Variation of Flavor-Related Characteristics of Peanuts during Roasting As Affected by Initial Moisture Contents

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Two lots of mature peanut kernels containing 3.40 and 10.50% moisture were roasted at 150 °C for 45 min. Hunter *a* values of the roasted unskinned kernels increased while *L* and *b* values decreased with time. The change of visual color in peanuts containing 10.50% moisture was more pronounced than that of peanuts containing 3.40% moisture. Total carbohydrate and glucose contents were higher in peanuts in the early stage of roasting compared to contents before roasting. Free amino acid contents in peanuts after 10 min of roasting were higher than contents in unroasted peanuts. Changes in specific amino acid content depended upon time of roasting and initial moisture content. SDS–PAGE analysis revealed that protein patterns varied quantitatively rather than qualitatively during the course of heat treatment. Proteins in peanuts containing 10.50% moisture were less heat resistant.

INTRODUCTION

Free amino acids and monosaccharides are essential flavor precursors for the development of unique "peanutty" flavors during roasting of peanut kernels (Newell et al., 1967; Mason et al., 1969). Specific amino acids in raw peanuts have been classified as the typical or atypical flavor precursors (Newell et al., 1967). Most research attention has been directed toward comparing amounts of precursors in raw peanuts and roasted peanut products. Knowledge concerning detailed variations in free amino acid composition, monosaccharide content, and other flavor-related components during the roasting process is limited.

Free amino acids and monosaccharides, the building blocks of polypeptides and complex carbohydrates in peanuts, are released from these respective macromolecules through undefined processes resulting from hydrolysis under specific conditions during roasting. The precursor content may increase due to hydrolysis and then decrease due to involvement in further chemical reactions. Consequently, the original precursor content in raw peanuts may not solely govern the final flavor quality of roasted peanuts or peanut products. An optimized roasting process and/or an appropriate pretreatment of the raw peanuts, such as adjustment of moisture content, may cause a substantial release of the precursors during roasting and significantly enhance the formation of desirable peanutty flavors. Therefore, from the viewpoint of peanut scientists and processors, it is of interest and importance to gain an in-depth understanding of changes in peanut flavor precursors during roasting.

In this study, the objective was to investigate changes in free amino acid composition, total α-amino nitrogen, and total soluble carbohydrate and glucose content in peanut kernels during roasting as affected by two initial moisture contents. Changes in the internal temperature, moisture content, color, and protein patterns of these peanuts were studied.

MATERIALS AND METHODS

Peanuts. Freshly dug peanuts (Tainan 9, a Spanish cultivar) were classified into three hull-scrape maturity classes (Drexler and Williams, 1981), i.e., mature class with black exocarp, intermediate class with orange or brown exocarp, and immature class with yellow exocarp. Mature peanuts were dried with ambient air under sunlight, hand shelled, and sorted according to size. Kernels of medium size (6–8 × 10–12 mm) were vacuum packaged in polyethylene/nylon laminated bags and stored at −14 °C until used in the roasting experiments. For each experiment, peanuts were removed from the freezer and tempered at room temperature overnight before opening the bags.

Moisture Content Conditioning. Peanut kernels were stored over saturated CH_3COOK (A_w 0.227, 25 °C) and $(NH_4)_2SO_4$ (A_w 0.800, 25 °C) solutions in desiccators at 4 °C to achieve desirable moisture contents. After 4 weeks of conditioning, the average moisture contents of the peanuts were 3.40 ● 0.30 and 10.50 ± 0.50%, respectively (dry weight basis, measured by drying ground peanut meals in an oven at 105–110 °C until their constant weights were reached).

Procedures for Roasting and Determining Moisture Content, Internal Temperature, and Color. Peanuts (11 kernels per batch) adjusted to two moisture contents were weighed and placed in a stainless steel net basket (ca. 100 cm^2 of the base area), hung in the central part of a forced-air oven at 150 °C, and roasted for 0, 3, 5, 10, 20, or 45 min.

After roasting, the kernels were cooled in a desiccator and weights were measured to determine the weight loss due to water evaporation. Moisture contents were calculated on a dry weight basis. Kernels were then lyophilized (Lab Conco Freeze Drier 80) and stored in brown vials at −14 °C until further analyses.

To determine the internal temperature of kernels, a thermocouple (Omega 36 K-type wire) was inserted into the center of one cotyledon of each of four kernels at a position just beneath the inner surface of its counterpart cotyledon. The internal temperature of kernels roasted at 150 °C for 45 min was simultaneously monitored with a multichannel recorder (Yokogawa 4156, Japan).

