Evaluation of Analytical Methods for Optimizing Peanut Roasting for Snack Foods

D. A. Smyth[1]*, C. Macku[1], O. E. Holloway[1], D. M. Deming[2], L. Slade[2], and H. Levine[2]

ABSTRACT

Roasting *Arachis hypogaea* L. seeds for snack foods requires control of roasting temperature and time to optimize eating quality. Extra large virginia and jumbo runner peanut seeds were oil roasted at different thermal input levels to examine relationships between roast color and other analytical measurements related to roast quality. A laboratory roaster and commercial lots of peanut seeds were used to simulate the commercial process. The concentration of volatiles such as pyrazines increased in roasted seeds with increased thermal energy. Descriptive sensory analyses on these same roasted seed samples showed that optimal balance of important flavor characteristics such as roasted peanut, dark roast, and sweet had distinct roast temperature and time requirements. Excessive heat increased negative flavor components such as bitter. Conventional tests for roaster control such as roast color (CIELAB L*) or seed moisture content changed only slightly during the period when optimal roast quality was achieved. For a given seed lot, optimal roast required both appropriate roast color and tests of roasted peanut flavor. Roasted peanut products dependent on the enhanced stability of the high oleic acid trait required measurements of either oxidative stability, or the fatty acid profile, to ensure the desired product shelf life. Analytical methods such as those discussed here allow the commercial roaster to reach an optimal roast quality while using a diverse raw material supply.

Key Words: *Arachis hypogaea*, Argentine, color, flavor, gas chromatography, hexanal, moisture, oleic acid, peanut, pyrazines, roast conditions, runner, sensory, snacks, virginia-type peanut.

The objective in roasting *Arachis hypogaea* L. seeds for snack foods is to optimize roasted flavor, texture, and appearance in a stable, finished product. Roasted peanut flavor and aroma are key sensory attributes defining quality, and the subject of much research over the last 30 yr (1, 22).

The generation of roasted peanut flavor is complex. Peanut seed constituents such as reducing sugars, free amino acids, and amino acids released during protein denaturation are important precursors for flavors developed via the Maillard reaction pathway (1, 21, 22). Descriptive sensory panels have described a desirable flavor profile as one with roast peanut, sweet aromatic, and some dark roast character, with a minimum of negative flavors such as raw or fruity (9, 12, 22).

Roasted peanut seed aroma consists of hundreds of small molecular weight compounds. Generally, pyrazines such as methylpyrazine, dimethylpyrazine, and methylethylpyrazine have been associated with roasted peanut aroma during analysis by gas chromatography techniques (7, 13, 27). Descriptive sensory evaluations of the roasted seeds also have correlated headspace pyrazine content and dark roast (9), or roasted peanut attribute (8). Prolonged roasting produces both bitterness and higher pyrazine content in the seed (8, 9, 11, 14). Consequently optimum flavor development has a distinct roast energy requirement, and is not simply a function of increased pyrazine concentration (9, 27). Although many of the volatile compounds mentioned here are associated with roasted peanut flavor, simple combinations of these compounds do not duplicate the complex sensory properties of the roasted seed itself.

Peanut seeds accumulate melanoidin pigments during roasting via the same Maillard reaction pathways that produce the flavor volatiles (20). Maximum roasted peanut flavor develops at a distinct surface color, or roast color (9, 17, 18, 19, 20, 23). In many cases, roast color is the primary parameter used to control commercial roasting operations because of this useful relationship. Differences in seed flavor potential due to raw material factors such as seed variety (17, 18, 19) and seed maturity (15, 22, 23) have been based on roasting to a common color to reduce experimental variability.

Roasting also gives peanut seeds a desirable crunchy texture (1). Little has been done on the optimization of this trait in roasted peanuts. Seed moisture loss is important. Furthermore, it seems likely that changes in the structure of seed constituents like storage proteins during roasting (21) may be important in crispness.

