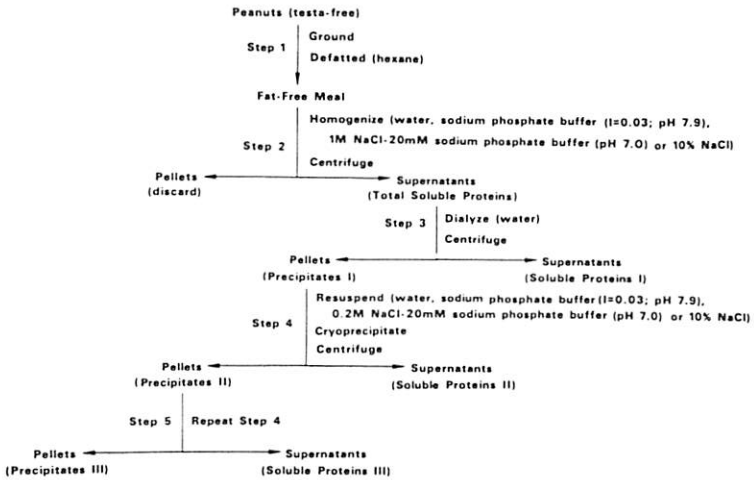

Fig. 9. Isolation and fractionation of peanut seed proteins. Reprinted from J. Agric. Food Chem. 24:359 (1976). Copyright 1976 by Amer. Chem. Soc.

tates I, II, and III in Figures 9 and 10; Basha and Cherry, 1976). As shown in Figure 11A, B, the electrophoretic patterns of the final fractions of α-arachin (denoted as BCP_3) and α-conarachin (BCS_3) proteins were prepared with 1 M NaCl-20 mM $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer, dialyzed against water, and lyophilized to a creamy white, crystalline-like powder.

Proteins of the total soluble extract of 1 M NaCl-20 mM $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer, BCP_3, and nonarachin fractions, BCS_3, were dissociated with sodium dodecyl sulfate (SDS) and a thiol reducing agent, dithiothreitol (DTT). The polypeptide components resulting from this procedure were distinguished according to their molecular weights by SDS-gel electrophoresis (Figure 11B; Table 2). Proteins in the total soluble fraction showed 5 major and 5 minor components on SDS gels that ranged in molecular weight from 130,000 to 21,000. α-Arachin had 1 minor and 4 major components of molecular weights between 81,000 and 20,000. The α-conarachin fraction contained 2 major and 3 minor components with molecular weights of 84,000 to 23,000.

The subunit components of α-arachin and α-conarachin differ slightly in molecular weight; this can be accounted for by differences in the amino acid composition of the 2 proteins. However, the possibility still exists that com-

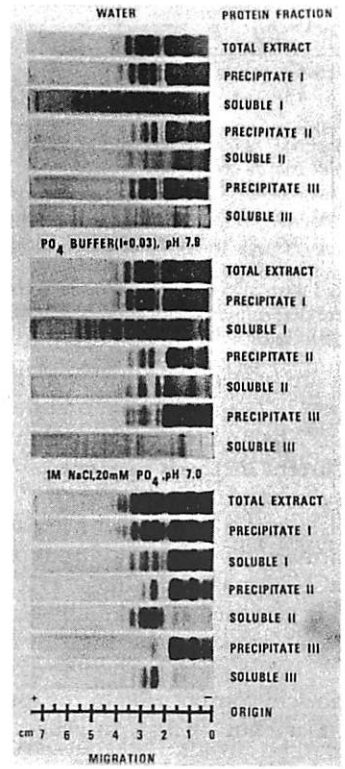

Fig. 10. Polyacrylamide disc gel electrophoretic patterns of proteins fractionated using different extraction meida. For details on preparation of the various fractions shown, see Figure 9. Reprinted from J. Agric. Food Chem. 24:359 (1976). Copyright 1976 by Amer. Chem. Soc.

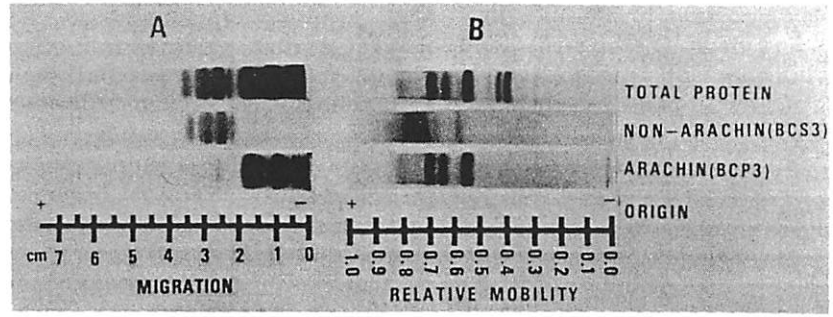

Fig. 11. Standard (A) and SDDS-(B) polyacrylamide disc gel electrophoretic patterns of the total proteins extracted with 1 M NaCL-20 mM sodium phosphate buffer (pH 7.0) at a meal to salt-buffer ratio of 1:18 (w/v) and the final purified fractions of nonarachin and arachin proteins made from this preparation. The proteins, labeled as BCS_3, and BCP_3, respectively, are lyophilized samples resulting from step 5 in Figure 8. BCS_3, = Basha-Cherry Soluble 3 or α-conarachin; BCP_3 = Basha-Cherry Precipitate 3 or α-arachin. Reprinted from J. Agric. Food Chem. 24:359 (1976). Copyright 1976 by Amer. Chem. Soc.

Table 2. Molecular weights of the protein fractions obtained during protein fractionation.[a] (Basha and Cherry, 1976.)

Protein fractions[b]	1	2	3	4	5	6	7	8	9	10	11
Total	130,000	115,000	84,000	78,000	66,000	50,500	45,000	37,000	31,500		21,000
Soluble I	130,000	115,000	84,000	78,000	66,000	50,500		37,000	31,500		21,000
Soluble II			84,000						31,000	26,000	21,500
Soluble III			84,000				46,000	34,000	31,000		23,000
Arachin			81,000			50,500		37,000	32,000		20,000

[a]Protein fractions were dissociated with SDS and DTT and subjected to SDS gel electrophoresis. Molecular weights (±2000) were determined using protein standards as markers.
[b]See Figure 9 for description of fractions.

mon subunit components are present in both proteins. Singh and Dieckert (1973b) and Shetty and Rao (1974) have shown that the number of subunits of arachin can range from 4 to 7 having molecular weights between 10,000 and 71,000. Quite possibly, current methods may not be efficient in dissociating α-arachin to the smallest subunit of molecular weight 10,000. This may be related to the isolation conditions of α-arachin which may alter molecular bonds in the basic structure to forms which resist SDS-induced dissociation.

Proteins in the 1 M NaCl-20 mM $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 extract reflect the typical amino acid composition of peanut seed, i.e., low in half-cystine, methionine, lysine, and tyrosine, and high in aspartic acid, glutamic acid, and arginine (Table 3; Basha and Cherry, 1976). Significant differences were observed in the amino acid composition of the total soluble fraction, the α-conarachin (BCS_3) and α-arachin (BCP_3). In general, levels of serine, half-

Table 3. Amino acid composition (% of protein) of different protein fractions resulting during fractionation in 1 M NaCl-20 mM sodium phosphate buffer (pH 7.0). (Basha and Cherry, 1976.)

AA	Total[a]	Sol. I[b]	Sol. II[b]	Sol. III (BCS_3)[b]	Precip. III (BCP_3)[c]
Asp	11.89	11.57	10.33	7.91	11.06
Thr	2.67	2.71	1.14	1.03	2.23
Ser	5.11	5.08	6.76	7.51	4.94
Glu	19.83	18.67	19.96	15.16	18.40
Pro	4.44	4.30	3.05	1.69	4.52
Cys	0.33	1.60	3.29	2.67	1.42
Gly	6.59	3.17	10.49	24.60	4.22
Ala	4.12	3.65	2.00	1.73	3.52
Val	3.88	3.95	1.57	1.58	3.40
Met	0.51	1.01	1.28	1.98	0.66
Ile	3.40	3.05	1.55	1.42	2.80
Leu	6.53	5.85	5.27	4.13	5.67
Tyr	4.09	4.25	5.13	5.72	5.06
Phe	6.38	7.26	3.76	3.06	8.02
His	3.17	3.51	2.71	2.79	3.78
Lys	3.87	3.81	4.28	5.62	3.09
NH_4	1.54	1.89	2.18	1.64	1.98
Arg	11.58	13.98	15.65	11.77	14.13

[a]Total soluble protein, step 2, Figure 9.
[b]Solubles I, II, III, steps 3, 4, and 5, Figure 9.
[c]Precipitate III, step 5, Figure 9.

cystine, glycine, methionine, and lysine were higher in the nonarachin proteins than in the total soluble fraction and α-arachin. Aspartic acid, threonine, glutamic acid, proline, alanine, valine, isoleucine, phenylalanine, histidine, and arginine were high in α-arachin.

The α-arachin resulting from the extraction process of Basha and Cherry (1976) contains similar quantities of amino acids as those reported by previous workers (Tombs, 1965; Neucere, 1969; Dawson, 1971; Singh and Dieckert, 1973a). The amino acid composition of arachin -P6 from Singh and Dieckert (1973a,b) compares closely with that of the α-arachin fractions of Tombs (1965), Neucere (1969), and Dawson (1971); P6 has higher amounts of serine, glycine, alanine, and valine than the other α-arachin preparations, possibly due to contamination from conarachin which is high in these amino acids. On the other hand, the α-conarachin from the technique of Basha and Cherry (1976) differs somewhat from those of previous investigations; e.g., it is higher in serine, glycine, tyrosine, methionine, and lysine. These differences may be due to the high purity of the α-conarachin of Basha and Cherry (1976) compared to those of the previous reports.

In most cases, procedures used to prepare peanut seed proteins begin by blending full-fat or fat-free meal with either water, buffer, or salt solutions. Fractionation of solubilized proteins then follows, taking advantage of 1 or more of their physicochemical properties relative to $(NH_4)_2SO_4$ saturation, pH solubility, chromatographic properties, and/or temperature (heat, cryoprecipitation). The proteins in each fraction are then characterized as to their purity and physicochemical properties. Improved techniques such as those used for gel electrophoresis and amino acid analysis to better define the composition of these protein fractions have shown them to be heterogeneous. Interestingly, many of the proteins prepared by different procedures are in fact similar, based on criteria such as gel electrophoretic patterns and amino acid composition. Differences among proteins are related to the degree of purity of the major α-arachin and α-conarachin components. This in turn has been related to the degree of dissociation of these major globulins during extraction procedures or variations in chromatographic, salt solution, or heat coagulation procedures. However, with regard to food use, these differences are probably minor since arachin or conarachin prepared by various techniques show similar amino acid composition.

Thus, use of various fractions of peanut seed proteins as food ingredients may not require extensive purification of the individual components. Instead, techniques for proper preparation of partially purified protein extracts such as concentrates and isolates from peanut seed with unique physicochemical, functional, and nutritional properties for use as specific food ingredients may be more important.

PRODUCTION

Excellent reviews are available on the production technology of edible protein products from peanut seed (Ascham, 1936; Arthur, 1953; Milner, 1962; Orr and Adair, 1967; De and Cornelius, 1971; McWatters, 1973; Ayres et al., 1974; Ayres and Davenport, 1977; Natarajan, 1980). The popularity of peanut seed in human foods makes them natural candidates for sources of vegeta-

ble protein ingredients. A group of peanut seed products with protein content ranging from 25 to 95% has been developed experimentally, and some of these are produced commercially. Processes used to prepare protein ingredients from peanut seed are similar to those for preparing soybean products.

