Antioxidative Activity in Oils Prepared from Peanut Kernels Subjected to Various Treatments and Roasting

Robin Y.-Y. Chiou

Department of Food Industry, National Chiayi Institute of Agriculture, Chiayi, Taiwan 60083, Republic of China

Significant antioxidative activity was observed in oil prepared from peanuts subjected to treatments consisting of rehydration, blanching, and dehydration, followed by roasting at 160 °C for 90 min. The activity was close to that of 200 ppm of TBHQ. After storage of the oil at 62 °C for 40 days, the fatty acid composition was unchanged. Changes in lipid and protein contents and amino acid profiles resulting from treatments and roasting were minor. Sucrose and free amino acid contents decreased in a stepwise manner over a limited range with steps of treatment. However, during roasting, more sucrose, total amino acids, and free amino acids were degraded in treated compared to untreated peanuts. Color of the treated, deskinned, and unroasted kernels was darker than that of untreated kernels. During roasting, both types of kernels underwent the same color changes. During storage, linoleic acid was much more susceptible than other fatty acids to oxidation.

INTRODUCTION

Antioxidative activity of natural chemical constituents in plant extracts has been extensively studied (Chang et al., 1977; Bishov and Henick, 1978; Sherwin, 1978; Onyeneho and Hettiarachchy, 1991). Many natural antioxidants are phenols and polyphenols. Other natural substances with antioxidative or synergistic activity include ascorbic acid, amino acids, proteins, and other hydrolysates. The antioxidative activity of tocopherols in foods has been well-known for many years (Stuckey, 1977).

Some antioxidants are not naturally present in foodstuffs but are produced during processing. Maillard browning reaction products formed during heat treatment are of particular interest to food scientists. Long roasting times have been observed to result in increased oxidative stability in peanuts (Cheng et al., 1987; Huang et al., 1988; Chiou et al., 1991b). In general, the longer the roasting time, the more extensive are browning reactions, with resultant decreases in free amino acids and soluble carbohydrates (Chiou et al., 1991b).

Effective, economic treatment of raw foodstuffs for the purpose of enhancing antioxidative activity during processing has not been reported. In this study, the objectives were to determine the effects of rehydration, germination, blanching, and dehydration treatments, as well as roasting time, on the formation of antioxidative activity in peanut oils. An attempt to characterize compositional variation as affected by treatments and roasting and changes in fatty acid composition of peanut oils stored at 62 °C were also investigated.

MATERIALS AND METHODS

Peanut. Freshly harvested, sun-dried, shelled, and manually sorted peanut kernels (Tainan 9, a Spanish cultivar) were packaged in laminated polyethylene/nylon plastic bags and stored at 4 °C for use in this study. The moisture content was 7.5 ± 0.5% (dry basis). Bags were adjusted to room temperature (25–28 °C) overnight before opening. The germination ratio of peanut kernels was 97 ± 3%.

Rehydration, Germination, Blanching, Dehydration, and Roasting. Peanut kernels were soaked with an equal amount (w/w) of tap water at 4 °C for 15–16 h to achieve rehydration. Kernels were then drained, covered with wet cheesecloth, and kept at room temperature (25–28 °C) for 24 h to promote germination. Germinated and control (soaked but not germinated) kernels were blanched by cooking in a boiling water bath for 5 min. After blanching, the kernels were dried in a forced-air oven at 70 ± 2 °C for 22–24 h to reach the original moisture content of 7.5 ± 0.5%.

Roasting of kernels was done in a forced-air oven at 160 °C. Roasting times of 0, 30, 60, and 90 min were administered to kernels subjected to various treatments. A composite experiment to assess the effects of rehydration, germination, blanching, and dehydration on the antioxidative activity of oil in roasted kernels was conducted.