Commercially, peanut seeds are sold by size or as a certain seed count per unit weight. Consequently, roasting operations must use a raw material which is a mixture of genotypes, seed sizes and maturities, seed developmental environments, and seed curing and storage histories.

In this laboratory study, several common methods for measuring physical, chemical, and sensory changes were applied to the roasting of commercial lots of peanut seeds in order to examine relationships between roast color and other analytical measurements related to roast quality. Patterns in the generation of volatile chemicals and sensory attributes were characterized and compared to the changes in more commonly used measurements of seed surface color and moisture content. Peanut roasting was optimized more readily by a combination of analytical methods. Products depending on high oleic acid trait for stability needed an additional test to confirm the purity of the raw material.

Materials and Methods

Peanut Seed Source

Commercial lots of jumbo runner and extra large virginia grade seeds were used from harvest years 1991 through

[1]Planters Company.
[2]Nabisco Research, 200 DeForest Ave., East Hanover, NJ 07936.
*Corresponding author.

1995. The growing environment was the U.S., Argentina, or Mexico, as indicated. One exception was that sound mature kernel grade seeds from the University of Florida Peanut Breeding Program were used in stability tests for the high oleic acid trait (25). These experiments used the wider range of seed sizes because seeds were limited. The seeds from genotypes with variable oleic acid content were grown in Marianna, FL in 1993 and were selected with a 6.4 x 19-mm screen.

Blanching Procedure

With U.S. commercial seed lots, the raw seeds were dried in a continuous, forced-air oven system. The seed coats were removed as the seeds were forced through sets of rotating rollers at the end of the process. Raw seeds from the University of Florida, Argentina, and Mexico were dried at 95 C for 1 hr in a mechanical convection oven (Precision Model 625, Precision Scientific Inc., Chicago, IL). The seed coats were removed by hand after the drying process.

Oil Roasting

Blanched peanut seeds were roasted in a Pitco Model 12S oil fryer (Pitco Frialator, Inc., Concord, NH). The fryer had an oil capacity of approximately 16 L of peanut oil. Oil was changed daily. Seeds (0.2 to 1 kg) were submerged in the roaster oil using a stainless steel wire basket. Roast temperature was measured at the bottom of the basket using a thermometer. Temperature was 152, 157, 163, or 174 C. Roast time varied from 0 up to 14 min. After roasting, seeds were rapidly cooled to room temperature by forced air flow. Air was pulled through a 49 x 30-cm stainless steel mesh holding the roasted seeds by a 15-cm diameter fan and Dayton Model 4C445A motor (Dayton Electric Mfg. Co., Chicago, IL). Roasted seeds were stored in quart Mason jars at 18 C. The jar lids were sealed under approximately 50 cm Hg of vacuum. Roasted seeds were usually analyzed within a week.

Roast Color

Surface color of whole seeds was measured with a HunterLab Model D25-9 colorimeter (Hunter Associates Laboratory, Inc., Reston, VA). The instrument was calibrated by placing the white calibration tile directly on the port plate. The polycarbonate sample dish (16.5 cm diameter) was filled to a 4-cm height with seeds. The CIELAB L*, or lightness value, was the average of three readings taken on the same sample.

Moisture

Seeds were ground in a Braun household coffee mill, and moisture content was measured with a Computrac Model MA-5A moisture analyzer (Arizona Instruments, Phoenix, AZ) according to manufacturers instructions. The analyzer temperature was set at 137 C.

Analysis of Roasted Seed Volatiles by Gas Chromatography

Roasted seeds were finely ground using a Hobart grinder (The Hobart Mfg. Co., Troy, OH) just prior to analysis. Volatiles were isolated from the ground seeds and analyzed by two methods.

The SPSE/FID Method. Volatiles were collected using the simultaneous purging and solvent extraction (SPSE) method of Umano and Shibamoto (26). Ground seeds (100 g) were placed in a two-neck, round-bottom flask for 3 d at 50 C. The volatiles released from a sample were purged with argon gas at a rate of 50 mL/min, and transferred into deionized water at 10 C. A constant countercurrent flow of dichloromethane extracted the volatiles initially trapped by the water. The dichloromethane extract was mixed with sodium sulfate overnight. The organic solution was transferred to a round-bottom flask and concentrated by fractional distillation with a Vigreux column.