The color of the unskinned, deskinned raw, and roasted kernels was measured with a color difference meter (Nippon Denshoku 80 color difference meter, Japan) in terms of the Hunter *L*, *a*, and *b* values. The values for each kernel were obtained from the side-view position (Tsai et al., 1988). Eleven kernels from each lot were examined, and two determinations were obtained from both cotyledons of each kernel.

Preparation of (Methanol–Chloroform–Water) Extract. The procedures reported by Young et al. (1974) and Rodriguez et al. (1989) were followed with minor modification. Deskinned kernels from which hearts were removed were ground with a cyclone mill. Meals were mixed with precooled *n*-hexane (−20 °C) in a ratio of 1:10 (w/v), homogenized at 5000 rpm for 2 min with a homogenizer (ACE homogenizer, Japan), and filtered through a filter paper (Toyo Advantec 2, Japan). The defatted

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meal was sieved (1 mm) and stored at −14 °C until further analysis. The nitrogen content in defatted meal was determined by using the Kjeldahl method (AOAC, 1985). For each meal, 500 mg was extracted with 2.5 mL of methanol–chloroform–water (MCW) (60:25:15 v/v/v) in a cap-sealed centrifuge tube (Nalgene 3119–0010 centrifuge ware) and vigorously rocked with a plate shaker (Shang Chung 4115, Chiayi, Taiwan) for 30 min at 5 °C. The tube was centrifuged at 0 °C for 10 min at 8500*g* (Sigma 2K15 centrifuge). The supernatant was decanted into a test tube emersed in an ice bath. The pellet was resuspended in 2.5 mL of alcohol–water (80:20 v/v), re-extracted in the same manner for 30 min, and centrifuged. The supernatant was combined with the former extract, designated MCW extract, and stored at −14 °C.

Analysis of Total α-Amino Nitrogen and Amino Acid Composition. Total α-amino nitrogen was quantitated according to the ninhydrin method (Moore, 1968) using leucine as a standard. For each test, 50 μL of MCW extract was mixed with 2 mL of deionized water and 0.2 mL of ninhydrin reagent (Sigma N1632) (freshly opened, nitrogen flushed, stopper sealed, and stored in an ice bath), sealed with aluminum foil, and heated for 5 min in a boiling water bath. After the extracts were chilled for 5 min in an ice bath, the absorbance at 570 nm was monitored.

One milliliter of MCW extract in a test tube was placed in a desiccator and vacuum dried overnight at room temperature. The dried residue was dissolved in 1 mL of sodium citrate buffer (0.5 N, Pierce No. 27216, Pierce Chemical Co., Rockford, IL) at pH 2.2 and analyzed for amino acid composition (Beckman System 6300 high-performance amino acid analyzer). Amino acid content was expressed as micrograms per gram of protein in the defatted peanut meal used for MCW extraction.

Determination of Total Soluble Carbohydrate and Glucose. MCW extract (0.1 mL) was vacuum dried in a test tube and rehydrated in 2 mL of deionized water. For each test, 50 μL of solution was mixed with 2 mL of 0.2% anthrone reagent (1 g of anthrone was dissolved in 50 mL of concentrated sulfuric acid and subsequently mixed with 450 mL of sulfuric acid solution which was prepared by adding 300 mL of concentrated sulfuric acid into 150 mL of deionized water) and heated for 10 min in a boiling water bath. After the solutions were chilled for 5 min in an ice bath, absorbance of the mixture at 625 nm was monitored (Yemm and Willis, 1954). Glucose was used as the standard.

MCW extract (0.3 mL) was vacuum dried in a test tube, rehydrated with 0.3 mL of deionized water, mixed with 2 mL of glucose reagent (Merck, West Germany) and incubated at 37 °C for 10 min. Absorbance (510 nm) of the reaction mixture was measured to determine the glucose content (Free, 1963). Glucose was used as the standard.