Lipid, Protein, Total and Free Amino Acid, Sucrose, and Glucose Analyses. Freeze-dried, unroasted peanut kernels, with and without pretreatments, were roasted (160 °C for 90 min) and deskinned. Hearts were removed, and kernels were ground with a cyclone mill into meal. The moisture content in each meal was determined by dehydrating the sample in an oven at 105 °C until a constant weight was attained. Crude lipid content was determined according to the Soxhlet method (AOAC, 1985) using *n*-hexane as the extraction solvent. The defatted meal was analyzed for nitrogen content using the Kjeldahl method (AOAC, 1985), and total amino acid profiles were determined (Chiou et al., 1992). Samples subjected to methanol–chloroform–water (MCW) extraction were following the procedures reported by Young et al. (1974), Rodriguez et al. (1989), and Chiou et al. (1991a). For each defatted meal, 500 mg was extracted with 2.5 mL of MCW in a cap-sealed centrifuge tube and vigorously rocked with a plate shaker for 30 min at 5 °C. The tube was centrifuged at 0 °C for 10 min at 8500*g*. The supernatant was decanted into a test tube emersed in an ice bath. The pellet was subsequently resuspended in 2.5 mL of alcohol–water (80:20 v/v) and absolute alcohol, respectively, reextracted in the same manner for 30 min, and centrifuged. The supernatants were combined with the former extract and subjected to quantitation of free amino acid, sucrose, and glucose contents (Chiou et al., 1991a,b).

Color Measurement. Raw peanut kernels and kernels treated by rehydration, blanching at 100 °C for 5 min, and dehydration at 70 °C for 24 h were roasted at 160 °C for 0, 30, 60, and 90 min. After roasting, the kernels were cooled in a desiccator at room temperature, and deskinned manually, and color measurements (L, a, and b values) were determined using a color difference meter (Nippon Denshoku color difference meter, Model 80, Tokyo, Japan).

Peanut Oil Preparation and Determination of Oil Oxidation. Freeze-dried, unroasted kernels as well as roasted kernels were deskinned, and hearts were removed. The splits were wrapped in a nylon net, and oil was expressed by applying a hydraulic press operated at 180–200 kg/cm^2. Oils were sealed in brown glass vials and stored at −25 °C until analyzed.

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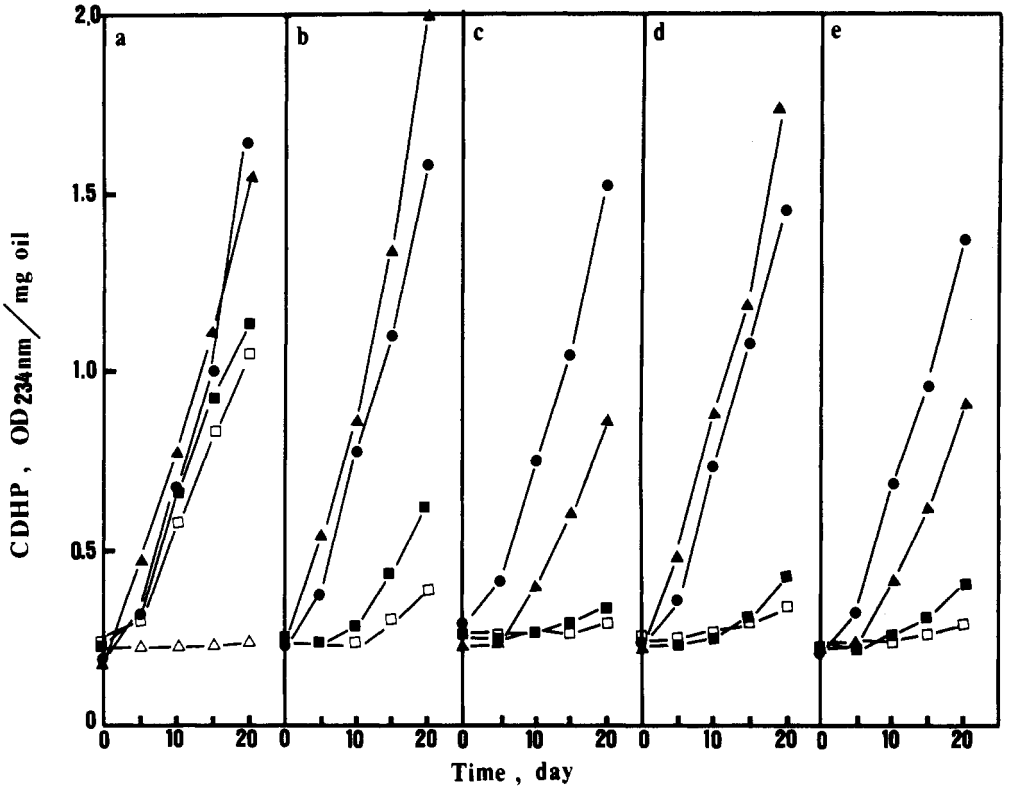

Figure 1. Variations in conjugated diene hydroperoxide contents in oils prepared from peanuts subjected to various treatments and roasting times and stored at 62 °C. (a) Control; (b) rehydrated and dehydrated peanuts; (c) rehydrated, blanched, and dehydrated peanuts; (d) rehydrated, germinated, and dehydrated peanuts; (e) rehydrated, germinated, blanched, and dehydrated peanuts; (●) 0, (▲) 30, (■) 60, and (□) 90 min of roasting time; (△) addition of 200 ppm of TBHQ.