Volatiles were analyzed with a Hewlett-Packard HP5890 Series II gas chromatograph (Palo Alto, CA). Two μL of the concentrated extract was injected in a 250 C split/splitless injector, set at a ratio of 30:1. Volatile components were separated with a DB-Wax 30 m x 0.25 mm (film thickness = 0.5 μ) fused silica capillary column (J&W Scientific, Folsom, CA). Helium was used as the carrier gas at a linear velocity of 25 cm/sec. The temperature profile for chromatography was 40 C for 10 min, then 40 C to 180 C at a rate of 3 C/min, followed by 180 C for 10 min. The flame ionization detector (FID) was set at 250 C. The peak area of the internal standard dodecane (99+ %, Aldrich Chemical Co., Milwawkee, WI) was used to calculate the relative amount of volatile components. This technique was called the SPSE/FID method.

The SH/SIM Method. For static headspace (SH) extraction, a 100-g sample of ground seeds was placed in a 500-mL Erlenmeyer flask along with an upright, open vial containing dodocane internal standard. The flask was capped with a custom Teflon stopper containing a high pressure stopcock. The flask was placed in a 50 C water bath for 2 hr until sample collection. A 10-mL sample of headspace was withdrawn over a 3-min period from the Erlenmeyer flask with a 10-mL Hamilton syringe (Reno, NV) and a 22 cm-long microbore-fused-silica needle (internal diameter = 0.1 mm).

The 10-mL sample of headspace volatiles was injected with a Hewlett-Packard on-column injector into the same gas chromatograph and capillary column used for the SPSE/FID method. The front of the capillary column was submerged in liquid nitrogen (-196 C) to trap volatiles. After sample injection, the carrier gas flow was set to 17 cm/sec. The liquid nitrogen trap was kept in place for an additional 2 min. The temperature profile for chromatography was 35 C for 6 min, 35 to 150 C at a rate of 20 C/min, 150 to 186 C during a 3-min period, followed by 186 C for 6.25 min. A Hewlett-Packard Model 5971 mass selective detector detected volatiles using single ion mode (SIM). Both retention time and a specific mass spectrum ion were used to identify compounds and determine relative amounts in a semi-quantitative manner. The relative peak area of volatiles was calculated using the peak area for ion 127 of the dodecane internal standard. Comparisons of relative peak area are only valid for the same compound under different roast conditions, and not between different compounds. This technique was called the SH/SIM method.

Descriptive Sensory Analyses

Panels of adults were trained in the organoleptic characteristics of roasted seeds according to standard practice (5, 10, 13). Panel size for individual experiments ranged from seven to 12 people. Panelists practiced with intensity standards and roasted peanut seed samples for 2 hr the day before experimental samples were evaluated. Some key flavor standards were raw peanut seeds for raw/beany, variable oil roast treatments of blanched seeds for roast peanut and dark roast, caffeine for bitter, and sucrose for sweet. Two definitions of textural attributes were hardness measures the force to bite completely through the sample with the front teeth or molars, and crispness equals the force required to break through the sample after three

chews. A maximum of four experimental samples was evaluated by any panelist on 1 d. The intensity of an attribute was evaluated on a 0 to 150-mm line scale. The intensity scale was 50 for slight, 100 for moderate, and 150 for strong. Experimental sample differences were determined by analysis of variance and Duncan's statistical tests.

Sucrose and Fatty Acid Analyses

The sucrose content of raw seeds was measured using a liquid chromatography method (4). The oil fraction was pressed out of raw seeds with a Model C Carver laboratory press (Fred S. Carver, Inc., Menomonee Falls, WI). Maximum pressure was 6 mt. Fatty acids in the pressed oil were derivatized to methyl esters, and separated by capillary gas-liquid chromatography on a SP-2560 (Supelco, Inc., Bellefonte, PA) column (2). Only the concentrations of the more abundant fatty acid species are reported here.

