Flavor Fortification and Characterization of Raw Peanut Oils Subjected to Roasting with Partially Defatted Peanut Meal under Various Atmospheric Conditions

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Raw peanut oil was combined with partially defatted peanut meal at a ratio of 10:1 (w/w) and roasted at 160 °C for 30 min in a closed chamber under various atmospheric conditions. The addition of 10–20% moisture to peanut meal was essential for the formation of peanutty flavor in oil. A unique and pleasant roasted peanut flavor was achieved when roasting was carried out under atmospheres of CO_2 and He. The free fatty acid content increased in the oil when the atmosphere during roasting consisted of O_2, while slight decreases were observed in oils prepared using other atmospheric gas systems. After storage at 62 °C for 35 days, free fatty acid and conjugated diene hydroperoxide contents increased in oils subjected to all treatments. However, the fatty acid composition in oils varied only within a limited range. Significant antioxidative activities were observed in peanut oils roasted with partially defatted peanut meal under CO_2, He, and N_2.

INTRODUCTION

In general, a pleasant peanutty flavor is produced by roasting peanut kernels at an elevated temperature for an appropriate period of time. When peanut kernels are split, chopped into pieces, ground into meal, and pressed to expel oil before being subjected to roasting, the intensity of the unique roasted flavor in each successive product is diminished. The smaller the particle size, the larger the total surface area exposed to the roasting atmosphere. When peanut kernels are roasted under an O_2 atmosphere, poor flavor quality develops compared to that of kernels roasted under other atmospheric conditions (Chiou et al., 1991c). The presence of atmospheric O_2 during roasting might promote the development of undesirable flavors or mask the intensity of desired flavors. Therefore, exclusion of O_2 in the roasting atmosphere may enhance the production of desired peanutty flavor compounds.

In this study, flavor generation resulting from the roasting raw peanut oils together with small amounts of partially defatted peanut meal under various atmospheric environments was investigated. The effects of moisture content of the peanut meal on flavor formation during roasting and characterization of peanut oil during subsequent storage were also investigated.

MATERIALS AND METHODS

Peanuts. Freshly harvested and dried peanuts (Tainan 9, a Spanish cultivar) were hand-shelled, visually sorted, packaged in polyethylene/nylon laminated bags, and stored at −18 °C until used in this study. The moisture content of kernels was 7.30 ± 0.30% (dry basis). Peanuts were removed from the freezer and tempered at room temperature for 24 h before being subjected to various experimental treatments.

Raw Peanut Oil and Partially Defatted Meal Preparation. The moisture content of the peanut kernels was increased to 9.0% by spraying with a predetermined amount of deionized water. After equilibration at 4 °C for 3 days, peanuts were pressed hydraulically (150–200 kg/cm²) to prepare raw peanut oil and partially defatted kernels. The raw oil was passed through filter paper (Advantec No. 2, Toyo, Japan) and stored at −25 °C for further use. The moisture content of the raw oil was determined by a Karl-Fischer moisture titrator (Model MKC 210, Kyoto Electronics, Japan). The partially defatted kernels were deskinned manually and pulverized with a cyclone mill to prepare peanut meal (1-mm screen) and stored at −25 °C for further use. Moisture, crude lipid, and protein (N × 5.46) contents of the defatted meals were 9.90, 29.93, and 33.43% (wet basis), respectively.

Peanut Oil Roasting and Organoleptic Evaluation. Prior to roasting under various atmospheric conditions, 2 mL of raw oil and 0.2 g of the partially defatted peanut meal were deposited in a digestion tube, flushed with the desired gas for 1 min, and sealed with a Teflon screw stopper. Controls consisted of 2 mL of raw peanut oil under CO_2 and ambient atmospheric gas conditions using a heating module (Pierce Reacti-Therm, Pierce Chemical Co., Rockford, IL). Oil and meal mixtures were roasted at 160 °C for 30 min. The tubes were cooled at room temperature, and the clarified oil fractions were deposited in brown glass vials and stored at −25 °C before being subjected to sensory evaluation and chemical analysis. For sensory evaluation, five trained panelists were instructed to use a 9-point (1–9) hedonic scale to evaluate flavor notes: 6–9, in increasing numerical score, signified an increased intensity of peanutty flavor; 5 was the midpoint; and 4 to 1, in decreasing numerical score, signified an increased intensity of unpleasant flavor.