For the determination of oxidative stability of oil, the conjugated diene hydroperoxide (CDHP) (Yoon et al., 1985; Chiou et al., 1991b) and weight increase methods were applied. For the CDHP method, 1.0 g of oil was deposited in a 5-mL brown glass vial and stored at 62 ± 2 °C (Joyner and McIntyre, 1938) for 20 days. The CDHP content in oil was periodically determined and expressed as absorbance units at 234 nm per milligram of oil.

To determine weight increase, 1.0 g of oil was deposited in a 5-mL brown glass vial and stored at 62 ± 2 °C for 60 days. The weight of each oil sample in each vial was taken periodically to determine the weight change during storage. A commercial antioxidant, Tenox 20 (containing 20% *tert*-butylhydroquinone and 10% citric acid dissolved in propylene glycol), was added at a concentration of 0.1% (w/w) to oil from untreated raw peanuts roasted at 160 °C for 60 min as a reference.

Fatty Acid Composition Analysis. Oils extracted from freeze-dried, raw peanut kernels, untreated kernels roasted at 160 °C for 90 min, and raw peanut kernels after rehydration, blanching at 100 °C for 5 min, dehydration at 70 °C for 24 h, and roasting at 160 °C for 0 and 90 min were deposited in brown glass vials and stored at 62 ± 2 °C for 40 days as described above for weight increase determination. Fatty acids were methylated and analyzed by gas chromatography (Bannon et al., 1982; Chiou et al., 1992). The percentage of each fatty acid was determined using a digital integrator and normalization of the peak areas. Fatty acids which were detected included myristic acid (14:0), palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1), linoleic acid (18:2), arachidic acid (20:0), eicosenoic acid (20:1), behenic acid (22:0), and lignoceric acid (24:0) in the order of elution on a capillary column. Minor or unknown fatty acids are not reported.

Statistics. Duplicate experiments were conducted. Means with standard deviations are reported.

RESULTS AND DISCUSSION

Effect of Treatments and Roasting Time. The effects of various treatments and roasting times on oxidative stability of peanut oils determined by CDHP and weight-increase methods are shown in Figures 1 and 2, respectively. In comparison, the CDHP method required less time than the weight-increase method. Figures 1a and 2a show data for control peanuts. Kernels were roasted without any pretreatment. The oil prepared after 90 min of roasting was slightly more stable to oxidative changes than oils prepared from peanuts roasted for less time. This was in agreement with observations reported by Cheng et al. (1987) and Huang et al. (1988), who reported that the longer the roasting time of peanut kernels, the higher the oxidative stability of oils. However, in this study, no significant differences were noted between unroasted kernels and kernels roasted for 30 min.

When peanut kernels were rehydrated and then dehydrated before roasting for 60 and 90 min (Figures 1b and 2b), a significant antioxidative activity was exhibited in the oils. When the rehydrated kernels were subjected to blanching at 100 °C for 5 min and subsequently dehydrated and roasted (Figures 1c and 2c), the longer the roasting time, the higher the antioxidative activity in the oils. The oil prepared from kernels roasted for 90 min was particularly stable against oxidation. Its oxidative stability was close to that of oil from peanuts roasted for 60 min and treated with 200 ppm of *tert*-butylhydroquinone (TBHQ) (Figures 1a and 2a). St. Angelo et al. (1977), who compared the effects of water and spin blanching on oxidative stability of raw and roasted peanuts, found that there was no significant difference in shelf life between unblanched and spin-blanched raw peanuts but that water-blanched raw peanuts had a shorter shelf life and developed lipid peroxides faster than the spin-blanched and control peanuts. However, for roasted peanuts, the unblanched controls had the shortest shelf life, and the roasted water-blanched peanuts had the longest shelf life of all three.