Electrophoresis of Peanut Proteins. The procedure of Chiou (1990) was followed with minor modification. For each sample, defatted meal (containing 25 mg of protein) was homogenized with 4 mL of phosphate buffer (pH 7.9, 0.2 M) and rinsed with 1 mL of the buffer. After centrifugation (25000*g*, 20 min at 15 °C, Hitachi SCR20B), 0.2 mL of supernatant was mixed with 0.2 mL of SDS reagent and heated at 100 °C for 5 min. Then 5 μL was loaded on a minigel (Bio-Rad Mini-Protein II dual slab cell) (16% polyacrylamide, 7 × 10 cm) and subjected to 200 V for 50 min. The gel was fixed with 20% trichloroacetic acid, stained with Coomassie blue, and destained with an aqueous acetic acid and methanol solution.

Statistics. Duplicate experiments were conducted. At least two samples were analyzed for each determination. Mean values of determinations, with standard deviations or ranges, are given.

RESULTS AND DISCUSSION

Changes in Internal Temperature, Moisture Content, and Color of Peanuts during Roasting. Peanuts containing 3.40 and 10.50% initial moisture contents were roasted for 45 min in an oven at 150 °C, and their internal temperatures and moisture contents were monitored (Figure 1). The initial rate of temperature increase in peanuts containing 3.40% moisture was more rapid than that in peanuts containing 10.50% moisture. When peanuts were roasted for up to 30 min, the internal temperature of low-moisture kernels was higher than that of high-moisture kernels. This is in agreement with the previous observation that the initial rate of temperature increase of peanut splits decreased with an increase of initial moisture content (Chiou and Tsai, 1989). The rate of moisture loss was more rapid in peanuts containing 10.50% moisture compared to that in peanuts containing 3.40% moisture.

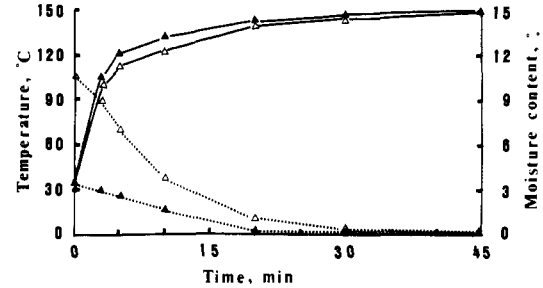

Figure 1. Internal temperature and moisture content profiles of peanut kernels containing two initial moisture contents when roasted at 150 °C: (▲) 3.40% moisture; (△) 10.50% moisture; (—) internal temperature; (- - -) moisture content.

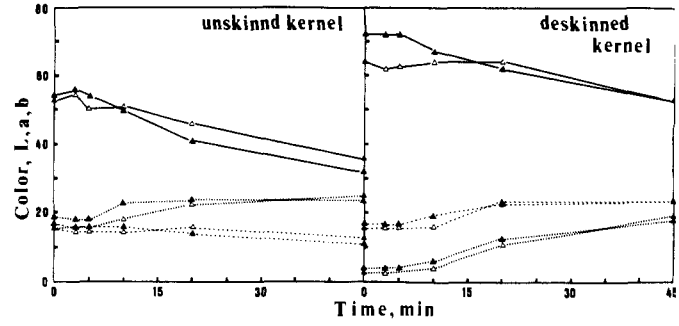

Figure 2. Color measurements of roasted unskinned and deskinned kernels expressed as Hunter *L*, *a*, and *b* values: (▲) 3.40% moisture; (△) 10.50% moisture; (—), *L* value; (···) *a* value; (- - -) *b* value.

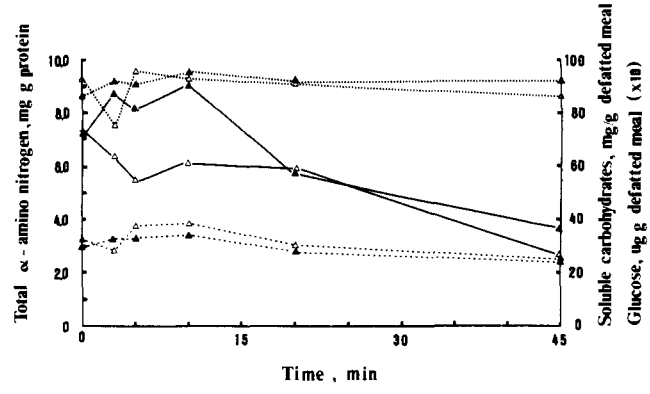

Figure 3. Changes in total α-amino nitrogen, total soluble carbohydrate, and glucose contents of peanut kernels roasted at 150 °C: (▲) 3.40% moisture; (△) 10.50% moisture; (—), α-amino nitrogen; (···) soluble carbohydrate; (- - -) glucose content.