Precooked full-fat, partially-defatted, and defatted peanut flakes that contain 29.4, 41.0, and 58.7% protein, respectively, have been developed. Meals that have between 45 and 60% protein are prepared by hydraulic pressing, screw pressing, solvent (hexane) extraction, and prepressing followed by solvent extraction to remove oil; essentially all of the oil is removed by prepress-solvent or solvent extraction procedures. The meals can be ground to different particle sizes to produce grits or flours. The flours, in turn, can be processed into concentrates containing 70% or more protein, or into isolates containing 90% or more protein. If the flour is made from peanut seed with skins (testa), it can be either air-classified or solvent-classified by the liquid cyclone process. In each procedure, 2 fractions are obtained as follows: (1) a fine ground 70% protein concentrate, and (2) a coarse ground meal that has less protein and the skins. Protein isolates can be extracted from flours with dilute alkali between pH 7.5 to 10.5. The insoluble residue is removed by centrifugation or filtration. The isolate is precipitated from the extract by acidification to pH 4.5, recovery by centrifugation, washing with water, neutralization, and then drying it. Selective extraction or selective precipitation methods can be used to prepare isolates having different functional properties. These vegetable protein ingredients are bland in taste; i.e., they have virtually none of the flavor that is normally associated with roasted peanuts. The following is a discussion of selected methods developed for making food-grade vegetable protein ingredients from peanut seeds.

Flakes

A process of converting peanut seed into precooked flakes, high in proteins and calories, begins by heating them for 1 hour at 107 C in an electric oven to assist in removal of skins and hearts (Mitchell and Malphrus, 1968; Mitchell, 1972). After lowering the moisture content of the seed to about 6% by weight, they are ground to a flour consistency and mixed with water to form an emulsion of oil droplets and a suspension of solids. The emulsion-suspension is preheated to a temperature between 93-116 C for a time to inactivate the enzyme lipoxygenase. The final step includes drum drying the peanut product by coating the drum surface evenly and removing the coating by scraping it with knives to form flakes. Full-fat (51.7% oil; 29.4% protein), partially defatted (30.7%; 41.0%), and defatted (0.2%; 58.7%) flakes can be made by this process.

Flours, Meals, and Grits

A schematic flow diagram of a pilot plant process for producing edible peanut flours, meals, and grits by conventional methods is presented in Figure 12 (Harris et al., 1972). In conventional industrial methods, oil extraction is either by mechanical expression, usually in a continuous screw press (expeller), or by solvent extraction after an initial step of low-press expelling (prepress solvent extraction). After prepressing, the crushed cakes are flaked before solvent

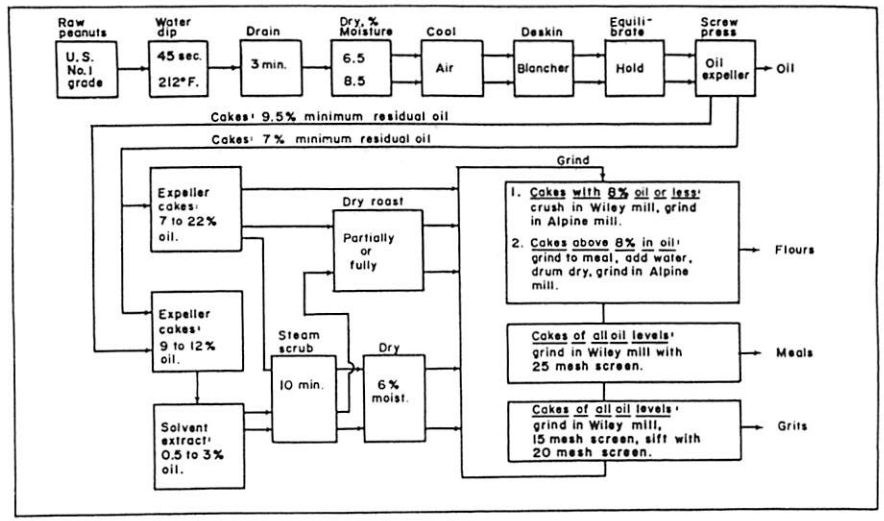

Fig. 12. Flow diagram of procedures used in the making of defatted peanut flours, meals, and grits. Reprinted from Auburn Univ. Agric. Exp. Sta. Bull. 431, 1972.

extraction, an important step because seed particles must be thin enough to be extracted readily, and large enough to form a mass through which the solvent will flow freely.

Examining the flow diagram (Figure 12), Harris et al. (1972) explained that level and equilibrium of moisture in peanut seed, as well as processing temperature and expeller adjustments, were crucial in this operation. Pretreatment of the peanut seed consisted of dipping them for 45 seconds in boiling water followed by drying them to 5.9-6.4% moisture content at 121 C in a forced air oven. The pretreatment and moisture level was ideal for best skin removal by conventional blanching equipment. Screw pressing studies showed that the following critical conditions are necessary to form a cake with residual oil as low as 7.5% from deskinned peanut seed. Seed moisture must be equilibrated to between 5.8 and 7.0%; the expeller, once its aperture clearance and rate per minute are properly adjusted, must be preheated before starting oil extraction; and supplementary heat must be added to maintain temperature of the expeller barrel between 82 and 93 C. Cakes with up to 26% residual oil were produced by pressing peanuts with higher moisture content and/or using more clearance on the expeller aperture. Oil level in the expeller cake was further reduced to less than 1% by a 3-step hexane extraction involving either mechanical stirring or rolling in a container. The 2-step process of screw-press followed by solvent extraction of the press cake was more efficient than direct extraction.

The raw peanut flavor and hexane residue were removed by scrubbing the cake with saturated or superheated steam at atmospheric pressure. Roasted flavors were obtained by steam or dry heat treatment of expeller or solvent extracted cakes; intensity of roasted flavor increased with increase in cake oil contents.

Ayres et al. (1974) developed a commercial prepress solvent extraction me-

thod similar to that of Harris et al. (1972) for production of edible peanut flours and grits. A major difference between the 2 methods is that after grinding of the peanut seed, Ayres et al. (1974) passed the granulated peanuts through a stack cooker for 45-60 minutes at 116 C prior to expeller treatment. This initial cooking step has 2 valuable assets other than oil mobilization: (1) reduction of microbial counts to near sterility, and (2) gelatinization of the starch giving the finished product some unique functionality not observed in other oilseed products. The rigorous cooking does, however, reduce protein solubility substantially as indicated by its nitrogen solubility index.

A process has been developed that omits the need for the prepressing step and allows direct solvent extraction of oil from raw peanut seed slices or flaked peanuts (Fan et al., 1948; Anonymous, 1976; Pominski et al., 1977). The key step in this process is the production of extremely thin peanut seed slices or flakes prior to the oil extraction step. The slices are in such a form that allows the use of conventional countercurrent extraction equipment and solvent recovery systems currently used to process peanut seed and soybeans. Removing the solvent under low-temperature conditions (under vacuum) produces a white-colored, bland, and highly functional peanut flour with 60% protein and less than 1% oil content. The protein is highly soluble because little heat is used in the process. The extracted oil has the appearance of refined soybean oil.

Defatted peanut flour may also be produced from white-testa peanuts, which are more bland in flavor and contain less reducing sugars and raffinose than red-testa cultivars (Conkerton and Ory, 1976). The flour could be produced at a lower cost than flours from red-testa cultivars since the blanching step to remove the testa could be eliminated. The bland flavor of this type of peanut would restrict its use in certain products requiring a well-developed roasted peanut flavor; however, this characteristic would appear to make this type of peanut quite suitable for preparation of flour where little or no typical peanut flavor is desired (Conkerton et al., 1978).

Table 4 presents the quality specifications for processing of peanut seed flours for human consumption as summarized by Natarajan (1980) from Anonymous (1968a,b; 1970), Mottern (1973) and Milner (1979). Grits made from these products have similar proximate compositions but have lower nitrogen solubilities (e.g., flour, 59.0%; grits, 28.0%; Ayres and Davenport, 1977). While aflatoxin is discussed in more detail in Chapter 13, it is an important consideration of quality specifications for foods. Some specifications are shown in Table 4. The current United States guideline level is 20 parts per billion (ppb) for peanut butter and all other peanut products, and no component of a mixture may have more than 20 ppb of aflatoxin even though the final food mixture will contain less than that amount. In some countries, however, the tolerance level is based on the final food composition; thus, dilution of a component's aflatoxin level is permitted. On the other hand, some countries have tolerance levels which are distinctly lower than the USA level, e.g., 5 ppb for West Germany (Rodricks et al., 1977).

Concentrates

Bitter-tasting and odoriferous, or off-flavored compounds, trypsin inhibitor, aflatoxins, and flatulence sugars are usually removed in the preparation of protein concentrates from peanut seed products (Rayner and Dollear, 1968; Rayner et al., 1970; Spadaro et al., 1973; Vix et al., 1973; Cater et al., 1974; Nagaraj and Subramanian, 1974; Rhee et al., 1977; Natarajan, 1980). Process variations, including water leaching at the isoelectric point, aqueous alcohol leaching, air classification liquid cyclone fractionation, moist heat denaturation followed by water leaching, and aqueous extraction have been developed at the experimental level to produce concentrates with 60 to 70% protein content (Figure 13). All processes, except that of the aqueous extraction method, usually begin with defatted flours or flakes. The aqueous extraction process involves simultaneous separation of a pH 4.0 aqueous extract of comminuted full-fat seed into oil, solid, and aqueous phases. Acid soluble proteins, carbohydrates, oil, and other constituents are extracted leaving the fiber and acid insoluble substances in the protein concentrate. Low molecular weight, nonprecipitable proteins, sugars, and salts may be recovered from the whey by the

Table 4. Quality specification for edible peanut flour. Adapted from Anonymous (1970). Protein Advisory Group (PAG) specifications for peanut flour have been revised and updated by M. Milner (Food and Nutrition Bulletin of the United Nations University, Vol. 1, No. 3, May 1979), Indian Standards Institute (ISI) (Anonymous, 1968), Mottern (1973).

Specifications	PAG	ISI	U. S. Flour
Moisture (%)	7.0-11.0	8.0	9.0
Crude fat (%, max)	8.0	1.5	2.0
Protein (N x 6.25) (%, min)	48.0	47.0	55.0
Crude fiber (%, max)	3.5	5.0	5.0
Ash (%, max)	4.5	5.0	4.5
Free fatty acid (% of oil, max)	1.0	4.0	2.0
Available lysine (gm/16 gm N, min)	2.5	2.0	2.5
Acid-insoluble ash (%, max)	0.1	0.35	0.2
Aflatoxin (ppb, max)	30	120	Within allowable tolerance
Total bacterial count/gm (max)	20,000	50,000	50,000
Salmonella/gm (max)	Nil	Nil	Nil
Escherichia coli/gm (max)	Nil	10	10
Other pathogens	Nil	-	-

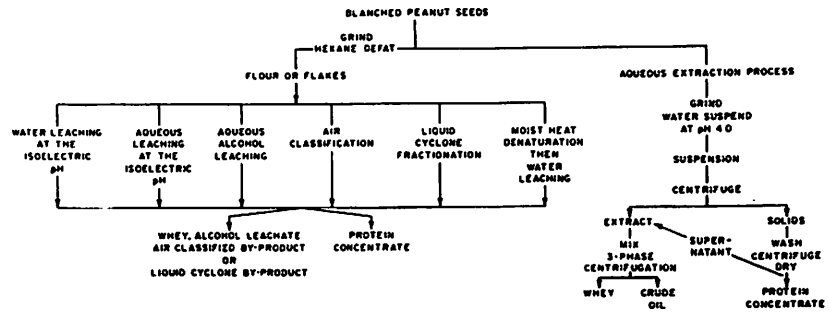

Fig. 13. Processing of peanut seed protein concentrates.

techniques of ultrafiltration and reverse osmosis (Cater et al., 1974). Approximately 96% of the oil is recovered by this process.

Isolates

Processing of peanut seed isolates of 90% or more protein involves extracting, in addition to those constituents that are necessary to make concentrates, the water-insoluble polysaccharides, water-soluble sugars, and other minor constituents (e.g., minerals, etc.). Studies of the various factors involved in protein isolation, including particle size of the flour, flour-to-water ratio, pH, time and temperature of extraction that affect yield and extractability are well documented (Pominski et al., 1952; Arthur, 1953; Amantharaman et al., 1959; Bhatia et al., 1966; Chandrasekhara et al., 1971; De and Cornelius, 1971; Rhee et al., 1972, 1973a,b, 1977; Cater et al., 1974; Van den Berg, 1974; Natarajan, 1980).