When rehydrated peanut kernels were allowed to germinate at room temperature for 24 h, whether blanched or not (Figures 1d,e and 2d,e), no additional antioxidative

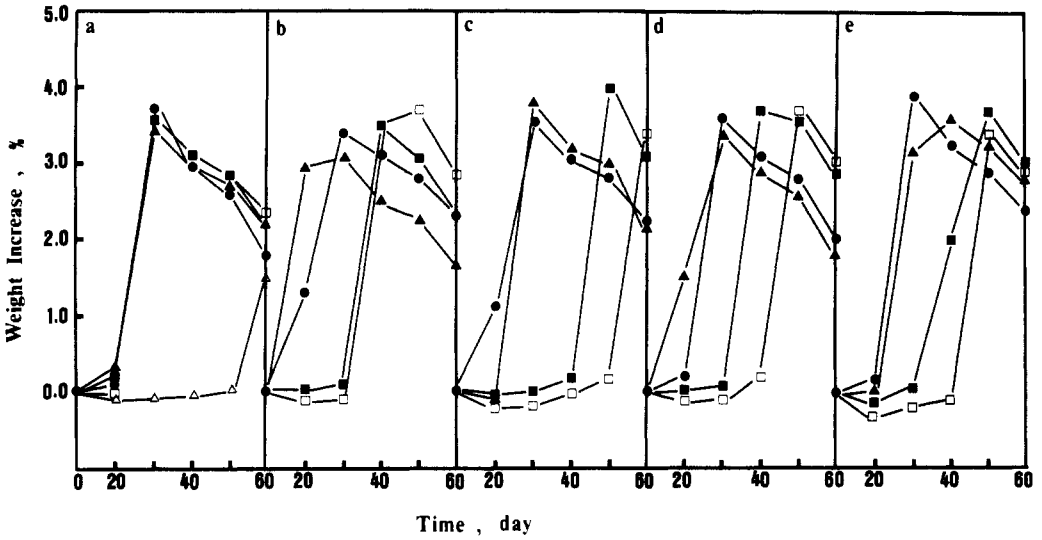

Figure 2. Weight variations of oils prepared from peanuts subjected to various treatments and roasting times and stored at 62 °C. (a) Control; (b) rehydrated and dehydrated peanuts; (c) rehydrated, blanched, and dehydrated peanuts; (d) rehydrated, germinated, and dehydrated peanuts; (e) rehydrated, germinated, blanched, and dehydrated peanuts; (●) 0, (▲) 30, (■) 60, and (□) 90 min of roasting time; (△) addition of 200 ppm of TBHQ.

Table I. Variation of Protein, Lipid, Sucrose, and Glucose Contents in Peanuts Subjected to Various Treatments and/or Roasted at 160 °C for 90 min

	component[a]			
treatment	protein, % (db)[b]	lipid, % (db)	sucrose, mg/g of defatted meal	glucose, mg/g of defatted meal
raw (control)	32.63 ± 0.56	47.63 ± 0.82	107.5 ± 1.7	0.480 ± 0.014
roasted, without treatment	33.18 ± 1.21	49.06 ± 0.90	81.4 ± 8.5	0.411 ± 0.027
rehydrated	32.83 ± 0.33	48.53 ± 0.24	110.0 ± 3.7	0.451 ± 0.003
blanched	33.10 ± 0.46	48.74 ± 0.52	97.7 ± 2.6	0.458 ± 0.001
dehydrated	33.52 ± 0.24	48.54 ± 0.55	89.2 ± 1.9	0.463 ± 0.014
roasted, with treatments	35.68 ± 0.85	50.54 ± 1.10	38.6 ± 1.8	0.409 ± 0.010

[a] Mean of two determinations from duplicate experiments. [b] Dry basis.