Oxygen Stability Index

The stability of the pressed oil fraction from raw seeds was measured using an ADM Omnion oxidative stability instrument (Omnion, Rockland, MA). Oil samples were tested at 110 C according to manufacturer's instructions and standard technique (3).

Accelerated Oxidation Test (Schaal Oven Test)

Roasted seed samples (100 g) were placed in replicate 500-mL I-CHEM flint glass jars (VWR Scientific, Greenbelt, MD). The jars contained ambient atmosphere, but were tightly capped, and were stored at 64 C in a convection oven. Jars were removed from storage at the indicated times. The seeds in the sample were ground and analyzed for volatiles using the SH/SIM method described above. Hexanal was measured by monitoring ion 56 with the SIM detector.

Results

The surface color of blanched seeds changed in multiple phases during oil roasting (Fig. 1). The CIELAB L* value, or lightness value, decreased rapidly during the initial 4-min period. Seeds had a raw or green flavor and a rubbery bite during this period. The CIELAB L* value changed very little after 8 to 11 min of roasting for U.S. jumbo runner seeds (Fig. 1) and extra large virginia seeds (data not shown). Optimal roast peanut flavor and crisp texture developed for U.S. seeds during this roast phase where CIELAB L* value showed minimal change. The surface color of jumbo runner Argentine seeds darkened during roasting in a curve similar to that found for U.S. seeds (Fig. 1), but the changes in CIELAB L* values were greater.

The size and weight of the jumbo runner seeds were similar for the U.S. and Argentine lots used here. The more rapid darkening of Argentine seeds during roasting was consistent with compositional differences compared to U.S. seeds. For example, the sucrose content of raw Argentine seeds was 6.7 and 5.7%, respectively, for the 1993 and 1994 harvests. The sucrose content of U.S. seeds was commonly around 4%.

Seeds lost moisture content rapidly during the early phases of oil roasting (Fig. 2). Seed moisture changes were minimal during the roasting interval of 6 to 12 min when optimal roast peanut flavor and texture developed.

The generation of potential flavor compounds during the roasting process was characterized in an experiment where both the roast temperatures (174, 163, 152 C) and roast times (3, 7, 11 min) were varied (Fig. 3). Sixty-three volatile compounds were identified and measured in roasted seeds using capillary gas chromatography technique. Roasted extra large virginia seeds contained more total volatile compounds either with increasing roast time at a constant temperature, or with higher roast temperature at a constant roast time (Fig. 3). Relative changes in the concentration of specific compounds during roasting were further studied using the SH/SIM method. Volatile compounds such as pyrazine, methylpyrazine, dimethylpyrazines, 2,3-dimethyl-

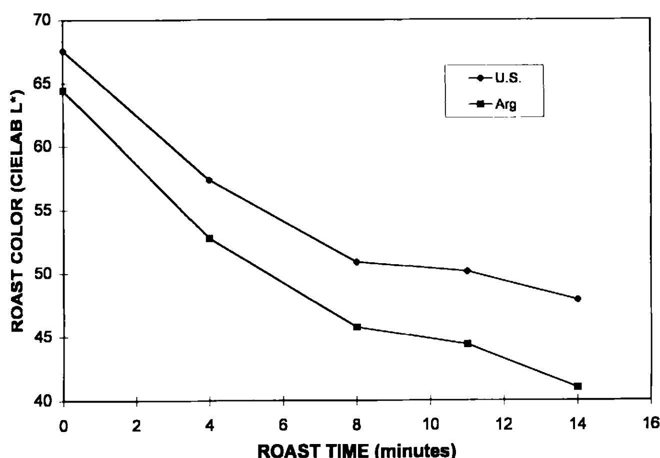

Fig. 1. Changes in surface color of jumbo runner seeds with increased roast time. Seeds were grown in either the U.S. or Argentina (Arg) in 1994. Temperature of the roaster oil was 157 C.