Effect of Moisture Content of Defatted Peanut Meal on Peanutty Flavor Formation during Roasting. Partially defatted peanut meal was freeze-dried and ground manaully to prepare dehydrated peanut powder. Dehydrated peanut powder (0.2 g) was placed in a series of digestion tubes, and 0, 5, 15, 20, 30, 40, 50, and 100 μL of deionized water was added to result in 0, 2.5, 7.5, 10, 15, 20, 25, and 50% moisture, respectively. Raw peanut oil (2.0 mL) was added to each tube, which was then flushed with CO_2 for 1 min, sealed with a screw stopper, and heated at 160 °C for 30 min. After cooling to room temperature, the oil was withdrawn from each tube and subjected to sensory evaluation using the procedure described above.

Determination of the Oxidative Stability of Oils. The conjugated diene hydroperoxide (CDHP) contents in stored oil samples were determined using the procedure described by Chiou et al. (1991b). Oil (0.3 g) was placed in a 5-mL brown glass vial and stored at 62 ± 2 °C for up to 35 days. The CDHP content was determined periodically.

Determination of Fatty Acid Composition and Free Fatty Acid Content. The fatty acid composition of peanut oils was determined using the methylation procedure reported by Chiou

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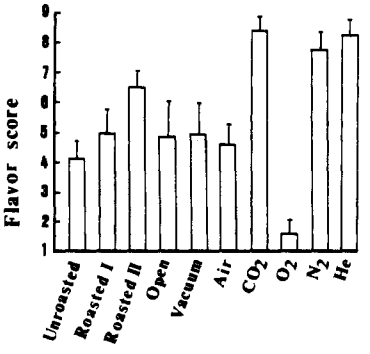

Figure 1. Flavor scores for raw peanut oil and oil roasted with partially defatted peanut meal under various atmospheric conditions.

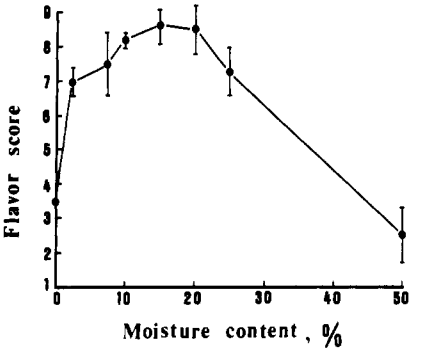

Figure 2. Flavor scores for raw peanut oil roasted with partially defatted peanut meal having various moisture contents.

et al. (1992) and gas chromatography. A packed column (GP 3% SP2310/2% SP2300 on 100/120 Chromosorb W AW, 6 ft × 1/8 in. stainless steel column, Supelco Inc., Bellefonte, PA) was used. The injector and detector temperatures were 230 and 250 °C, respectively, sample size was 0.5 μL, and carrier gas (He) flow rate was 20 mL/min. For each run, the initial column temperature held at 190 °C for 2 min, was programmed to increase to 220 °C at 2 °C/min, and was then held for 5 min. Data were collected by an integrator/recorder. The relative proportion of each component fatty acid was expressed as a percentage of the total peak areas.

The free fatty acid content in oil subjected to oxidative stability tests was determined using a colorimetric (copper soap) method (Koops and Klomp, 1977; Shipe et al., 1980) with a minor modification. Oil (50 mg) was deposited in a centrifuge tube (Nalgene 3114-0010) and mixed with 5 mL of chloroform–heptane–methanol (CHM, 49:49:2 v/v/v) and 2 mL of the copper reagent. The capped tube was shaken for 30 min at room temperature and subjected to centrifugation at 8500*g* at 20 °C for 10 min. One milliliter of the solvent layer was withdrawn and mixed with 4 mL of CHM and 0.1 mL of the color reagent. The absorbance at 440 nm was measured spectrophotometrically. Linoleic acid was used as a reference for constructing a standard curve, and the free fatty acid content was expressed as milligrams of linoleic acid per gram of oil.