Table II. Variation in Total Amino Acid Composition in Peanuts Subjected to Various Treatments and/or Roasted at 160 °C for 90 min

	amino acid content,[a] mg/g of protein (N × 5.46)					
amino acid	control	roasted, without treatment	rehydrated	blanched	dehydrated	roasted, with treatments
Asp	118.3 ± 2.8	117.2 ± 2.6	121.2 ± 2.3	116.3 ± 0.6	112.1 ± 5.7	111.8 ± 1.4
Thr	25.3 ± 0.7	25.2 ± 0.7	26.1 ± 0.4	25.0 ± 0.2	24.1 ± 1.4	24.1 ± 0.3
Ser	46.9 ± 1.1	44.7 ± 1.1	47.8 ± 0.9	44.8 ± 0.6	43.2 ± 2.1	41.3 ± 0.4
Glu	217.5 ± 5.6	210.6 ± 5.4	219.9 ± 3.9	206.5 ± 1.1	198.4 ± 10.3	199.7 ± 1.5
Pro	48.1 ± 1.6	46.3 ± 0.6	49.7 ± 2.1	44.4 ± 0.1	42.6 ± 2.1	51.0 ± 0.7
Gly	46.6 ± 1.3	45.6 ± 1.2	47.6 ± 0.7	43.2 ± 0.3	41.4 ± 1.9	41.1 ± 0.4
Ala	34.0 ± 0.6	33.4 ± 1.3	35.2 ± 0.6	33.2 ± 0.2	32.2 ± 1.6	32.8 ± 0.4
Cys	10.4 ± 0.3	8.9 ± 0.3	10.0 ± 0.4	10.3 ± 0.2	10.2 ± 0.4	5.5 ± 0.1
Val	40.6 ± 1.1	39.7 ± 1.3	41.3 ± 0.1	39.5 ± 0.1	38.1 ± 2.0	38.4 ± 0.4
Met	11.4 ± 0.3	12.0 ± 0.2	10.8 ± 0.1	9.9 ± 1.2	10.4 ± 0.1	11.5 ± 0.1
Ile	34.1 ± 0.8	33.5 ± 1.1	35.1 ± 0.5	33.3 ± 0.1	32.1 ± 1.7	32.2 ± 0.4
Leu	66.2 ± 1.6	65.7 ± 1.9	67.6 ± 1.1	64.4 ± 0.3	62.4 ± 3.1	63.1 ± 0.7
Tyr	31.0 ± 0.6	30.6 ± 0.8	30.2 ± 0.7	29.7 ± 0.5	29.4 ± 1.3	29.5 ± 0.2
Phe	61.2 ± 1.8	58.3 ± 2.3	61.4 ± 1.4	58.3 ± 0.3	56.6 ± 2.9	56.4 ± 0.6
His	23.6 ± 0.6	22.7 ± 0.7	24.1 ± 0.3	23.0 ± 0.1	22.1 ± 1.1	20.9 ± 0.3
Lys	34.3 ± 0.9	20.5 ± 0.8	34.9 ± 0.3	33.2 ± 0.4	31.7 ± 1.9	15.8 ± 0.3
Arg	82.1 ± 2.0	74.1 ± 2.4	81.2 ± 0.8	79.1 ± 0.3	76.4 ± 3.5	62.2 ± 0.7
total	931.6	889.0	944.1	894.1	863.4	837.3

[a] Mean of two determinations from duplicate experiments.

activity resulted. Therefore, a comparison of chemical characteristics of raw peanuts and peanuts after rehydration, blanching, dehydration, and roasting for 90 min deserves additional research attention.

Variation of Protein, Lipid, Sucrose, and Glucose. Variations in protein, lipid, sucrose, and glucose contents in raw peanut kernels before and after roasting and in kernels subjected to rehydration, blanching, dehydration, and subsequent roasting are shown in Table I. In general, variation in protein, lipid, and glucose contents caused by various treatments and roasting was limited. Protein and lipid contents in treated peanuts before and after roasting were slightly higher. Sucrose content decreased gradually when raw kernels were stepwise subjected to rehydration, blanching, and dehydration. Finally, a tremendous decrease in sucrose content resulted from roasting at 160 °C for 90 min. However, when kernels were not subjected to treatments before roasting, most of the sucrose was retained.