The basic method involves the extraction of protein from defatted peanut seed flour with an aqueous alkaline solution followed by removal of insoluble material by centrifugation and/or filtration methods, precipitation of the proteins at their isoelectric pH 4.5, collection of the precipitated protein curd by centrifugation or filtration methods, and drying of the isolate by spray-drying or lyophilization procedures (Figure 14). Aqueous alkaline extraction is conducted at pH values below 9.0 to minimize protein denaturation. The protein isolate can be neutralized before drying to make it water dispersible. The highest yields of isolates are attained from flours prepared by methods that minimize denaturation of the proteins to retain their maximum solubility properties.

Rhee et al. (1972, 1973a, 1977) developed a method, similar to that used for preparation of concentrates (Figure 13), to separate peanut seed protein isolate and oil by an aqueous extraction process (Figure 14). The major difference between this method and that used to prepare the concentrate is the use of an alkaline (pH 8.0) extraction and a filtration step to separate the proteins from the fiber fraction of the peanut seed.

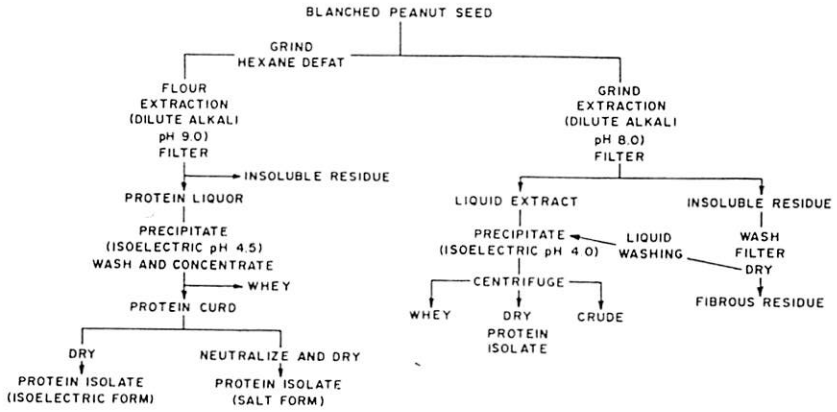

Fig. 14. Processing of peanut seed protein isolates.

Peanut protein isolates can be precipitated from alkaline extracts by heating them in the presence of Ca^{++} ions (Liggett, 1969; Oke and Smith, 1975). This method assists in the elimination of the beany flavor and aflatoxins.

Co-isolates

Co-precipitated isolates containing 95% protein can be prepared from various combinations of peanut seed, cottonseeds (liquid cyclone processed or glandless) and soybean flours (Cherry et al., 1978; Berardi and Cherry, 1979, 1981); this process can also be used to prepare isolates from these flours. Co-isolate methodology involves protein extraction with dilute aqueous NaOH, acidification of the protein extract to pH 2.5, and adjustment of the resulting mixture to pH 5.0 to precipitate protein curds (Figure 15). The protein curds are then recovered, resuspended in water, neutralized and dried. Disc-gel electrophoresis showed that some of the proteins in the combined extracts dissociated into subunits at pH 2.5, then reassociated into their original or new protein forms, or both, as the pH was adjusted to pH 7.0. The co-isolates had better amino acid content, functionality and nutritional value than their corresponding isolates.

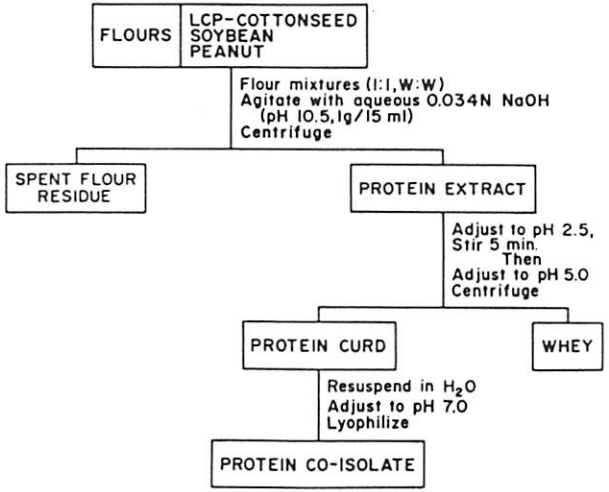

Fig. 15. Processing of co-isolates. Reprinted from Cereal Chem. 56:95 (1979). Copyright 1979 by Amer. Assoc. of Cereal Chem.

FUNCTIONAL PROPERTIES

Solubility

The extent to which proteins can be dissolved or dispersed in a substance is often used as an indicator of functionality and potential application of vegetable protein products. Nitrogen solubility profiles, over a range of pH values, are considered to be basic to investigations of functionality (Mattil, 1971;

Wolf and Cowan, 1971; Kinsella, 1976, 1979; Shen, 1981). Solubility characteristics of proteins are influenced by many factors including protein source, processing history, temperature, pH, ionic environment, protein concentration, and the presence of other ingredients (Kinsella, 1979; Shen, 1981).

Several studies have shown substantial differences in solubility or extractability characteristics of peanut proteins by variations in pH and/or composition of the extraction medium (Hagenmaier, 1972; Lawhon et al., 1972; Rhee et al., 1972; Ayres et al., 1974; Basha and Cherry, 1976; McWatters et al., 1976; McWatters and Cherry, 1977; McWatters and Holmes, 1979a). The effects of several mono- and divalent salts at concentrations ranging from 0.01-1.0 M on the extraction of peanut protein at various pH levels are shown in Figures 16 and 17 (Rhee et al., 1972). These workers reported that all 4 salts

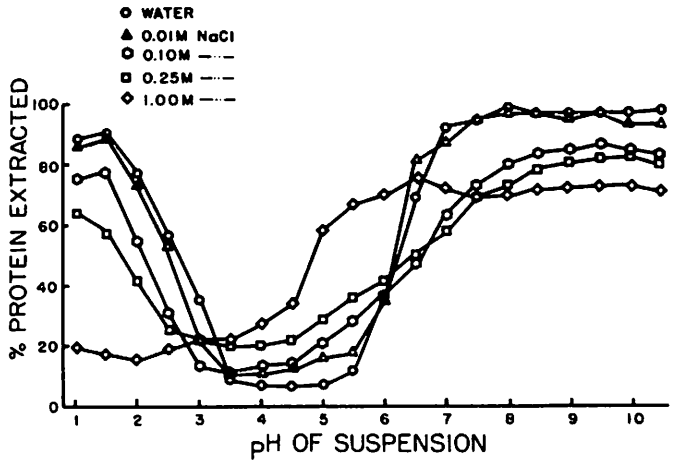

Fig. 16. Effect of NaCl (or KCl) at different levels of concentrations on the extraction of protein at various pH's. Reprinted from J. Food Sci. 37:90 (1972). Copyright 1972 by Inst. of Food Tech.

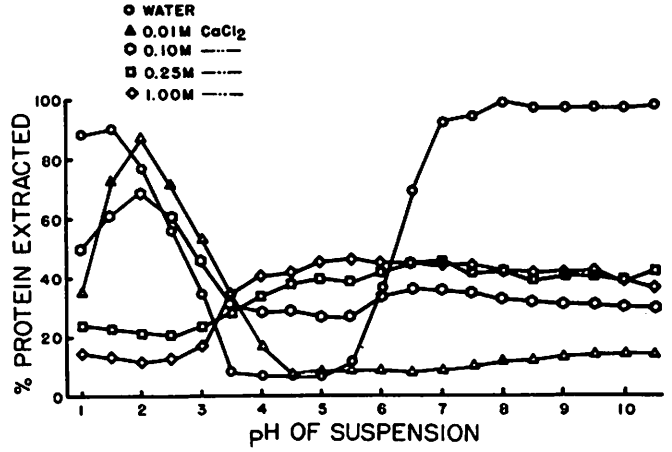

Fig. 17. Effect of $CaCl_2$(or $MgCl_2$) at different levels of concentrations on the extraction of proteins at various pH's. Reprinted from J. Food Sci. 37:90 (1972). Copyright 1972 by Inst. of Food Tech.

acted to suppress extractability at all concentrations tested at pH 7.0 or higher. This suppressive effect was more pronounced with the divalent salts. With monovalent salts, extraction of protein was suppressed by the higher salt concentration; with the divalent salts, suppression was greatest at the lower concentrations.

Both the mono- and divalent salts enhanced the extraction of protein in the pH 3.5-5.5 range where peanut protein is normally least extractable in water. In this pH range, protein extraction increased with increasing concentrations of the salts. At pH 3.0 or lower, protein extractability decreased markedly as the concentration of the monovalent salts increased. A similar effect was observed with divalent salts at higher concentrations (0.25 M or higher). At low salt concentrations (0.1 M or lower), however, the effects were somewhat different. Extraction at very low pH levels (below 2.0) was suppressed considerably by the added salts, but protein extractability was enhanced as the pH of the dispersion increased to levels above pH 2.0.

Conkerton and Ory (1976) demonstrated varietal differences in nitrogen solubility profiles of peanut flour; flour prepared from a red-skinned spanish variety had lower nitrogen solubility than flours prepared from a virginia and a white-skinned spanish variety. The solubility curves of the 3 flours were similar, showing minimum solubility in the pH 3.0-6.0 range and high solubility above pH 7.0 and near pH 1.0. Ory et al. (1978) investigated the solubility characteristics of peanut and citrus seed proteins at various pH levels and found that peanut proteins were much more soluble than citrus seed proteins. Solubility of a 1:1 blend of peanut and citrus seed proteins was intermediate.

Cherry et al. (1975) heated full-fat peanut seed in water at 50, 75, 100, and 120 C for 15 to 210 minutes and found only minor changes in levels of water soluble proteins at 50 and 75 C for 15 to 90 minutes (Figure 18). Increasing the temperature to 100 or 120 C decreased protein solubility; concurrent increases in the nitrogen level of the insoluble fraction occurred, indicating that soluble proteins were converted to insoluble forms. Schmidt and Mendelsohn (1977) also reported decreases in soluble protein when peanut protein dispersions were heated above 80 C.

Cherry and McWatters (1975) demonstrated that peanuts grown at different locations and/or stored for different lengths of time responded differently to moist heat treatment at 100 C. Protein solubility was substantially reduced when heating time was extended to 210 minutes, though the rate of decline was slower for the freshly harvested seed than for those harvested the previous year. Patterns of protein solubility were also affected by the sequence of freezing, grinding, and length of time the seed were held prior to extraction.

Ahmed and Schmidt (1979) investigated the influence of various processing conditions and storage on solubility characteristics of peanut protein isolates. These workers found no difference in solubility due to centrifugation speed; spray- and freeze-dried preparations had substantially higher solubility values than drum-dried preparations. Solubility of all preparations was pH-dependent, being lowest at pH 4.0 and highest at pH 9.0. Solubilities at pH 7.0 ranged 5-11% less than at pH 9.0. Similar solubilities were obtained for non-heated peanuts and those steamed at 107 C for 20 minutes prior to protein extraction. Storage at 24 C for periods up to 36 months reduced solubility of spray-dried peanut protein preparations.

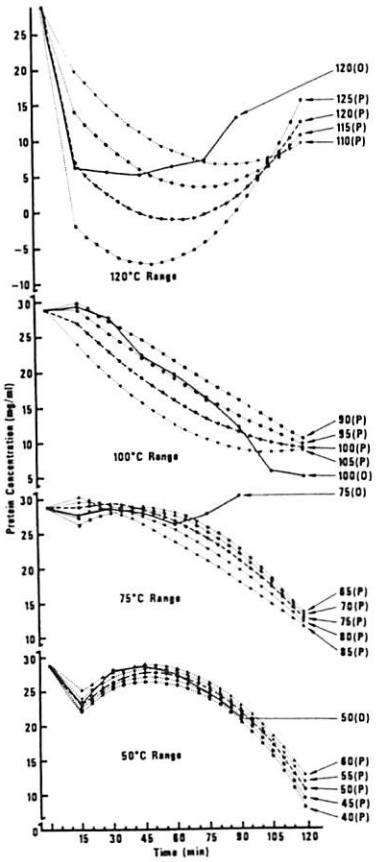

Fig. 18. Observed (0) and mathematically simulated (P) changes in protein solubility of peanuts seeds moist heated at different temperatures (40-125 C at intervals of 5C) for various time intervals of 0-120 minutes. Reprinted from J. Food Sci. 40:1199 (1975). Copyright 1975 by Inst. of Food Tech.