Color characteristics of roasted unskinned and deskinned kernels expressed as Hunter *L*, *a*, and *b* values are presented in Figure 2. After moisture conditioning, Hunter *L*, *a*, and *b* values of unskinned and deskinned kernels containing 10.50% moisture were lower than values of kernels containing 3.40% moisture. This was in agreement with observations reported by Pattee et al. (1982) that Hunter *L*, *a*, and *b* values of the raw red-skinned peanuts with 8.7% moisture were lower than values of peanuts containing 6.7% moisture after 7 months of storage. During roasting of sound kernels at two moisture contents, *a* values increased while *L* and *b* values

Table I. Changes in Free Amino Acid Content of Peanut Kernels at Two Initial Moisture Contents during Roasting

	amino acid, μg/g of protein[a]									
	moisture content, 3.40 ± 30%					moisture content, 10.50 ± 0.50%				
amino acid	0 min roast time	5 min roast time	10 min roast time	20 min roast time	45 min roast time	0 min roast time	5 min roast time	10 min roast time	20 min roast time	45 min roast time
Asp	113 ± 6	141 ± 5	240 ± 6	143 ± 17	104 ± 16	110 ± 6	118 ± 1	134 ± 7	159 ± 37	110 ± 4
Thr	163 ± 1	143 ± 6	174 ± 1	146 ± 5	74 ± 1	140 ± 1	118 ± 1	154 ± 4	106 ± 1	72 ± 15
Ser	264 ± 7	216 ± 5	202 ± 5	155 ± 1	89 ± 4	228 ± 6	181 ± 4	190 ± 7	242 ± 2	87 ± 11
Glu	1856 ± 52	1901 ± 51	1964 ± 51	1216 ± 1	564 ± 22	1784 ± 38	1601 ± 8	1648 ± 17	1457 ± 15	493 ± 70
Pro	215 ± 1	214 ± 7	214 ± 1	207 ± 9	174 ± 1	188 ± 10	182 ± 1	168 ± 12	157 ± 10	133 ± 24
Gly	101 ± 1	85 ± 2	92 ± 1	74 ± 2	48 ± 1	90 ± 4	77 ± 1	92 ± 5	100 ± 1	43 ± 7
Ala	787 ± 66	742 ± 17	712 ± 17	582 ± 10	320 ± 6	773 ± 73	720 ± 6	802 ± 15	739 ± 1	373 ± 54
Cys	179 ± 15	212 ± 2	210 ± 2	15 ± 1	6 ± 1	145 ± 6	157 ± 7	85 ± 4	17 ± 4	10 ± 2
Val	316 ± 6	300 ± 5	293 ± 6	286 ± 4	165 ± 5	264 ± 4	239 ± 1	294 ± 13	272 ± 2	182 ± 31
Met	34 ± 1	34 ± 1	34 ± 2	33 ± 1	24 ± 1	35 ± 1	34 ± 1	38 ± 2	37 ± 2	28 ± 7
Ile	188 ± 2	193 ± 2	182 ± 7	173 ± 1	93 ± 2	166 ± 4	150 ± 1	188 ± 6	150 ± 7	111 ± 26
Leu	134 ± 1	142 ± 1	129 ± 7	129 ± 1	82 ± 10	118 ± 2	110 ± 1	132 ± 16	105 ± 7	62 ± 15
Tyr	163 ± 4	151 ± 1	179 ± 4	176 ± 1	106 ± 4	148 ± 4	142 ± 4	163 ± 17	190 ± 5	120 ± 31
Phe	1237 ± 41	1377 ± 46	2037 ± 9	1369 ± 79	1000 ± 50	1119 ± 12	1107 ± 11	1514 ± 37	1429 ± 72	1076 ± 24
His	79 ± 1	70 ± 4	88 ± 1	56 ± 2	24 ± 1	70 ± 1	67 ± 1	74 ± 2	79 ± 1	24 ± 9
Lys	31 ± 2	29 ± 1	31 ± 1	29 ± 1	16 ± 1	31 ± 1	28 ± 4	33 ± 5	28 ± 1	17 ± 2
Arg	71 ± 2	62 ± 1	74 ± 2	78 ± 1	55 ± 10	76 ± 2	66 ± 2	90 ± 5	90 ± 4	55 ± 7
total	5931	6012	6855	4867	2944	5485	5097	5799	5357	2996
variation	100%	+1.4%	+15.6%	−17.9%	−50.4%	100%	−7.1%	+5.7%	−2.3%	−45.4%