Variation in Total and Free Amino Acids. Total

Table III. Variation in Free Amino Acid Composition in Peanuts Subjected to Various Treatments and/or Roasted at 160 °C for 90 min

	amino acid content,[a] mg/g of protein (N × 5.46)					
amino acid	control	roasted, without treatment	rehydrated	blanched	dehydrated	roasted, with treatments
Asp	0.183 ± 0.006	0.033 ± 0.004	0.146 ± 0.013	0.120 ± 0.029	0.109 ± 0.002	0.009 ± 0.001
Thr	0.061 ± 0.001	0.012 ± 0.001	0.077 ± 0.002	0.056 ± 0.003	0.056 ± 0.001	
Ser	0.210 ± 0.006	0.026 ± 0.007	0.327 ± 0.036	0.241 ± 0.032	0.187 ± 0.005	
Glu	2.098 ± 0.032	0.160 ± 0.003	1.209 ± 0.093	1.028 ± 0.059	1.050 ± 0.034	0.015 ± 0.002
Pro						
Gly	0.208 ± 0.007	0.020 ± 0.002	0.190 ± 0.004	0.147 ± 0.001	0.129 ± 0.001	0.008 ± 0.001
Ala	0.376 ± 0.004	0.049 ± 0.006	0.476 ± 0.024	0.363 ± 0.023	0.369 ± 0.005	0.021 ± 0.002
Cys						
Val	0.181 ± 0.002	0.022 ± 0.003	0.181 ± 0.005	0.134 ± 0.008	0.125 ± 0.002	
Met	0.027 ± 0.001	0.017 ± 0.001	0.035 ± 0.001	0.028 ± 0.002	0.023 ± 0.002	0.007 ± 0.001
Ile	0.117 ± 0.001	0.019 ± 0.001	0.111 ± 0.001	0.091 ± 0.002	0.086 ± 0.001	
Leu	0.083 ± 0.003	0.046 ± 0.001	0.103 ± 0.002	0.085 ± 0.003	0.075 ± 0.001	0.010 ± 0.001
Tyr	0.081 ± 0.001		0.098 ± 0.003	0.076 ± 0.001	0.076 ± 0.001	
Phe	0.728 ± 0.136	0.366 ± 0.018	0.627 ± 0.025	0.660 ± 0.012	0.551 ± 0.022	0.075 ± 0.012
His	0.059 ± 0.002	0.006 ± 0.001	0.067 ± 0.004	0.054 ± 0.008	0.052 ± 0.002	
Lys	0.026 ± 0.001		0.033 ± 0.003	0.028 ± 0.003	0.028 ± 0.001	
Arg	0.417 ± 0.017	0.100 ± 0.004	0.421 ± 0.009	0.404 ± 0.049	0.382 ± 0.014	
total	4.855	0.876	4.101	3.515	3.295	0.145

[a] Mean of two determinations from duplicate experiments.

Table IV. Variation of Fatty Acids of Peanut Oils before and after Storage at 62 °C for 40 Days

	fatty acids,[a] % of total detected fatty acids								
treatment	14:0	16:0	18:0	18:1	18:2	20:0	20:1	22:0	24:0
0 days, unroasted, without treatment	0.003 ± 0	14.29 ± 0.38	3.01 ± 0.06	39.21 ± 0.36	39.47 ± 0.32	1.09 ± 0	0.68 ± 0.05	1.62 ± 0.32	0.42 ± 0.10
40 days, unroasted, without treatment	0.15 ± 0.01	31.39 ± 0.76	6.95 ± 0.04	31.58 ± 0.39	0.13 ± 0.06	3.90 ± 0.17	1.05 ± 0.01	4.09 ± 0.10	1.15 ± 0.03
0 days, roasted,[b] without treatment	0.05 ± 0.02	13.46 ± 0.20	3.12 ± 0.47	39.17 ± 0.14	38.86 ± 0.90	1.25 ± 0.16	0.85 ± 0.01	2.23 ± 0.02	0.80 ± 0.05
40 days, roasted,[b] without treatment	0.10 ± 0.04	29.58 ± 5.23	5.86 ± 0.89	37.64 ± 4.96	0.41 ± 0.20	3.34 ± 0.76	0.82 ± 0.33	2.64 ± 1.33	0.92 ± 0.57
0 days, unroasted, with treatments	0.04 ± 0	13.44 ± 0.26	3.33 ± 0.17	40.25 ± 0.12	38.60 ± 0.02	1.15 ± 0.02	0.73 ± 0.05	1.81 ± 0.16	0.51 ± 0.04
40 days, unroasted, with treatments	0.12 ± 0	29.09 ± 0.17	7.93 ± 0.44	29.76 ± 1.42	0.20 ± 0.04	4.08 ± 0.02	0.92 ± 0.06	5.29 ± 0.23	1.75 ± 0.01
0 days, roasted,[b] with treatments	0.03 ± 0	13.67 ± 0.23	3.23 ± 0.36	40.47 ± 0.11	38.32 ± 0.57	1.12 ± 0.08	0.68 ± 0.01	1.70 ± 0.13	0.56 ± 0.08
40 days, roasted,[b] with treatments	0.03 ± 0.01	13.16 ± 0.12	2.92 ± 0.87	38.76 ± 2.25	38.76 ± 2.06	1.41 ± 0.09	0.65 ± 0.05	2.36 ± 0.08	0.80 ± 0.10