Data in Figure 19 show that enzyme hydrolysis of peanut flour with pepsin, bromelain, and trypsin substantially increased nitrogen solubility in water at pH 4.0-5.0 and in 0.03 M Ca^{++} (as $CaCl_2$) at pH 4.0-11.0 (Beuchat et al., 1975). Pepsin treatment resulted in the greatest increase in nitrogen solubility. Beuchat (1977a) reported that control peanut flours which had been adjusted to pH 2.0 and, to a lesser extent, pH 4.5 and 7.6 had reduced nitrogen solubility when suspended in water at pH 2.0-9.0. Enzyme hydrolysis with pepsin, bromelain, or trypsin generally restored solubility with notable increases occurring at the isoelectric pH range (4.0-5.0) of most peanut proteins. A wide range of induced solubility properties was possible with enzyme, pH, and heat treatments. Sekul et al. (1978) also demonstrated an improvement in nitrogen solubility of peanut proteins partially hydrolyzed with papain at all pH levels except 2.0 and 8.0; bitter peptides were not produced as a result of the enzyme treatment.

Data presented in Figure 20 indicate that succinylation of peanut flour with

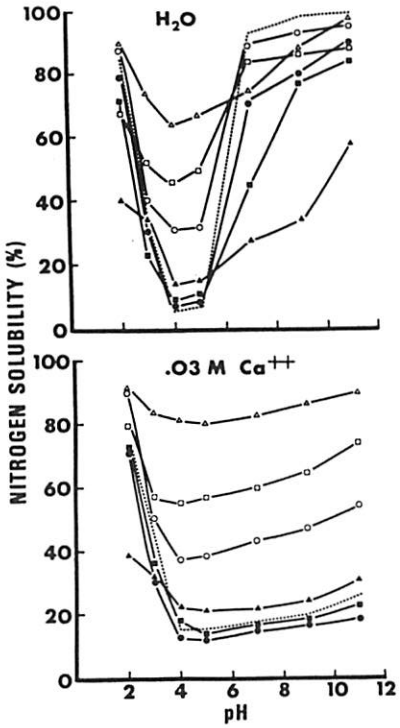

Fig. 19. Nitrogen solubility profiles for enzyme-treated and non-treated peanut flour. Dashed line indicates no pH-heat treatment (control 1); solid lines indicate 50-minute treatment at 50 C followed by 10 minutes at 90 C. Symbols: triangles, pH 2.0; squares, pH 4.5; and circles, pH 7.6 during heat treatment; open triangles, pepsin treatment; open squares, bromelain treatment; and open circles, trypsin treatment; closed triangles, squares, and circles indicate controls 2, 3, and 4 for respective enzyme treatments. All samples were adjusted to pH 6.9 prior to freeze-drying and analytical examination. Reprinted from J. Agric. Food Chem. 23: 616 (1975). Copyright 1975 by Amer. Chem. Soc.

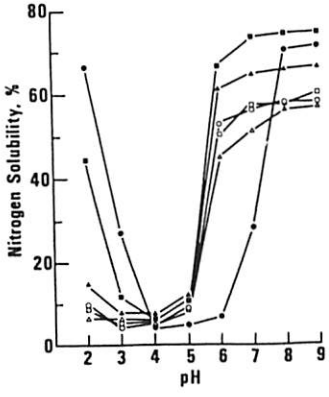

Fig. 20. Nitrogen solubility profiles for control and succinylated peanut flour. Symbols: (●) control; (■) 10% (w/w succinic anhydride/protein during succinylation procedure); (▲) 40%; (○) 70%; (□) 100%; and (Δ) 130%. Reprinted from J. Agric. Food Chem. 25:258 (1977b). Copyright 1977 by Amer. Chem. Soc.

various amounts of succinic anhydride (10, 40, 70, 100, and 130% of the weight of protein in the suspension) produced substantial changes in nitrogen solubility profiles (Beuchat, 1977b). Succinylation caused a slight increase in the nitrogen solubility of flours in the isoelectric pH range (4.0-5.0) of most peanut proteins. At pH levels below the isoelectric region, nitrogen solubility decreased progressively in flours treated with increasing levels of succinic anhydride. Solubility of nitrogen at pH 6.0-7.0 was increased dramatically by succinylation. The milder succinylation treatments (10 and 40% levels) produced greater increases in solubility than the more extensive treatments at 70, 100, and 130% levels. Sundar and Rao (1978) reported that alkali-extracted peanut proteins had higher solubilities than those extracted with acid. Acetylation and succinylation improved the solubility of the acid-extracted proteins in the pH 6.5-8.5 range.

Nitrogen solubility profiles of peanut flour were altered substantially by fermentation with each of 5 fungi used in traditional oilseed fermentation processes (Quinn and Beuchat, 1975). Data in Figure 21 demonstrate that each fungus increased the nitrogen solubility of the substrate over the nonheated,

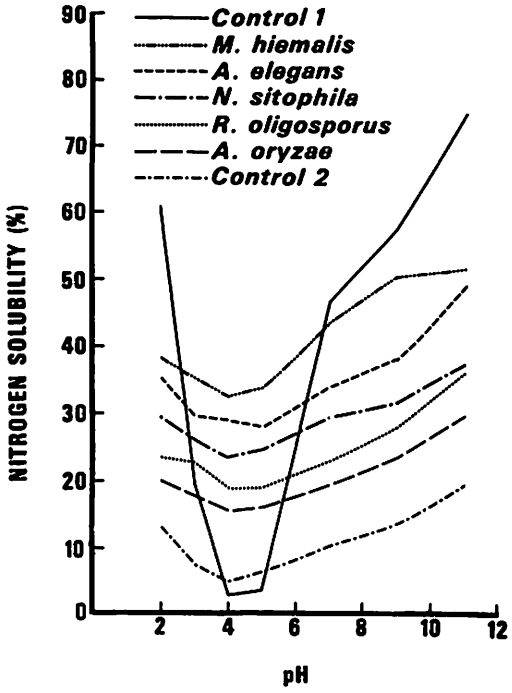

Fig. 21. Nitrogen solubility of nonfermented and fermented peanut flour in water in the pH range 2.0-11.0. Reprinted from J. Food Sci. 40:475 (1975). Copyright 1975 by Inst. of Food Tech.

nonfermented control flour in the pH 3.0-6.0 range. *Mucor hiemalis*, in particular, increased the nitrogen solubility at pH 4.0-5.0 from less than 5% in the nonheated control to about 34% in the ferment. The increased nitrogen solubility in this pH range was due to protein hydrolysis by fungal acid proteases to form peptides and free amino acids.

Viscosity

The flow properties of proteins are related to molecular shape, size, charge, solubility, and swelling capacity of protein molecules. Therefore, factors such as environmental conditions, temperature, concentration, pH, ionic strength, and previous processing history which affect protein molecules also affect the flow properties (Hermansson, 1975; Kinsella, 1976, 1979; Shen, 1981).

The effects of reacting various amounts of succinic anhydride (10, 40, 70, 100, and 130% of the weight of protein in suspension) at pH 7.4-8.0 on viscosity of peanut flour dispersed in water at concentrations of 1, 2, 5, and 10% (w/v) were investigated by Beuchat (1977b). Viscosities of succinylated and untreated control flour dispersions increased as flour concentration increased. At the 1% flour concentration, no differences in viscosity were observed between control flour and treated-flour dispersions. At 2 and 5% flour concentrations, a significant increase in viscosity occurred when flour was treated with at least 40% succinic anhydride. When the flour concentration was increased to 10%, significant increases in dispersion viscosity occurred only at the 10% succinic anhydride level.

Viscosities of the soluble fraction of 8% dispersions (w/v) of untreated peanut flour and flour fermented with each of 5 fungi used in traditional oilseed fermentation processes were measured in water and 4% NaCl solution by Quinn and Beuchat (1975). Dispersions in salt solution exhibited slightly higher apparent viscosities than water dispersions. Changes in viscosity due to fermentation were minimal. McWatters et al. (1976) measured the viscosities of 8% dispersions (w/v) of defatted peanut meal in water, 0.1 M NaCl, or 1.0 M NaCl at pH levels of 1.5, 4.0, 6.7, and 8.2 (Table 5). All dispersions had low viscosities and were similar regardless of salt concentration or pH level.

Emulsification

Emulsion formation and stabilization are surface active functions of proteins (Tornberg, 1979; McWatters and Cherry, 1981). Complex mechanisms involved in formation of stable emulsions include reduction of interfacial tension between hydrophilic and hydrophobic components (e.g., water and oil), formation of a rigid interfacial film, and electrical charges. Large shearing forces are required for a protein's surfactant activity to bring about emulsion formation. For the most part, emulsification properties of peanut proteins have been determined in model systems where oil is added at a constant rate to a protein dispersion during mixing; addition of oil continues until a sudden drop in viscosity occurs due to oil-water phase separation. A few studies have used meat systems to measure emulsification properties of peanut proteins, but mechanisms involved in these types of systems are a combination of emulsification, binding, and gelation rather than emulsification alone. Problems associated with the use of model systems for emulsion studies relate to variable results obtained by small modifications in technique, equipment, blending speed, oil addition rate, protein source and concentration, pH, temperature, or type of oil (Saffle, 1968; Kinsella, 1976, 1979; Tornberg and Hermansson, 1977; Pearce and Kinsella, 1978; Cherry et al., 1979; Tornberg, 1979). Factors which affect protein structure and behavior (e.g., pH, temperature, ionic en-

Table 5. Effect of pH and suspension medium on functional properties of defatted peanut meal. (McWatters et al., 1976.)

Treatment, pH	Suspension medium	Viscosity, cP	Emulsion		Foam	
			Capacity, ml of oil	Type	Capacity, ml, 1 min	Stability, ml, 60 min	% change
6.7 → 1.5	Water	23.0	119.1	Mayonnaise-like	228.7	145.3	36.5
	0.1 M NaCl	19.0	92.4	Mayonnaise-like	198.0	110.7	44.1
	1.0 M NaCl	18.7	38.6	None formed	180.7	104.7	42.1
6.7 → 4.0	Water	22.8	38.7	None formed	143.0	86.0	39.9
	0.1 M NaCl	18.3	41.9	None formed	140.0	85.0	39.3
	1.0 M NaCl	20.5	49.9	None formed	145.0	83.0	42.8
6.7	Water	17.3	57.4	Pourable suspension	76.0	58.0	23.7
	0.1 M NaCl	18.0	42.4	Pourable suspension	82.0	58.0	29.3
	1.0 M NaCl	20.8	62.2	Pourable suspension	108.7	60.0	44.8
6.7 → 4.0 → 6.7	Water	20.7	62.0	Thick salad dressing	90.0	72.0	20.0
	0.1 M NaCl	18.3	47.0	None formed	103.0	72.0	30.1
	1.0 M NaCl	19.3	57.3	Sl. thickening, pourable	138.0	85.0	38.4
6.7 → 8.2	Water	17.7	74.9	Thick salad dressing	102.7	78.0	24.1
	0.1 M NaCl	19.8	61.3	Sl. thick salad dressing	96.7	68.0	29.7
	1.0 M NaCl	22.5	57.9	None formed	125.3	79.3	36.7
6.7 → 4.0 → 8.2	Water	22.3	94.8	Mayonnaise-like	141.3	95.3	32.6
	0.1 M NaCl	21.5	66.3	Salad dressing	136.0	90.7	33.3
	1.0 M NaCl	25.0	68.3	Salad dressing	127.3	87.3	31.4

vironment, processing conditions) in turn affect emulsifying properties.