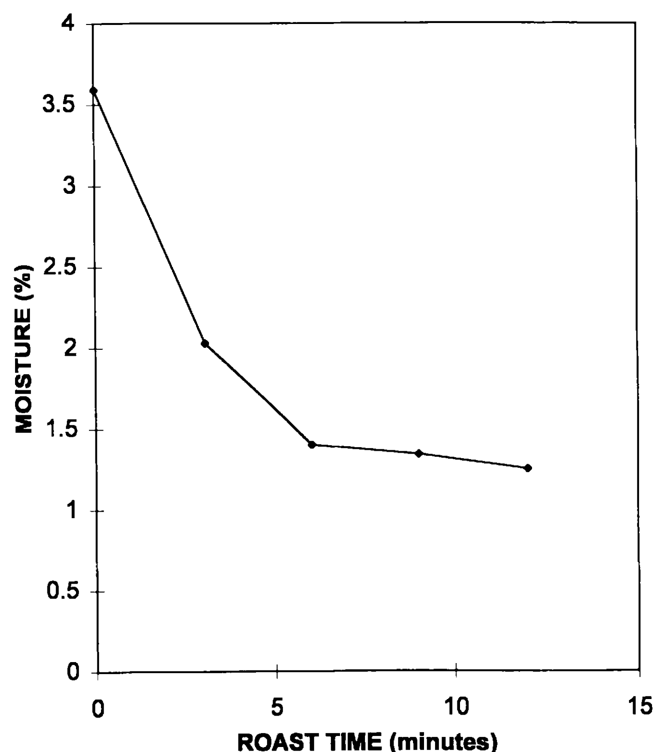

Fig. 2. Changes in moisture content of U.S. extra large virginia seeds with increased roast time. Seeds were from the 1995 harvest. Temperature of the roaster oil was 157 C.

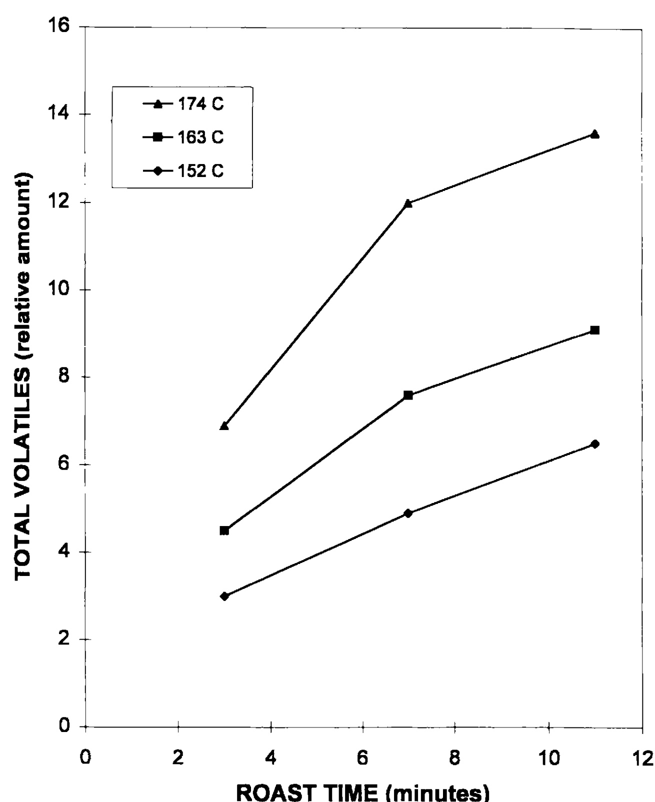

Fig. 3. Relationship between total volatiles produced by roasted U.S. extra large virginia seed and the time (3, 7, 11 min) and temperature (152, 163, 174 C) conditions used for roasting. Seeds were from the 1991 harvest. The concentration of compounds was measured using the SPSE/FID gas chromatography method.

pyrazine,2,6-diethylpyrazine,trimethylpyrazine, and ethyl, methylpyrazines were present in higher concentrations in the more roasted seeds (Table 1).