[a] Mean of two determinations from duplicate experiments. [b] Oil was prepared from peanuts roasted at 160 °C for 90 min.

and free amino acid profiles in raw peanuts before and after roasting and in peanuts subjected to treatments and then roasted for 90 min are shown in Tables II and III. When raw peanuts were directly roasted without treatment, the overall decrease of total amino acids was approximately 43 mg/g of protein. The decrease was largely caused by a decrease in lysine. For peanuts stepwise subjected to treatments before roasting, total amino acid content increased slightly upon rehydration and decreased gradually when subjected to blanching, dehydration, and roasting. The overall decrease was 94 mg/g of protein, which was equivalent to approximately twice the decrease in peanuts roasted without pretreatment. Again, lysine was the amino acid that decreased most significantly in comparison to other amino acids.

Direct roasting of raw peanut kernels without treatment resulted in an overall decrease in free amino acid content from 4.86 to 0.88 mg/g of protein. However, when peanuts were subjected to rehydration, blanching, dehydration, and roasting, free amino acid contents were 4.10, 3.52, 3.30, and 0.15 mg/g of protein, respectively.

Color Variation of Peanuts. Color measurements, expressed as L, a, and b values, made during roasting are presented in Figure 3. Before roasting, L and b values of treated peanuts were lower than those of peanuts that had not been treated. Color changes during roasting were not markedly influenced by pretreatment. Consequently, the color of roasted peanuts which had been treated was darker than that of peanuts which had not been treated.

On the basis of observations that considerably more sucrose and amino acids were degraded in treated peanuts, which undoubtedly contributed to a darker color, and significantly more antioxidative activity was present in

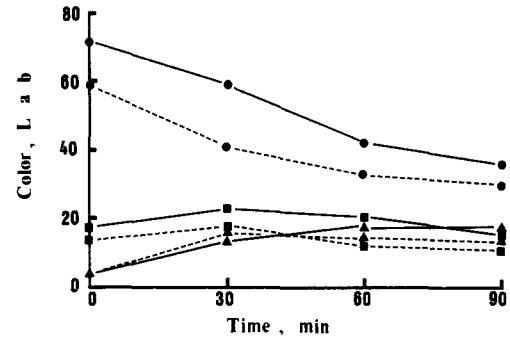

Figure 3. Changes of deskinned peanut kernel colors expressed as L, a, and b values during roasting, with and without treatments. (●) L values; (▲) a values; (■) b values; (- - -) peanuts with treatments; (—) peanuts without treatment.

treated peanuts than in untreated peanuts, it is possible to conclude that treatment of peanuts may enhance color formation and render kernels with high oxidative stability. In a previous study (Chiou et al., 1991b), darker color and higher antioxidative activity were noted in peanuts roasted under oxygen compared to other atmospheric environments.

Variation of Fatty Acids. The fatty acid composition of oils in unroasted and roasted peanuts subjected to oxidative tests after storage at 62 °C for 40 days is shown in Table IV. In general, in comparison to oils before storage, treatments and roasting caused only a slight decrease in linoleic acid content. After 40 days of storage, the percentage of linoleic acid decreased to below 0.5% in unroasted peanuts, regardless of treatment, and in roasted peanuts that had not been treated. Meanwhile, the relative proportions of saturated fatty acids, i.e., palmitic, stearic,

and eicosenoic acids, in these oils increased more than 2-fold over their original levels before storage. The fatty acid composition of oils from peanuts that had been treated and subsequently roasted at 160 °C for 90 min was unchanged after 40 days of storage. Therefore, linoleic acid in oil prepared from treated peanuts roasted at 160 °C for 90 min should be effectively protected against oxidation during storage as a result of antioxidative factors produced during roasting. The antioxidative mechanisms and the chemical properties of the antioxidants need to be further studied.