[a] Mean of two determinations from two replicate experiments.

decreased. The change of visual color during roasting of peanuts containing 10.50% moisture was more pronounced than changes in peanuts with 3.40% moisture. For roasted deskinned kernels, a and b values increased while L values decreased with time of roasting. L values of the deskinned kernels containing 3.40% moisture began to decrease significantly after 5 min of roasting. However, for peanuts containing 10.50% moisture, L values decreased slightly within 3 min and then increased with roasting time up to 20 min and subsequently decreased with further roasting. There was no significant influence of initial moisture content on changes in a and b values of deskinned kernels.

Changes in Total Soluble Carbohydrate and Glucose Contents during Roasting of Peanuts. After 4 weeks of moisture conditioning, total soluble carbohydrate and glucose contents were higher in peanuts containing 10.50% moisture than in peanuts containing 3.40% moisture (Figure 3). Pattee et al. (1982) reported that when peanuts containing 6.2–6.3% and 8.7–9.2% moisture were stored, glucose, fructose, inositol, and raffinose contents were higher in peanuts with higher moisture content. During the early stage of roasting, e.g., 5 or 10 min, total carbohydrate and glucose contents were higher than the levels in raw peanuts. In this stage of roasting, changes in total carbohydrate and glucose contents were dependent upon the initial moisture content and time of roasting. The increase in soluble carbohydrate and glucose content undoubtedly resulted from a release of free sugars from complex carbohydrates through hydrolysis. Free sugar concentrations depended on the net balance of products of hydrolysis of complex carbohydrates and rate of subsequent chemical reactions to cause the concentration to decrease. The fact that higher concentrations of free sugars appeared after a specific period of roasting indicates that chemical reactions actively proceeded in the early stage of roasting, subsequently influencing sensory characteristics when peanuts were subjected to a prolonged time of roasting. Most comparisons reported by researchers are made between the raw and well-roasted peanuts. Free sugar content is generally observed to decrease as a result of roasting and is thought to play an important role in the peanut flavor formation during roasting (Newell et al., 1967; Mason et al., 1969; Rodriguez et al., 1989).

Changes in Total α-Amino Nitrogen and Amino Acids. After moisture conditioning, total α-amino nitrogen content (expressed as grams of leucine per gram of protein in the defatted meal) was slightly higher in peanuts containing 10.50% moisture compared to peanuts containing 3.40% (Figure 3). During roasting, the initial moisture content of peanuts played a marked role in affecting changes in the total α-amino nitrogen content. In the early stage of roasting, e.g., after 10 min, total α-amino nitrogen in peanuts containing 3.40% moisture was significantly higher than in unroasted peanuts. However, for peanuts initially containing 10.50% moisture, the total α-amino nitrogen content during roasting was lower than in raw peanuts. Amino nitrogen, mainly in free amino acids, could be released by hydrolysis of polypeptides, resulting in an increase, or otherwise undergo a series of chemical reactions that result in a decrease. The fact that lower α-amino nitrogen content was detected in peanuts containing 10.50% moisture in the early stage of roasting reveals that α-amino nitrogen in peanuts with higher moisture content undergoes further chemical reactions more than α-amino nitrogen in peanuts with lower moisture content. Differences in behavior of peanuts with two initial moisture contents might be related to effects of moisture or internal temperature (Figure 1). Since most of the moisture in peanuts was essentially removed by evaporation after 20 min of roasting, a continued hydrolysis of polypeptides to release amino acids is unlikely. Therefore, after 20 min of roasting, the α-amino nitrogen content decreased significantly with roasting time. The subsequent involvement of the free amino acids in the development of peanut flavor during prolonged roasting, eventually causing a decrease of the α-amino nitrogen content, is likely. This is in agreement with the observations reported by Newell et al. (1967) and Mason et al. (1969).