McWatters et al. (1976) and McWatters and Holmes (1979a) investigated the influence of pH, salt concentration and flour concentration on emulsifying properties of defatted peanut flour. Emulsion capacity values for peanut flour dispersed in water, 0.1 M NaCl, and 1.0 M NaCl (8% suspensions, w/v) and adjusted to pH values ranging from 2.0-10.0 are shown in Figure 22 and Table 5. Peanut flour/water suspensions had higher emulsion capacities than either of the salt suspensions at pH levels of 2.0-4.0 and 8.0-10.0. No emulsions were formed by the high-salt samples at pH 2.0-4.0 and by the low-salt sus-

Fig. 22. Emulsion capacity (ml oil per mg total protein) of 25 ml of peanut flour suspended in distilled water, 0.1 M NaCl, and 1.0 M NaCl (8% suspensions, w/v) in the pH range 2.0-10.0. Reprinted from J. Food Sci. 44:765 (1979). Copyright 1979 by Inst. of Food Tech.

pensions at pH 4.0. Emulsion-forming properties of water and low-salt suspensions were improved by adjusting the pH to levels below or above pH 4.0. All suspensions above pH 4.0 increased in emulsifying capacity as the pH was raised to 10.0 except high-salt samples which peaked at pH 6.0 and then declined slightly.

These workers also found that emulsion viscosities were also influenced by pH and salt concentration (Table 6). In most instances, water dispersions produced more viscous emulsions than either of the salt suspensions. At all pH levels except 6.0 and 7.0, emulsion viscosities decreased as salt concentration increased. The poorest emulsifying properties in terms of emulsion formation and thickening were demonstrated by the high-salt suspensions. By contrast, thick mayonnaise-like emulsions with viscosities ranging from 24,320-133,280 cps were produced by the water dispersions at pH 2.0, 3.0, 8.0, 9.0, and 10.0 and by the low-salt suspensions at pH 2.0 and 3.0 (99,680 and 29,440 cps, respectively). Pourable salad dressing-like emulsions were produced by the water suspensions at pH 4.0-7.0 and by both salt suspensions at pH 5.0 and above.

Thus, altering the electrovalent properties of peanut protein by shifts in pH as well as changing the ionic environment of the protein strongly influenced the emulsifying properties of peanut flour. Shifting the pH away from the

Table 6. Influence of pH and salt concentration on viscosities (cps) of peanut flour emulsions.* (McWatters and Holmes, 1979a.)

pH	Water	0.1 M NaCl	1.0 M NaCl
2	133,280	98,680	no emulsion
3	96,800	29,440	no emulsion
4	1,920	no emulsion	no emulsion
5	6,400	3,200	2,400
6	2,400	2,080	4,960
7	8,320	5,760	6,080
8	24,320	10,080	4,960
9	31,680	8,640	2,400
10	26,400	4,800	1,600

*8% flour suspensions (w/v); for comparison, a commercial mayonnaise had a viscosity of 44,640 cps and two commercial salad dressings, 6,400 and 16,800 cps.

isoelectric pH, a point of minimum solubility and reactivity, apparently improved emulsion capacity of peanut flour by giving the protein an electrical charge and possibly by increasing the protein's solubility (Cherry et al., 1979; McWatters and Cherry, 1981). McWatters et al. (1976) and Cherry et al. (1979) reported similar improvements in emulsifying capacity with pH and salt concentration adjustments, which probably caused structural rearrangements of protein molecules and an increase in the number of potential binding or reactive sites. These investigators suggested that peanut protein solubility was more closely related to emulsion consistencies than to volume of oil emulsified.

Ramanatham et al. (1978) reported a reduction in emulsion capacity and an increase in emulsion viscosity with increasing protein concentration, which was also confirmed by McWatters and Holmes (1979a). Ramanatham et al. (1978) further demonstrated that a peanut protein isolate (90% protein) had higher emulsion capacity than peanut flour (50% protein) and that emulsion capacity and viscosity were increased by increasing the fineness of peanut flour. Emulsion capacity versus pH profiles resembled typical protein solubility curves. Sodium chloride at low concentrations (0.05-0.2 M) increased the emulsion capacity of peanut protein isolate in the pH range 7.0-10.0. At higher NaCl concentrations (0.5-1.0 M), however, emulsion capacity decreased, particularly in low pH regions. Spray- and freeze-dried peanut protein isolates had identical emulsion capacities whereas roller-dried products were slightly lower. Increasing the speed rate of mixing during emulsion formation decreased emulsion capacity and increased emulsion viscosity.

Peanut flour reacted with 40% succinic anhydride (% based on weight of protein in the suspension) significantly increased emulsion capacity over untreated flour or flours treated at other levels (Beuchat, 1977b). The most extensive treatment (130% succinic anhydride) resulted in a significant reduction in emulsion capacity. Sundar and Rao (1978) reported that acid-extracted peanut proteins exhibited higher emulsion capacity than alkali-extracted products; subsequent acetylation and succinylation treatments considerably improved the solubility of the acid-extracted protein in the pH range 6.5-8.5 and also increased emulsion capacity.

In studies with enzyme-treated peanut flour, Beuchat et al. (1975) reported that enzymatic digestion with pepsin, bromelain, and trypsin completely destroyed the emulsifying capacity of the flour. Emulsions were formed, however, by untreated flours and by those flours hydrolyzed for the shortest amount of time (10 minutes); higher emulsion capacities occurred when the flours were dispersed in water than in 0.5 M NaCl. Sekul et al. (1978) also found that partial hydrolysis of peanut proteins with papain adversely affected emulsifying properties. Extreme reductions in emulsion thickness accompanied the decrease in emulsion capacity resulting from the enzyme treatment. A later study by Beuchat (1977a) which involved the use of a higher concentration of peanut flour than that reported previously (Beuchat et al., 1975) showed that pepsin hydrolysis at pH 2.0 (22 and 50 C) increased emulsion capacities to levels exceeding those of untreated controls subjected to various pH-heat treatments. Emulsion viscosities ranged from thin, pourable consistencies for pepsin and bromelain-hydrolyzed products to thick, mayonnaise-like consistencies for the trypsin hydrolyzates.

Fungal fermentation of peanut flour with each of 5 fungi used in traditional oilseed fermentation processes reduced the emulsion capacity of the flour (Quinn and Beuchat, 1975). Autoclaving a nonfermented peanut flour was even more severe than fermentation in adversely affecting emulsifying properties. Peanut protein isolates produced by ultrafiltration had significantly lower emulsion capacity than soybean and cottonseed products made by the same process (Manak et al., 1980); however, peanut protein isolates extracted with NaOH had twice as much emulsifying capacity as peanut products extracted with $Ca(OH)_2$. Ahmed and Schmidt (1979) found that spray- and freeze-dried peanut protein preparations had similar emulsion capacities and were substantially higher than drum-dried preparations. Freeze-dried peanut protein products stored for 18 months had half the emulsifying capacity of similarly processed, unstored material. Spray-dried peanut protein preparations stored for 24 months had as much emulsifying capacity as the unstored preparation; extending the storage time to 36 months decreased emulsion capacity slightly.

McWatters and Cherry (1975) found that heating full-fat peanut seed in water at 50, 75, 100, and 120 C for 15-180 minutes did not adversely affect emulsion-forming capacity of peanut paste, provided adjustments in emulsion capacity values were made to compensate for moisture increases which occurred during heating. Substantial reductions in protein solubility and changes in structural components of peanuts were noted at the high temperatures. Steam heating peanuts in the form of a finely ground flour, however, caused slight reductions in levels of soluble protein but sharp reductions in emulsion capacity (McWatters and Holmes, 1979b), indicating that the form in which peanut proteins are exposed to moist heat as well as the method of heating can have profound effects on protein structure and behavior.

Foam Formation and Stabilization

Foam formation and stabilization is a surface active function of proteins (Kinsella, 1979; Cherry and McWatters, 1981). A foam is a colloidal system which forms by incorporating air (gas) into a dispersion which contains a soluble surface active agent. Mechanisms by which surfactant proteins form and stabilize foams involve a lowering of surface and interfacial tension at the air/liquid interface and protective film formation around the air bubbles. The pro-

cess of incorporating air by beating or whipping results in partial protein denaturation which aids foam formation by the unfolding of protein molecules and protein-protein interactions which occur. Methods for measuring and factors influencing foaming properties (e.g., protein source, method of preparation, composition, solubility, concentration, pH, temperature, presence of salts, sugars, or lipids, and method of measurement) have been reviewed by Kinsella (1976, 1979).

Lawhon et al. (1972) compared the whipping potential of aqueous extracts from several oilseed flours. The results obtained from the peanut flour tests are shown in Table 7. Increasing the product concentration from 8 to 12% increased foam viscosity of products in distilled water and of all products in citrate-phosphate buffer (pH 3.0) except product A whipped without sugar. Products which had been adjusted to neutral pH (C) produced more viscous foams than comparable products whipped at a pH of minimum protein solubility (A). Foam viscosities were substantially higher when the extracts in either distilled water or pH 3 buffer were whipped with than without sugar. Viscosities were consistently higher in the citrate-phosphate (pH 3.0) buffer products than in comparable foams prepared with distilled water. There were no differences in volume increases due to pH adjustment, product concentration, or liquid medium. The peanut flour extract yielded foam which was significantly higher in viscosity than extracts from soybean, sesame, sunflower, and cottonseed (excluding a glanded cottonseed flour made by the liquid cyclone process).

McWatters et al. (1976) and Cherry et al. (1979) found that adjustments in pH of peanut meal dispersions prior to whipping influenced foam formation and stability (Table 5). The largest increase in foam volume (180-228ml) occurred at pH 1.5; increasing the salt concentration at this pH tended to depress foam formation. At pH 4.0, a point of low protein solubility, foam volume increases of 140-145 ml occurred; differences due to salt concentration were minimal at this pH. At neutral pH (6.7), the smallest increases in foam volume occurred (76-108 ml); foam volume tended to increase as salt concentration increased at this pH. A 2-step pH adjustment from 6.7 → 4.0 → 6.7 improved foaming capacity over the unadjusted sample (pH 6.7). At pH 8.2, a point of high protein solubility, increases in foam volume (96 to 125 ml) were not as great as those occurring at pH 1.5 or 4.0. A 2-step pH adjustment from 6.7 → 4.0 → 8.2 produced greater increases in foam volume (127-141 ml) than dispersions adjusted directly from pH 6.7 → 8.2 (96-125 ml). The foams produced at pH 1.5 were relatively stiff and peaked with small air bubbles; those produced at neutral pH (6.7) were frothy, lacked stiffness, and had large air bubbles. The acidic foams and those prepared from salt suspensions were in most instances the least stable. These data indicate that adjustments in pH and ionic environment should be considered as a possible approach to modifying foaming properties of peanut proteins.

Table 7. Whipping tests on spray-dried extracts from peanut flour in different liquid media. (Lawhon et al., 1972.)

				Distilled Water			pH 3 Buffer		
				Foam Viscosity, cps		Vol. increase	Foam Viscosity, cps		Vol. increase
Product	pH Adjustment after extraction	Product conc., %	pH	w/o sugar	with sugar	with sugar	w/o sugar	with sugar	with sugar
A	none	8	4.05	3,000	16,167	600	14,000	33,833	600
		12	3.86	6,500	30,333	600	7,667	39,000	600
C	neutral	8	6.67	16,500	21,000	600	23,500	38,000	600
		12	6.56	24,167	35,500	600	25,833	46,000	600

Another study by McWatters and Cherry (1977) compared foaming capacities of flours prepared from defatted peanuts, soybeans, peas, and pecans. A 2-step pH adjustment (6.7 → 4.0 → 8.2) produced a 120% increase in volume compared to 100% increases occurring at pH 4.0, 6.7, or a 1-step adjustment from 6.7 → 8.2. Different test conditions (equipment, sample size) than those employed in the earlier study (McWatters et al., 1976) may have accounted for the lack of variation observed due to pH. The types of foams produced by this method were of a thick, egg white-like consistency except at pH 4.0 where thinner foams were formed. Protein solubility was more clearly related to foam consistency than to volume increases.