Statistical Analysis. Two replicate experiments were conducted. Means of values with standard deviations are reported. Significant differences among samples were analyzed by the statistical *t*-test.

RESULTS AND DISCUSSION

Flavor evaluation scores for raw peanut oil and oil roasted with partially defatted peanut meal are presented in Figure 1. Peanutty flavor formation during roasting was significantly influenced by the addition of partially defatted peanut meal and varied depending upon the atmospheric gas content. The highest and lowest flavor scores resulted from roasting oil with partially defatted meal under CO_2 and O_2, respectively. When oil was roasted under He and N_2, flavor scores were slightly lower than that for oil and meal roasted under CO_2. Satisfactory typical peanutty flavor was not achieved by simply roasting the raw oil (without addition of the peanut meal) under an open atmosphere or under CO_2 or by roasting the oil with peanut meal under open, vacuum, and air conditions.

Chiou et al. (1991c) roasted peanut kernels under various atmospheric environments and reported that the best flavor was obtained by roasting peanuts under N_2 or CO_2. The presence of O_2 apparently influences the performance of typical peanutty flavor after roasting by inhibition of the flavor formation or direct destruction of the flavor compounds during roasting. On the basis of the general perceptions and descriptions given by panelists that more oxygen in the roasting environment resulted in more unpleasant flavor, it was conjectured that oxidation of peanut components at elevated temperature resulted in compounds with off-flavors which may mask or interfere with the normal intensity of typical peanutty flavor.

Partially defatted peanut meal contains the precursors of peanutty flavor. When raw peanut oil was roasted in the absence of peanut meal under CO_2, maybe due to the absence of these flavor precursors, the peanutty flavor did not develop (Figure 1). Peanutty flavor formation during roasting is a result of reactions between amino acids and reducing sugars, using lipid as the reaction medium (Woodroof, 1983). During roasting of whole peanut kernels, exposure of the internal portion of cotyledons to oxygen is limited and release of moisture is slow. The initial moisture content of peanut kernels greatly influences reactions of flavor-related precursors and eventually influences flavor formation during roasting (Chiou et al., 1991a). However, when ground raw peanut meal is conventionally roasted in an oven at an appropriate temperature, due to extensive exposure to O_2 from air and rapid release of moisture by surface evaporation, a pleasant roasted peanut flavor does not develop.

On the basis of the observation that typical roasted peanut flavor can be enhanced by roasting raw peanut oil and peanut meal under CO_2, the effect of moisture content of the peanut meal on the roasted flavor formation was further studied (Figure 2). Flavor scores for the roasted oils increased significantly with increased moisture content (0–15%) of the peanut meals and decreased when the moisture content was higher than 20%. Chiou et al. (1991a) roasted peanut kernels containing various initial moisture contents and reported that reactions of flavor-related precursors, i.e., amino acids and soluble carbohydrates, were influenced significantly by the moisture content of the peanut kernels. Since a closed system was used in the present study, the moisture in the roasting chamber may have played a role in facilitating hydrolysis of macromolecules to release flavor precursors and enhance flavor formation.

The fatty acid composition of raw and roasted peanut oils is presented in Table I. Changes in fatty acid profiles as a result of roasting were limited. Peanut oil roasted with peanut meal under vacuum had the highest 16:0 content and the lowest 18:0, 20:0, 20:1, and 24:0 contents. Peanut oil roasted with peanut meal under CO_2 had the lowest level of 16:0 and the highest levels of linoleic acid (18:2) and 22:0. In addition, peanut oil roasted with peanut meal under O_2 had the lowest level of linoleic acid (18:2); its linolenic acid (18:3) content was not detected.