The free amino acid content during roasting of peanuts containing two initial moisture contents is presented in Table I. The total free amino acid contents, expressed by quantity integration of all amino acid residues, were lower than the total α-amino nitrogen content presented in Figure 3, indicating that the α-amino nitrogen in the MCW extracts was composed of free amino acids as well as other ninhydrin-positive compounds. Before roasting, the total

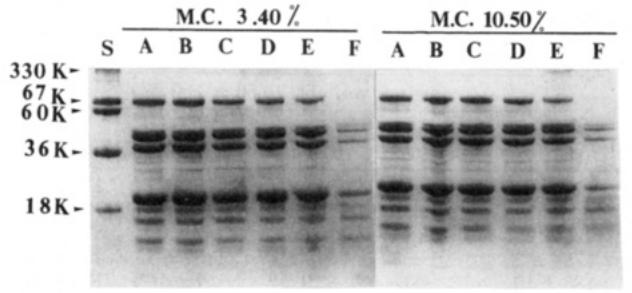

Figure 4. SDS–PAGE protein patterns of peanut kernels roasted at 150 °C: (S) protein marker; (A) 0, (B) 3, (C) 5, (D) 10, (E) 20, and (F) 45 min of roasting.

free amino acid content in peanuts containing 3.40% moisture was higher than the content in peanuts containing 10.50% moisture. This is not in agreement with the observation reported by Pattee et al. (1982), who found that the amounts of most free amino acids are slightly higher in peanuts with higher moisture content. Differences between observations might be due to differences in storage period, peanut cultivar, and methodology. During roasting, a significant increase in the free amino acid content was observed after peanuts containing 3.40% moisture were roasted for 10 min. For peanuts containing 10.50% moisture, the amino acid content decreased slightly after 5 min and increased after 10 min of roasting. After 45 min of roasting, 50.4 and 45.4% of the original free amino acid contents were absent for peanuts containing initial moisture contents of 3.40 and 10.50%, respectively.

When comparisons of specific free amino acids are made, changes can be attributed to the nature of the amino acid, the time of roasting, and the initial moisture content of peanuts. When the initial moisture content was 3.40%, the amounts of all amino acids except serine, proline, glycine, alanine, methionine, and lysine increased compared to original concentrations during roasting, particularly during the early stages. In peanuts initially containing 10.50% moisture, a similar phenomenon was observed for all amino acids except glutamic acid and proline. The increased concentrations of amino acids caused by roasting varied considerably among amino acids and were influenced by time of roasting and the initial moisture content of peanuts.

Glutamic acid accounted for about one-third of the total free amino acids. Its concentration increased significantly in the early stage of roasting and then markedly decreased after 45 min. A considerable amount of phenylalanine was present in peanuts, and significant increases were observed in the early stage of roasting. A direct comparison of peanuts roasted 0 and 45 min indicates that a substantial amount of phenylalanine that was actually involved in the roasting process was not noted due to a considerable amount of the amino acid that remained after 45 min of roasting. Most of the cysteine disappeared after 20 min of roasting. Typical peanut flavor precursors, e.g., aspartic acid, glutamic acid, phenylalanine, and histidine (Newell et al., 1967), generally increased significantly in the early stage of roasting and then decreased with prolonged roasting. A similar trend was noted for atypical peanut flavor precursors, e.g., threonine, tyrosine, and lysine. On the basis of changes in amino acid content during roasting, methionine and lysine were comparatively stable.

Peanut Protein Pattern Variation during Roasting. Results of SDS–PAGE analyses of proteins extracted from roasted peanuts containing two initial moisture contents are presented in Figure 4. In general, peanut proteins varied quantitatively rather than qualitatively when subjected to various heat treatments. However, significant protein denaturation was observed in peanuts after 45 min of roasting. Proteins in peanuts containing 10.50% initial moisture were slightly less heat resistant than proteins in peanuts containing 3.40% moisture. The higher the moisture content of peanuts, the less heat resistant the proteins when subjected to the same heat treatment (Chiou and Tsai, 1989). In the present study, a marked change in the total α-amino nitrogen content and free amino acid profile occurred within 10 min of roasting (Figure 3 and Table I). However, peanut proteins did not simultaneously undergo a significant change during this stage of roasting. During the late stages of roasting, e.g., from 20 to 45 min, most peanut proteins underwent denaturation and became insoluble in the extraction medium.

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Registry No. Asp, 56-84-8; Thr, 72-19-5; Ser, 56-45-1; Glu, 56-86-0; Pro, 147-85-3; Gly, 56-40-6; Ala, 56-41-7; Cys, 52-90-4; Val, 72-18-4; Met, 63-68-3; Ile, 73-32-5; Leu, 61-90-5; Tyr, 60-18-4; Phe, 63-91-2; His, 71-00-1; Lys, 56-87-1; Arg, 74-79-3; H_2O, 7732-18-5; glucose, 50-99-7.