Sekul et al. (1978) investigated the effect of partially hydrolyzing peanut proteins with papain on their foaming properties. Incorporation of air was achieved by beating 8% dispersions (w/v) of papain-hydrolyzed peanut protein in water in a kitchen-type mixer. Partial hydrolysis of peanut proteins significantly increased foaming capacity and foam volume at all pH levels examined; a 2-step pH adjustment from 6.7 → 4.0 → 8.2 prior to foam formation increased foaming capacity threefold.

Ahmed and Schmidt (1979) investigated the influence of spray, freeze, and drum drying of extracted peanut proteins on their foaming properties. Foaming was accomplished by bubbling N_2 gas at a controlled rate through a 10-ml aliquot of a 2% protein sample in 0.02 M $NaH_2PO_4 \cdot H_2O$-Na_2HPO_4 buffer (pH 7.0). There were no significant differences in foaming capacity of peanut proteins due to drying method. Tests for stability of peanut protein foams showed that those produced from freeze-dried products were the most stable while those from drum-dried products were the least. Spray-dried and freeze-dried peanut protein preparations stored for 24 and 18 months, respectively, showed about 80% foam stability. Extending the storage period to 36 months for the spray-dried protein decreased foam stability to about 8%.

Gelation

Gel formation has been described as a complex phenomenon by which proteins form a structural network or matrix for holding water, flavorings, or other food ingredients (Kinsella, 1976; Schmidt and Illingworth, 1978; Hermansson, 1979; Schmidt, 1981). The preparation of such products as gelatin gels, milk curds, coagulated egg white, and comminuted meats is dependent upon gel-forming properties of proteins. Protein gelation in food processing systems may be induced by the addition of divalent cations (Ca) or by heating and cooling; it occurs as a 2-step process involving partial associative reactions to form the gel network.

Gel-forming properties of arachin, the major storage protein of peanuts, are influenced by protein concentration, heating temperature, heating interval,

cooling temperature of the heated solution, pH, ionic strength, and the dielectric constant of the medium (Kumar et al., 1980). Peanut protein alone has weak gelation properties but forms strong gels upon heating when combined at low concentrations with a whey protein gel matrix (Schmidt et al., 1978; Schmidt, 1981). Sodium chloride, $CaCl_2$, and cysteine adversely affect gel strength of protein dispersions containing only peanut flour but are less detrimental when whey protein concentrate is present in the gel system. Both thickening (aggregation) and gelation properties are important to the structure of many cultured dairy systems; dispersions of peanut proteins in the form of lipoprotein concentrate or flour increase considerably in viscosity with heating (Schmidt, 1978, 1981). In systems which contain peanut proteins in combination with nonfat dry milk, Ca-caseinate, or Na-caseinate, a range of viscosities is possible depending upon the choice of milk protein selected as a blending agent.

Seed origin and processing methods also influence gelation properties of oilseed proteins. Peanut protein isolate produced by extraction with $Ca(OH)_2$ and ultrafiltration had significantly greater gel strength than similarly-processed soy and cottonseed isolates or those extracted with NaOH (Manak et al., 1980). Sundar and Rao (1978) determined that the method of extraction, protein concentration, and addition of Ca^{++} also affected gelation characteristics of peanut proteins. Gels formed by H_3PO_4 - extracted protein at 22.5% concentration in the presence of Ca^{++} at pH 6.5 were firmer than those extracted with alkali or HCl, had a meat-like texture, and could replace up to 30% of the meat in sausages without appreciably affecting color, taste, or texture.

Water Sorption

Studies involving water sorption characteristics of peanut proteins describe adsorptive and absorptive properties. Hagenmaier (1972), Kinsella (1976, 1979), and Hutton and Campbell (1981) defined water adsorption as the water adsorbed by a dried protein powder after equilibration against water vapor of a known relative humidity. Water absorption, frequently used interchangeably with the term water binding, connotes that water which is retained by a protein following filtration and application of mild pressure of centrifugal force. Interactions of protein with water, particularly absorptive reactions, vary with protein source, composition, the presence of other hydrophilic compounds, lipids, pH, salts, and processing conditions.

Peanut protein isolate produced by extraction with NaOH and ultrafiltration absorbed up to 74.7% of its original weight in water, which was significantly greater than similarly processed soy and cottonseed isolates or peanut, soy, and cottonseed isolates extracted with $Ca(OH)_2$ (Manak et al., 1980). Hagenmaier (1972) demonstrated that animal proteins could bind more water and were lower in amide nitrogen than oilseed proteins; he suggested that deamidation of oilseed proteins might substantially increase their water binding potential and usefulness in food applications requiring more hygroscopic proteins.

Various treatments have been employed to modify water sorption properties of peanut proteins. Beuchat et al. (1975) determined that enzyme hydrolysis of peanut flour with pepsin, bromelain, and trypsin increased water adsorption

properties of the flour but decreased water absorption (liquid retention) capacity; adjusting the pH to levels below or above 6.9 also improved water adsorption properties. Increases of 80-100% in water binding capacity were achieved by adjusting the pH of peanut flour to 2.0 prior to heating; this treatment required peanut proteins to pass through their isoelectric pH range and was more effective than enzyme hydrolysis in enhancing the hydrophilic properties of the flour (Beuchat, 1977a). Reacting peanut flour with various amounts of succinic anhydride (10, 40, 70, 100, and 130% of the weight of protein in the suspension) at pH 7.4-8.0 also increased water absorption and adsorption properties (Beuchat, 1977b). Fermentation of peanut flour with fungi employed in traditional oilseed fermentation processes had little effect on water adsorption properties at equilibrium relative humidities below 75%; above this level, however, the ferments, particularly flours treated with *Aspergillus oryzae* and *Neurospora sitophila*, adsorbed more water than nonfermented controls. Fermented peanut flours were consistently more hydrophilic than lipophilic (Quinn and Beuchat, 1975).

Oil Absorption

Methods used to measure oil absorption properties of proteins relate to physical entrapment of oil; oil is mixed with protein, the mixture is centrifuged, and the volume of retained oil is determined (Kinsella, 1976, 1979; Hutton and Campbell, 1981). Interactions of peanut protein with oil have not been investigated extensively, but pH, enzyme hydrolysis, succinylation, and methods of extraction have been shown to influence oil absorption properties. Beuchat et al. (1975) determined that heating enzyme-treated and nontreated peanut flour dispersions at pH 4.5 and 7.6 enhanced oil retention capacity whereas no improvement was shown at pH 2.0. Flours subjected to enzyme hydrolysis were more lipophilic than hydrophilic. Succinylation of peanut flour improved oil retention properties over the untreated control; the mildest succinylation treatments (10 and 40% levels, based on the weight of protein in the suspension) produced highest oil retention values (Beuchat, 1977b). Peanut protein isolate extracted with $Ca(OH)_2$ and processed by ultrafiltration had higher oil absorption capacity than peanut protein isolate extracted with NaOH but was less than that of similarly processed isolates prepared from soybean and cottonseed products (Manak et al., 1980).

POTENTIAL APPLICATIONS

Dairy and Beverage-type Products

Peanut Milk Systems. In India, buffalo milk and cow's milk are extended ("toned") with skim milk powder to increase milk's availability to a larger segment of the population. Efforts to replace imported skim milk powder with indigenously available vegetable protein, namely peanut protein, have resulted in the development of "Miltone," a product which resembles animal milk in composition but costs 15-20% less than skim milk solids-toned milk and 25-30% less than pasteurized full-fat milk (Chandrasekhara et al., 1971; Anonymous, 1977). Miltone is manufactured by mixing peanut protein isolate and

cane sugar with animal milk, minerals, and vitamins, adjusting the fat content to 2%, homogenizing, and pasteurizing. A pasteurized formulation is being used in government feeding programs for school children to provide 30-50% of their daily protein requirement and almost 50% of their vitamin requirements. A sterilized formulation which is sold commerically is shelf stable at room temperature and costs less than many bottled drinks. Miltone has gained consumer acceptance and is suitable for drinking alone or in coffee and tea and for production of curds and yogurt.

The utilization of peanut proteins in some dairy applications may be hindered by the behavior of the proteins in the presence of low levels of divalent ions. The minimum concentration of calcium (0.03 M) proposed for imitation milk would effectively reduce the solubility of peanut protein in the pH range of milk (Rhee et al., 1972). However, protein blends of reasonable solubility and heat stability are possible in milk systems containing peanut protein if Ca^{++} is present at low levels (Schmidt and Mendelsohn, 1977). The use of peanut flour to fortify cow's milk to 15 and 18% total solids causes pseudoplastic (shear thinning) flow behavior at 4 C, but consistency index values of the blends can be raised by increasing the total solids from 15 to 18% and by increasing the temperature used for heating from 70 to 90 C (Schmidt et al., 1980). Heating peanut flour-fortified milk at 85 C or above also decreases sedimentation during refrigerated storage. Pominski and Spadaro (1977) reported that a stable milk-like product could be prepared from peanut flour by suspending the flour in water and heating the slurry. A formula for peanut flour-chocolate malted drink has been developed by Harris et al. (1972).

Fermented Peanut Milk and Yogurt Systems. Fermentation of peanut milk with lactic acid bacteria could yield end-products similar to buttermilk and yogurt and expand marketing potentials for peanut products. Bucker et al. (1979) demonstrated that 6 out of 19 cultures of lactic acid bacteria could ferment peanut milk and that acid production by most cultures could be increased by supplementation of the milk with 1% levels of glucose, sucrose, whey, tryptose, or yeast extract. Invertase treatment of peanut milk also increased acid production by cultures previously unable to ferment untreated milk. Sucrose at 0.63% (w/v) was the major fermentable carbohydrate present in milk. Beuchat and Nail (1978) developed an extraction technique which produced a milk-like substance capable of fermentation with *Lactobacillus bulgaricus* and *L. acidophilus*. Fermented peanut milk containing added sucrose (2%) and flavorings received acceptable sensory ratings and compared favorably with flavored buttermilk; coconut and lemon flavors were particularly compatible. Used as a buttermilk substitute in selected bakery products, fermented peanut milk produced corn muffins which were similar in sensory attributes to muffins made with buttermilk. In layer cakes, an undesirably dark color developed during baking, a characterisitic which would limit the fermented product's use for this particular application.

A primary consideration in the production of yogurt from peanut milk is acceptable organoleptic quality and consumer acceptance. Techniques which have been employed to overcome certain flavor and texture limitations associated with peanut-fortified yogurts include using blends of cow's milk and peanut milk instead of peanut milk alone, using commercial yogurt fruit flavorings (strawberry, raspberry, blueberry, orange) or tomato flavoring, and homogenization to eliminate gritty, chalky textures (Schmidt and Bates, 1976; Schmidt et al., 1977). Schmidt et al. (1980) also used heat treatments above 80 C to effectively reduce syneresis and visual sedimentation in yogurts processed from peanut milk and related the improved texture and body to complex interactions involving protein solubility, hydration, and gelation properties. These workers also noted subtle differences in yogurt quality due to the source and prior processing of peanut flour.

Beverage and Soup Bases. Dry mixes containing oilseed proteins which are easily reconstituted with water for use as beverages or soups are of interest for feeding programs in developing countries. A formulation containing whey solids, defatted peanut flour, soybean oil, and corn syrup solids was developed as a spray-dried, free-flowing powder for this purpose by Holsinger et al. (1978) and contains 20.6% protein, 21.6% fat, 5% ash, 3.5% moisture, 1% fiber and 48.3% carbohydrate. The standardized protein efficiency ratio of the product is 2.0 compared to 2.5 for casein, and its nitrogen solubility is 80% compared to 93% for casein. Served as hot soup and seasoned with chicken flavoring, the product was preferred to an unflavored control and at 15% total solids had a satisfying mouthfeel. A need for further efforts to improve the mixture's shelf life was indicated.