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LITERATURE CITED

AOAC. *Official Methods of Analysis*; Association of Official Analytical Chemists: Washington, DC, 1985.

Bannon, C. D.; Craske, J. D.; Hai, N. T.; Harper, N. L.; O'Rourke, K. L. Analysis of fatty acid methyl esters with high accuracy and reliability. II. Methylation of fats and oils with boron trifluoride methanol. *J. Chromatogr.* **1982**, *247*, 63–66.

Bishov, S. J.; Henick, A. S. Natural antioxidants. In *Encyclopedia of Food Sciences*; Peterson, M. S., Johnson, A. H., Eds.; Encyclopedia of Food Technology and Food Science Series; AVI Publishing: Westport, CT, 1978; Vol. 3, Chapter N.

Chang, S. S.; Ostric-Matijasevic, B.; Hsieh, O. A. H.; Huang, C.-L. Natural antioxidants from rosemary and sage. *J. Food Sci.* **1977**, *42*, 1002–1006.

Cheng, S.-L.; Bai, L.-I.; Tsai, T.-C.; Chiou, R. Y.-Y. Using glass beads as a solid thermal medium for peanut roasting. *Food Sci.* **1987**, *14*, 176–183.

Chiou, R. Y.-Y.; Chang, Y.-S.; Tsai, T.-T.; Ho, S. Variation of flavor-related characteristics of peanuts during roasting as affected by initial moisture contents. *J. Agric. Food Chem.* **1991a**, *39*, 1155–1158.

Chiou, R. Y.-Y.; Tseng, C.-Y.; Ho, S. Characteristics of peanut kernels roasted under various atmospheric environments. *J. Agric. Food Chem.* **1991b**, *39*, 1852–1856.

Chiou, R. Y.-Y.; Ferng, S.; Liu, Y.-F. Comparison of sound and shriveled peanut kernels from sized commercial lots. *J. Food Sci.* **1992**, *57*, 998–1001.

Huang, J.-J.; Shyu, S.-L.; Chang, R. L. The effects of roasting degree on the quality of peanut oil. *J. Chin. Agric. Chem. Soc.* **1988**, *26*, 466–475.

Joyner, N. T.; McIntyre, J. E. The oven test as an index of keeping quality. *Oil Soap* **1938**, *15*, 184–186.

Onyeneho, S. N.; Hettiarachchy, N. S. Effect of navy bean hull extract on the oxidative stability of soy and sunflower oils. *J. Agric. Food Chem.* **1991**, *39*, 1701–1704.

Rodriguez, M. M.; Basha, S. M.; Sanders, T. H. Maturity and roasting of peanuts as related to precursors of roasted flavor. *J. Agric. Food Chem.* **1989**, *37*, 760–765.

Sherwin, E. R. Oxidation and antioxidants in fat and oil processing. *J. Am. Oil Chem. Soc.* **1978**, *55*, 809–814.

St. Angelo, A. J.; Kuck, J. C.; Ory, R. L. Enzymes and oxidative stability of peanut products. In *Enzymes in Food and Beverage Processing*; Ory, R. L., St. Angelo, A. J., Eds.; ACS Symposium Series 47; American Chemical Society: Washington, DC, 1977; pp 229–243.

Stuckey, B. N. Antioxidants as food stabilizer. In *CRC Handbook of Food Additives*; Furia, T. E., Ed.; CRC Press: Cleveland, OH, 1977; pp 185–223.

Yoon, S. H.; Kim, S. K.; Shin, M. G.; Kim, K. H. Comparative study of physical methods for lipid oxidation measurement in oils. *J. Am. Oil Chem. Soc.* **1985**, *62*, 1487–1489.

Young, C. T.; Matlock, R. S.; Mason, M. E.; Waller, G. R. Effect of harvest date and maturity upon free amino acid levels in three varieties of peanuts. *J. Am. Oil Chem. Soc.* **1974**, *51*, 269–273.

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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; sucrose, 57-50-1; glucose, 50-99-7; myristic acid, 544-63-8; palmitic acid, 57-10-3; stearic acid, 57-11-4; oleic acid, 112-80-1; linoleic acid, 60-33-3; arachidic acid, 506-30-9; eicosenoic acid, 28933-89-3; behenic acid, 112-85-6; lignoceric acid, 557-59-5.