The free fatty acid content in raw and roasted peanut oils is presented in Table II. Peanut oil roasted with peanut meal under an O_2 atmosphere contained a significantly

Table I. Fatty Acid Composition of Raw Peanut Oil and Oil Roasted with Peanut Meal at 160 °C for 30 min under Various Atmospheric Conditions

atmospheric condition	fatty acid, %									
	14:0	16:0	18:0	18:1	18:2	18:3	20:0	20:1	22:0	24:0
unroasted	0.02 ± 0.00	12.11 ± 0.28	3.23 ± 0.02	37.58 ± 0.08	40.25 ± 0.06	0.03 ± 0.01	1.45 ± 0.05	0.90 ± 0.02	3.07 ± 0.25	1.08 ± 0.09
control I[a]	0.03 ± 0.01	13.11 ● 0.35	3.14 ± 0.00	37.54 ● 0.10	39.97 ± 0.06	0.04 ± 0.01	1.36 ± 0.05	0.84 ± 0.02	2.70 ± 0.14	0.98 ± 0.09
control II[b]	0.02 ● 0.01	11.85 ± 0.04	3.29 ± 0.01	37.66 ± 0.03	40.27 ● 0.06	0.05 ± 0.01	1.47 ± 0.02	0.91 ± 0.02	3.12 ± 0.04	1.07 ± 0.03
open[c]	0.03 ● 0.00	12.75 ± 0.53	3.19 ● 0.04	37.48 ± 0.23	40.01 ± 0.14	0.05 ± 0.01	1.41 ± 0.08	0.90 ± 0.03	2.86 ± 0.14	0.94 ± 0.17
vacuum[c]	0.04 ± 0.01	14.46 ± 0.09	3.05 ± 0.04	37.25 ● 0.14	40.14 ± 0.01	0.04 ● 0.01	1.19 ± 0.01	0.75 ± 0.01	2.13 ± 0.04	0.60 ± 0.08
air[c]	0.03 ± 0.00	12.81 ± 0.32	3.18 ± 0.01	37.29 ● 0.08	40.12 ± 0.15	0.05 ± 0.01	1.41 ± 0.04	0.86 ± 0.02	2.91 ± 0.01	1.02 ± 0.07
CO_2[c]	0.03 ± 0.01	12.06 ± 0.27	3.22 ± 0.01	37.51 ● 0.10	40.42 ± 0.17		1.44 ± 0.02	0.87 ± 0.01	3.08 ± 0.01	1.06 ± 0.01
O_2[c]	0.03 ● 0.01	13.45 ± 0.00	3.18 ± 0.02	37.54 ± 0.07	39.78 ± 0.09		1.33 ± 0.03	0.81 ± 0.02	2.72 ± 0.14	0.92 ± 0.02
N_2[c]	0.04 ± 0.01	13.34 ± 0.22	3.17 ± 0.03	37.32 ± 0.01	40.25 ● 0.10	0.03 ± 0.00	1.30 ± 0.03	0.80 ± 0.02	2.59 ± 0.02	0.90 ± 0.03
He[c]	0.03 ± 0.00	13.43 ● 0.36	3.13 ± 0.01	37.25 ± 0.04	40.03 ± 0.11	0.04 ± 0.01	1.35 ± 0.01	0.83 ± 0.02	2.70 ± 0.19	0.91 ± 0.08

[a] Raw oil was roasted without peanut meal at open condition. [b] Raw oil was roasted without peanut meal under CO_2. [c] Raw oil was roasted with defatted peanut meal in the ratio of 10/1 (w/w) under the specified atmospheric condition.