Blending peanut flour with pineapple juice or with citrus seed flour prepared from defatted grapefruit seed meal improves the protein content and nitrogen solubility of the fruit mixtures but increases turbidity (Conkerton and Ory, 1976; Ory et al., 1978). Pineapple/peanut blends resembled non-supplemented pineapple juice in organoleptic and sedimentation characteristics; however, the turbid appearance of the blends indicated that they might be more appropriate for use in cloudy or milk-type beverages or solid foods such as meats, bakery products, dry soup, or gravy mixes than in clear beverages.

Frozen Desserts. Recent developments in utilizing peanuts in ice cream-type products include a dry mix formulation in which the necessary fat system, predominant flavor, and important nutrients are supplied by powdered peanut butter processed from full-fat, roasted peanuts (Hoover, 1977). Water is the only ingredient needed for manufacture of the finished product. Flavored with vanilla, chocolate, or strawberry, the mix may be hydrated, pasteurized, and homogenized for packaging and distribution as a refrigerated milk-type beverage or frozen as an ice cream-type product. Both forms of the product were rated as highly acceptable in sensory evaluations. Defatted and partially defatted peanut flour may also be used to prepare the mix, but additional fat must be added to the formula to achieve desirable overrun and mouthfeel.

Soft-serve frozen desserts may also be prepared with peanut protein isolate used as a replacement for milk solids-not-fat (MSNF); the isolate is produced directly from defatted peanut flour extracts by a membrane isolation process which employs ultrafiltration membranes (Lawhon et al., 1980). It replaced MSNF at the 80% level without textural change in the finished product, at the 60% level without loss in overall acceptability, desirable flavor and odor, and at the 40% level without color loss. Peanut protein isolate may compete with whey solids, which are frequently employed as an alternative to MSNF in frozen desserts.

Nonfermented Cheese Analogs. The manufacture of cheese analogs using plant-derived protein and oil to replace more costly milk-derived protein and

fat is a means of extending cheese supplies and lowering the cost of some types. Peanut protein isolate substituted for dairy protein (caseinate) and peanut oil for milk fat were successfully utilized in the manufacture of nonfermented cheese analogs (Chen et al., 1979). The amount and type of peanut protein had a greater influence on textural quality of the analogs than fat or emulsifying salts. Caseinate, which controls rheological and melting properties of cheese, could be replaced at 40-50% levels with peanut protein isolate to produce analogs resembling cheddar, mozzarella, and process cheese. An 85% casein replacement produced other types of analogs suitable for use as cream cheese and cheese spread products.

Meat Products

Utilization of plant proteins, particularly those of soybeans, as ingredients in meat products may be a means of reducing production costs and extending meat supplies. Meat products which are formulated with plant proteins generally have less cooking loss than all-meat products, but consumer attitudes, government restrictions, and organoleptic considerations limit the levels at which some forms of these additives may be used. Present economic considerations (government support programs and cost of processing) do not favor the use of peanut protein products in meats as compared to soybean protein, but several potential applications have been explored in the event that beneficial changes in economic conditions occur.

Ground Beef Patties. Peanut protein used in the form of drum-dried peanut flakes at 5 and 10% levels in ground beef patties increased the tenderness and cohesiveness of the patties but did not affect juiciness (Cross and Nichols, 1979). Patties containing defatted peanut grits manufactured by a prepress, solvent extraction procedure and evaluated by panelists for raw and cooked appearance and for texture and flavor were judged either superior to those containing soy protein or showed no difference in overall rating; they compared favorably with soy grits and textured vegetable protein in reducing cooking loss and lateral shrinkage over all-beef controls (Ayres and Davenport, 1977). McWatters and Heaton (1979) found that ground beef patties extended with solvent-extracted peanut meal were more tender and had higher cooked yields and greater water retention than all-beef controls; they were also lighter in color in the uncooked state than all-beef patties, a factor to be considered in marketing raw meat mixtures of this type, as in supermarket sales of fresh meat. Steaming peanut meal for 30 minutes at 100 C effectively improved the aroma and flavor of patties in which it was incorporated without adversely affecting its binding properties. Sensory attributes of ground beef patties containing 5, 10, or 15% levels of steamed peanut, soybean, or cowpea meal were influenced to a greater degree by meal concentration than type of meal; in general, use of the meals at the 5% level caused no adverse changes in sensory quality (McWatters, 1977).

Extrusion processing of defatted peanut flour produces extrudates which are similar to textured soy protein in water retention, hardness characteristics, and capacity to retain structural integrity upon retorting (Aquilera et al., 1980). Meat patties containing textured peanut protein (30:70 hydrated textured protein to meat ratio) were as acceptable in organoleptic characteristics as all-meat patties and had lower cooking losses and shrinkage. Flavor considerations may limit the use of higher levels of textured peanut protein in meat patties.

Meat and Luncheon Loaves. Hwang and Carpenter (1975) evaluated the performance of several high protein additives, including solvent-extracted peanut grits and flour, in a meat loaf formulation and concluded that the additives, by virtue of their high protein content, are overrated in their ability to hold water. Each additive held water during chopping, the first stage of loaf preparation, but did not retain the water during cooking. The peanut and soybean proteins used in the study had substantially lower nitrogen solubility indices than the nonfat dry milk also evaluated, indicating that variations in protein origin and preparation conditions contribute to a protein's functionality and performance in food systems. Torgersen and Toledo (1977) also demonstrated variations in physical properties of proteins from different sources which were used as additives in a luncheon loaf formulation; peanut flour, whey protein concentrate, single cell protein, and chicken meat protein exhibited different rates of water absorption, solubility characteristics, and gel-forming properties. These workers suggested that a profile of solubility change with temperature appeared to be a better indicator of functionality than solubility at a single temperature; proteins that showed good binding properties in a luncheon loaf system were those that possessed the combined qualities of good gel strength, high water absorption capacity at 90 C, and increasing solubility with increasing temperature.

Peanut flakes produced by drum drying have been successfully utilized to replace at least 20% by weight of the meat in meat loaf without significantly affecting acceptability; formulations for boneless chicken and turkey rolls containing up to 50% peanut flakes have also been developed (Mitchell and Malphrus, 1968, 1972). A home recipe for meat loaf which utilized partially defatted peanut grit or meal manufactured by an oil expeller process was developed by Harris et al. (1972).

Frankfurters. Defatted peanut grits manufactured by a prepress, solvent extraction procedure were substituted at 0, 15, and 30% levels on a rehydrated basis for beef trimmings in the manufacture of frankfurters (Joseph et al., 1978). Cooking losses decreased and protein content increased with the addition of peanut grits, but musty and cereal-like flavors, soft texture, and pale color were noted by taste panelists, particularly at the high substitution level. However, these problems were considered minimal since frankfurter processing characteristics, many palatability attributes, and microbial considerations were not adversely affected by the addition of peanut grits.

Meat Analogs. Formulations for meat analogs of the bologna type prepared by comminution of meat and drum-dried peanut flakes have been developed by Mitchell and Malphrus (1972). Meat analogs may also be manufactured from edible fibers derived from plant proteins and produced by a wet spinning process; the fibers have structures which simulate the fibrous structure of meat tissues and, therefore, lend themselves to production of meat-like products or analogs. Techniques for producing fibers from peanut proteins have been developed by Fletcher and Ahmed (1977), who determined that the suitability of dope solutions for spinning was dependent upon interactions between protein concentration, pH, and dope maturity. The mechanical strength of the resulting fibers was also characterized (Ahmed and Fletcher, 1977).

Breads

White and Whole Wheat. Bread is a universally consumed food and, therefore, is frequently employed as a test system to evaluate the baking performance of nonwheat flours. This typically involves replacing wheat flour, nonfat dry milk solids, or eggs with nonwheat flour and measuring certain physical properties of the dough and quality characteristics of the baked product. The lack of gluten in nonwheat flours limits their usage in breads since their protein components do not possess the cohesive, elastic, and structure-forming characteristics of wheat flour proteins. The compatibility of oilseed protein products and wheat flour depends upon the type of oilseed, method of processing, the type of baking system used, and quality and quantity of wheat flour protein (Khan et al., 1978).

Matthews et al. (1970) determined that a 25% replacement of wheat flour with peanut and other oilseed flours increased absorption and decreased mixing tolerance of the doughs; modifications in preparations, i.e., increasing the fluidity of doughs and reducing mixing time, were suggested as means of improving bread quality. Roasting peanuts prior to flour preparation increased dough strength and improved breadmaking quality. Rooney et al. (1972) also reported that oilseed flours in bread formulas increased water absorption and that heat treatment improved dough mixing strength and stability. Peanut and sesame flours were more compatible with wheat flour for bread baking than sunflower or cottonseed flours and produced bread with good loaf volume and acceptable interior properties at both protein levels tested (17.5 and 20.0%). The quality of baked products was slightly impaired when heated peanut and sesame flours were used; a dark crumb color was produced.

Khan et al. (1978) determined that heated, low-fat peanut flour used at 15-20% levels in breads had better baking properties than unheated low, medium, or full-fat peanut flours. Bread made with heated peanut flour had acceptable aroma and flavor as fresh or toasted bread whereas bread made with unheated peanut flour required toasting to improve these sensory attributes. Protein content of bread was increased by the addition of peanut flour, and baking performance was not affected by variations in the oil content of peanut flours which ranged from 1 to 19%. Harris et al. (1972) also reported that commercial-type yeast bread containing roasted, solvent-extracted peanut flour had desirable organoleptic quality.

Khan and Rooney (1977) demonstrated that the type of baking system employed influenced baking properties of oilseed flours; breads baked by a short-time dough system had a higher loaf volume and darker crust color than similar oilseed flour products baked by a straight dough procedure. Use of a dough conditioner, sodium stearoyl-2-lactylate, in oilseed flour formulas improved crumb color and crumb grain scores. Lorenz and Maga (1972) determined that fermentation and proofing times for breads containing peanut and other high-protein flours could be reduced and bread volume, grain, texture, crumb color, and flavor improved by producing the breads under reduced atmospheric pressures. Baking at reduced atmospheric pressure conditions caused partial loss of many objectionable flavor components of the high-protein supplements which resulted in improved aroma and flavor characteristics. Taste panelists could detect and identify the high-protein additives used at the 15% level in breads baked at 765 mm Hg but not those baked at 525 mm Hg.

Methods by which peanut proteins are produced may also influence their bread-baking characteristics. Breads made with peanut protein concentrates manufactured by an aqueous extraction process were superior in flavor and crumb color to bread which contained defatted peanut flour made by a prepress, solvent extraction procedure or full-fat soy flour (Khan et al., 1975); however, use of the aqueous processed concentrates at levels higher than 10% significantly reduced bread loaf volume. Peanut protein isolates prepared by an alkaline extraction and ultrafiltration process and used at an 8% level produced bread with good loaf volume but poor crumb characteristics (tough texture and open grain); however, the peanut isolates had better overall baking properties than similarly processed soy and cottonseed isolates, indicating variations in baking properties due to seed source (Khan and Lawhon, 1980).

Ory and Conkerton (1978) used a white-testa peanut flour processed without removal of the testa (Conkerton and Ory, 1976) to replace 10% of the wheat flour in bread. Loaf volume and texture were not adversely affected; protein content, moisture retention, crust browning, and concentrations of certain metals increased.

Most studies of the bread-baking properties of oilseed flours have been approached from the standpoint of determining levels at which wheat flour could be replaced, or the gluten component diluted, without significant alterations in overall quality and acceptability. Another method, however, is to leave the level of wheat flour intact and to replace primary protein sources in bread formulas (e.g., milk or eggs) with protein derived from oilseed flours. Ayres and Davenport (1977) used this approach to evaluate the bread-baking properties of a prepress, solvent-extracted peanut flour which replaced total nonfat dry milk solids in white bread and total nonfat dry milk solids plus whole eggs in whole wheat bread. Peanut flour breads were described as having a light, resilient texture, uniform crust browning, and acceptable loaf volume. Taste panelists reportedly found no significant difference between the flavor and the appearance of breads made with either nonfat dry milk solids or peanut flour.

Specialty Breads. Low-sodium breads are of interest to individuals who, because of certain health considerations, must restrict their consumption of sodium. Lorenz et al. (1971) used high-protein, low-sodium peanut, soybean, and cottonseed flours to produce low-sodium breads as a means of adding nutritive quality and variety to sodium-restricted diets. Peanut and soy flour doughs were smooth and pliable and machined well. Fewer changes in bread quality, i.e., loaf volume, grain, crust and crumb color, texture, and flavor, were noted in formulas containing 5% peanut flour than in those made with 10%.

Chapati is a bland, unleavened bread made with whole wheat flour and consumed extensively in India. Incorporation of peanut and other high-protein oilseed flours into chapatis could provide a means of improving the protein quality of cereal-based Indian diets. Bhat and Vivian (1980) determined that peanut and soy flours used at 10 and 20% whole wheat flour replacement levels produced chapatis which were nutritionally superior and as acceptable in sensory quality characteristics as those made from 100% whole wheat flour. Chapatis with improved nutritional quality may also be prepared from blends of cornmeal and peanut flour (Bookwalter et al., 1978). Additional water was

needed to maintain workable doughs as levels of peanut flour in the cornmeal blends increased. Increasing the level of peanut flour also improved dough cohesion and pliability, increased darkening of dough and crumb colors, increased gas retention, and increased texture smoothness and tenderness. Acceptable chapatis were made with blends containing as much as 20% defatted peanut flour. Recipes for using peanut flour in nut bread, date nut loaf, banana bread, apricot bread, french onion bread, biscuits, and scones have been developed by Harris et al. (1972).

Corn Bread, Corn Muffins. Blends of cornmeal and defatted peanut flour used to prepare chemically leavened corn bread produced few changes in batter viscosity, grain, and texture when the level of peanut flour was 20% or less (Bookwalter et al., 1978). Crumb color darkened slightly with increasing amounts of peanut flour, but increases in openness of grain and texture coarseness were apparent only at the 35 and 50% peanut flour levels. Acceptable corn bread was made with blends containing as much as 20% peanut flour.

Cornmeal muffins were successfully fortified with defatted peanut flour without adversely affecting sensory quality (Ahmed and Araujo, 1978). Fortification with peanut flour produced muffins with 2-3 times as much nitrogen and about twice as much ash as unfortified muffins. Peanut flour muffins were similar to conventional corn muffins in color measurements for lightness, redness, and yellowness and in sensory acceptability.

Other Bakery Products

Bakery products such as cookies, cakes, and doughnuts are popular foods which add variety and palatability to the diet. It has been suggested that the traditional role of wheat-based snack or dessert foods should be reassessed in light of changing dietary patterns and life styles and that items of this type should be considered as important carriers of nutrients (Ranhotra et al., 1980).

Cookies. Cookies which contain 15% protein and substantial amounts of important minerals and vitamins may be made with soybean flour, using peanut butter and increased amounts of sweeteners to offset the soybean's undesirable flavor and to improve cookie spread (Ranhotra et al., 1980). Sensory acceptability was fair, and several alternatives for improving acceptability were suggested, i.e., addition of flavoring, chocolate chips, nuts, or oatmeal, addition of dough conditioners, and reduction in level of soybean flour and shortening.

Sugar cookies were successfully prepared with 10, 20, or 30% defatted peanut flour substituted for wheat flour without adversely affecting dough handling, diameter, height, spread characteristics, and sensory quality attributes (McWatters, 1978). Total protein content of the cookies was increased by about 1.5% with each increment of peanut flour; cookies made with 30% peanut flour contained 8.9% protein, which was twice that of 100% wheat flour control cookies. Beuchat (1977c) determined that certain baking properties of sugar cookies which were adversely affected by the addition of a commercial solvent-extracted peanut flour were improved by pH and enzyme treatments of the flour; cookies prepared with the modified peanut flours generally received high ratings for sensory attributes.

Macaroon cookies are made from ground almonds (almond paste), sugar, and egg white and may also contain coconut. McWatters and Heaton (1974) determined that paste prepared from peanut seed which had been heated in water at various times and temperatures could be substituted for almond paste in a macaroon cookie formula and that the handling properties of peanut paste and baked cookie quality were influenced by the conditions of moist heating. Cookies having the highest overall quality were those prepared from peanuts which had been heated in water at 82 C for 30-45 minutes or at 100 C for 15 minutes; the moisture content of these pastes ranged from 23-27%. Moist heat treatment of peanuts may provide outlets for utilizing peanuts other than as dry roasted items. Harris et al. (1972) developed several dry mixes and home recipes for using peanut flour in cookies; these included formulations for chocolate, peanut butter, oatmeal, and peanut-maple cookies and several kinds of brownies.

Cakes. Factors which affect the use of peanut flour in cakes include compatibility with other ingredients, physical characteristics of batter, and quality characteristics of the baked product. As with breads, a portion of the wheat flour is usually replaced with nonwheat flours to measure effects on overall quality. Increases in water absorption, development time, and stability have been noted in cake mixes supplemented with peanut, soybean, or sweet potato flour; no changes in cake volume occurred when these flours were used at the 15% level. Sensory evaluations indicated that acceptable products could be produced with 10% peanut flour whereas higher levels of sweet potato and soy flours could be used (Abdel-Baki et al., 1980; El-Samahy et al., 1980). Storage studies conducted on dry cake mixes indicated that those containing peanut flour were acceptable for 21 days when packaged in aluminum foil alone and for 135 days when aluminum foil plus polyethylene was used as the packaging material (Morad et al., 1980). Dry mixes and home recipes for using peanut flour in applesauce cake and chocolate cake were developed by Harris et al. (1972).

Doughnuts, Sweet Yeast Products. Lawhon et al. (1975) investigated the suitability of using peanut flour and other oilseed flours at 18, 22, and 26% protein levels in cake doughnuts and found that doughs containing the nonwheat flours did not require a floor time (rest period) after rolling and, therefore, could be cut immediately. Peanut-fortified doughnuts were not rated as high in acceptabiity as doughnuts containing the other flours, probably because of the high fiber content of the peanut flour which had been prepared from unblanched peanuts. Ayres and Davenport (1977) used an edible-grade, solvent-extracted peanut flour as a total replacement for nonfat dry milk solids and as a partial replacement for whole eggs in yeast-raised doughnuts. The fried product was described as having a rich crumb and surface color, and taste panelists could not distinguish between doughnuts containing nonfat dry milk solids and those made with peanut flour in evaluations for flavor and appearance. Harris et al. (1972) developed several home recipes for using peanut flour in sweet yeast products including honey, cinnamon, or caramel twists; orange or cinnamon rolls; and honey-orange bread.

Snack Products

Oil and dry roasted peanuts are well-established snack foods, but the con-

version of peanuts to new forms such as chips or extruded foods may extend their usefulness to an even greater extent in this segment of the food market. Chip-like products may be prepared from peanut meal either with (R. J. Reynolds Tobacco Co., 1969; Brown and Sinclair, 1971) or without (McWatters and Heaton, 1972; McWatters and Cherry, 1980) added binders; these types of products are similar to potato or corn chips but contain substantially higher levels of protein. Processing conditions employed in the manufacture of peanut flours for chip preparation influence their binding capacity, protein character, chip processing characteristics, and end product quality (McWatters and Cherry, 1980).

Successful extrusion processing of snack foods which utilize high protein ingredients such as peanut flour depends largely upon expansion or puffing characteristics which influence product density and tenderness. Ayres and Davenport (1977) determined that acceptable, high protein corn curl snacks can be produced with 15-20% defatted peanut flour without significantly affecting bulk density or flavor. Bongirwar et al. (1979) reported that combinations of defatted peanut/soybean flour and cereal/gram flour were suitable for extrusion processing of protein-fortified, ready-to-eat foods and described optimal processing conditions (extrusion temperature, flour moisture content, screw conveyor speed, and retention time).

Partially defatted peanuts which are substantially lower in calorie content than full-fat peanuts are of interest as a snack food. They are manufactured by hydraulic pressing of raw seed, restoration to their original size and shape by heating in water, drying, roasting in hot air or oil, and salting (Vix et al., 1967). As much as 80% of the oil can be removed by this process, and snack-type peanuts with over 50% of the oil removed are being produced commercially.

Breakfast Cereals, Gruels

Breakfast cereal with 21% protein can be produced by extrusion processing of prepress, solvent-extracted peanut flour with corn or oat flour (Ayres and Davenport, 1977). Peanut flour expanded easily during extrusion processing, had a low flavor profile, and did not increase the bulk density of the finished product substantially. Spadaro et al. (1971) reported that peanut flour extruded with white and brown rice yielded extrudates which, when comminuted, produced a high protein breakfast cereal; the brown rice, grits, and peanut flour combinations were among those judged to be the most acceptable by taste panelists. Harris et al. (1972) developed formulations for breakfast cereal flakes containing defatted peanut flour which compared favorably with commercial flakes.

Blends of degermed cornmeal and defatted peanut flour were evaluated in the form of cooked gruels (10% solids) to determine the amount of peanut flour which could be used without changing organoleptic characteristics (Bookwalter et al., 1978). Taste panel results indicated no significant change in preference, acceptability, and similarity to cornmeal when as much as 20% peanut flour was contained in the blend. Mixtures of partially or fully gelatinized cornmeal, nonfat dry milk, soybean oil, vitamins, and minerals which were fortified with defatted or partially defatted peanut flours and evaluated as

gruels (10% solids) had satisfactory nutritional value, organoleptic quality, and storage stability (Bookwalter et al., 1979). These types of formulations have been developed for use in food aid programs to alleviate hunger and malnutrition.

SUMMARY

Interest in the potential of peanut seed as a source of food protein has been stimulated by (1) improved protein extraction, fractionation, and characterization techniques; (2) the availability of technologies to produce high quality protein products; and (3) a better understanding of their physicochemical, functional, and nutritional characteristics. This chapter has focused upon the physicochemical properties, production technology, functional properties, and potential food applications of peanut seed proteins. Further expansion in the processing and utilization of these components may be constrained by economic conditions rather than by limitations in their functionality, nutritional quality, or consumer acceptability. Should changes occur to improve the competitive position of peanuts, the potential contributions of the protein components may be realized.

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Chapter 19

PEANUT MARKETING

DON W. SANDS

The marketing process for peanuts in the United States is best understood in the context of the governmental regulatory environment. All segments of the peanut industry must be keenly aware of the specific procedures and practices which are required in the marketing of peanuts. The laws which govern contracting, poundage quotas, sampling, grading, storage, shelling and packaging are reviewed in this chapter and in Chapter 15.

The marketing of peanuts should be seen as an extended process which includes the farmers' planting and contracting decisions, the harvesting and delivery of the peanuts to a peanut handler or sheller, the handling and shelling of the peanuts to conform to quality requirements and potential buyers' specifications, and finally the sale and distribution of the peanuts into the marketplace.

In recent years, the peanut industry has adopted a classical view of product definition, i.e., one in which the specific needs of the marketplace have been established. Moreover, changes in consumption patterns, new peanut varieties and developments in processing technology have demanded marketing flexibility. The market itself has three sectors: (1) domestic edible peanuts, (2) export peanuts, and (3) crushing stock peanuts. Since 1980, these markets have been influenced more than ever by changing supply and demand factors which directly influence price.

Because of market factors as well as weather and production variables, each segment of the market is faced with a degree of risk. Farmers, shellers, and processors face different uncertainties, but all try to make marketing decisions which will reduce some of their risk. In making these decisions, the farmer, sheller or processor must evaluate the interrelationship between the factors and stages in the entire marketing process.

THE ROLE OF THE UNITED STATES GOVERNMENT

Laws and Regulations

In 1938, the United States Congress passed the Agricultural Adjustment Act which first established the government's role in the United States peanut industry. Under this legislation, the United States government established an acreage quota system whereby designated farmers were permitted to grow peanuts on a specific number of acres. Except for a brief period during World War II when everybody was encouraged to grow peanuts, the United States government limited the amount of peanuts grown in the United States to the quantity produced on approximately 1,610,000 acres. Beginning in 1938, the United