Table II. Free Fatty Acid Content in Peanut Oil before and after Storage at 62 °C for 35 Days

atmospheric condition	FFA content,[a] mg of linoleic acid/g of oil	
	before storage	after storage
unroasted	0.752[b]	1.045[b]
control I[b]	0.629[bc]	0.976[bc]
control II[c]	0.616[bc]	0.950[bc]
open[d]	0.668[bc]	1.005[b]
vacuum[d]	0.571[c]	0.750[c]
air[d]	0.754[b]	1.118[b]
CO_2[d]	0.537[c]	0.854[bc]
O_2[d]	1.081[a]	1.744[a]
N_2[d]	0.683[b]	0.865[bc]
He[d]	0.700[b]	0.871[bc]

[a] Values in the same column not followed by the same superscript letter are significantly different at the $P \leq 0.05$ level. [b] Raw oil was roasted without peanut meal under open condition. [c] Raw oil was roasted without peanut meal under CO_2. [d] Raw oil was roasted with defatted peanut meal in the ratio of 10/1 (w/w) under the specified atmospheric condition.

higher free fatty acid content than did the raw oil and other oils ($P \leq 0.05$). Peanut oil roasted with peanut meal under air had about the same free fatty acid content as did raw oil. Other roasted peanut oils had fatty acid contents lower than that detected in the raw oil. The fact that a decrease in free fatty acid content resulted from roasting raw oil with partially defatted peanut meal is of importance from the viewpoint of edible oil processing. Low free fatty acid content in edible oil correlates with acid value and high oil quality. After storage of peanut oils at 62 °C for 35 days, the free fatty acid content in all samples increased significantly (Table II). The highest content was detected in oils roasted with peanut meal under O_2, followed by oil roasted with peanut meal under air; the lowest content was detected in oil roasted with peanut meal under vacuum.

Changes in conjugated diene hydroperoxide (CDHP) content of peanut oil during storage at 62 °C are shown in Figure 3. When raw peanut oil was roasted alone (in the absence of peanut meal), CDHP content increased slightly and its tendency to oxidize was very similar to that of raw oil. Obviously, no antioxidative effect was achieved by roasting raw peanut oil alone. However, when peanut oil was roasted with peanut meal, significant antioxidative activity was observed. The antioxidative potency of roasted oils was dependent upon the atmospheric environment. Oil roasted under CO_2 was the most stable to oxidative changes, followed in order by roasting oil with peanut meal under N_2, He, air, vacuum, open, and O_2. This was not in agreement with the findings of Chiou et al. (1991c), who observed that roasting peanut kernels under O_2 resulted in oxidative stability during the early stages of storage at 62 °C. When raw peanut oil was roasted

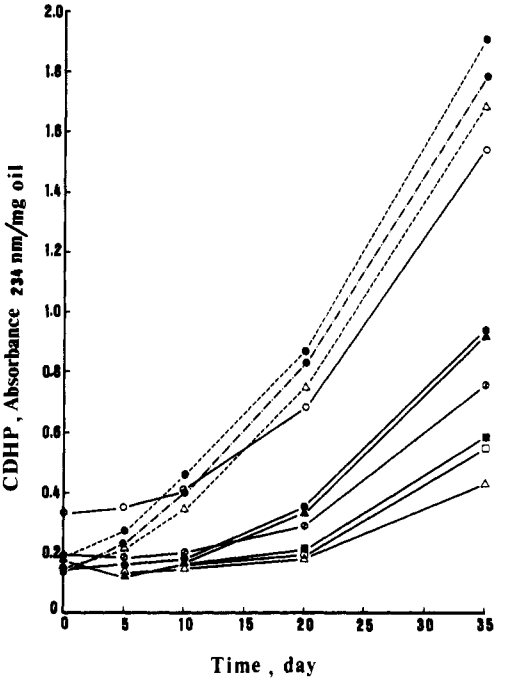

Figure 3. Changes on conjugated diene hydroperoxide contents in raw and roasted peanut oils during storage at 62 °C. (– · –) Raw oil; (—) roasted with addition of peanut meal; (- - -) roasted without addition of peanut meal. Atmospheric conditions: (●) open; (▲) vacuum; (○) air; (△) CO_2; (○) O_2; (□) N_2; (■) He.

with peanut meal under O_2 in this study, significant increases in CDHP content were observed. However, a continued rapid increase in CDHP content did not occur during storage at 62 °C. Therefore, the formation of hydroperoxides and antioxidative substances appears to have proceeded simultaneously during the process of roasting.

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