Descriptive sensory analysis (Fig. 4) on the same roasted seed samples used in experiment in Fig. 3 and Table 1 showed a complex relationship between key flavor attributes and the thermal energy input. Selected flavor attributes were measured on an intensity scale relative to known standards (5, 9, 12). Roasted peanut and sweet were desirable attributes, whereas dark roast was only desirable at lower amounts. Two negative traits were raw/beany associated with underroasted seeds, and high levels of bitter associated with highly overroasted seeds.

Roasted peanut character had a definite maximum during roasting (Fig. 4). Excessive thermal energy input increased the dark roasted and bitter notes associated with highly overroasted seeds. Both the positive attribute sweet and the negative attribute raw/beany decreased with more thermal energy during roasting. Extra large virginia seeds roasted at 163 C for 7 min had the optimum roast flavor ratings and crisp texture in this experiment. The seeds with optimum roast quality based on sensory testing did not correspond to the seed samples with the greatest amounts of flavor volatiles such as pyrazines (Table 1).

The importance of sensory evaluation is shown in Fig. 5. Jumbo runner seeds from three countries of origin were roasted for 11 min at 157 C. A descriptive sensory panel described the taste and texture qualities of the U.S. and Mexican seeds as similar. By contrast, the Argentine seeds roasted under the same conditions had significant amounts of dark roasted note, and increases in other indicators such as bitter and astringent that indicated excess roasting. These flavor differences between Argentine and U.S. or Mexican seeds were statistically significant at P = 0.001.

Argentine and U.S. seeds differed in two other important sensory traits. Argentine jumbo runner seeds from the 1993 (Fig. 5) and 1994 harvests had a harder texture than U.S. seeds. Some Argentine seeds from 1993-1995 lots also had an off flavor which severely from reduced flavor quality. The off flavor scores were included in the off note attribute shown in Fig. 5. The off flavor caused throat burn, or was characterized as a musty note. Some individual tasters are much more sensitive to this off flavor than others.

Argentine seeds had slightly more polyunsaturated fatty acid content than U.S. seeds. Argentine peanuts

Table 1. Effect of roast conditions on selected pyrazine volatiles isolated from U.S. extra large virginia seeds, 1991 harvest.

Pyrazine compound	Retention time	Ion monitored	152 C 3 min	152 C 7 min	152 C 11 min	163 C 3 min	163 C 7 min	163 C 11 min	174 C 3 min	174 C 7 min	174 C 11 min
	min	a.m.u.[a]	— relative peak area —			— relative peak area —			— relative peak area —		
Pyrazine	11.2	80	0.03	0.04	0.12	0.06	0.09	0.16	0.09	0.21	0.41
Methylpyrazine	11.8	94	0.15	0.37	1.10	0.49	1.10	4.30	1.80	3.00	6.50
Dimethylpyrazines[b]	12.4	108	0.31	1.10	4.00	1.00	2.90	6.10	2.90	6.90	13.00
2,3-Dimethylpyrazine	12.7	108	<0.01	0.03	0.16	0.04	0.14	0.38	0.17	0.36	0.86
Ethyl, methylpyrazines[c]	13.1	121	0.08	0.19	0.73	0.27	0.60	1.50	0.68	1.10	2.80
Trimethylpyrazine	13.3	122	0.07	0.19	0.54	0.23	0.46	1.10	0.78	1.10	1.90
2,6-Diethylpyrazine	13.9	135	<0.01	0.02	0.07	0.02	0.05	0.13	0.09	0.14	0.24

[a]Ion in atomic mass units (a.m.u.) used to calculate relative peak area by the SH/SIM method.

[b]Values represent the sum of 2,5- and 2,6-dimethylpyrazines.

[c]Values represent the sum of 2-ethyl, 6-methylpyrazines, and 2-ethyl, 5-methylpyrazines.

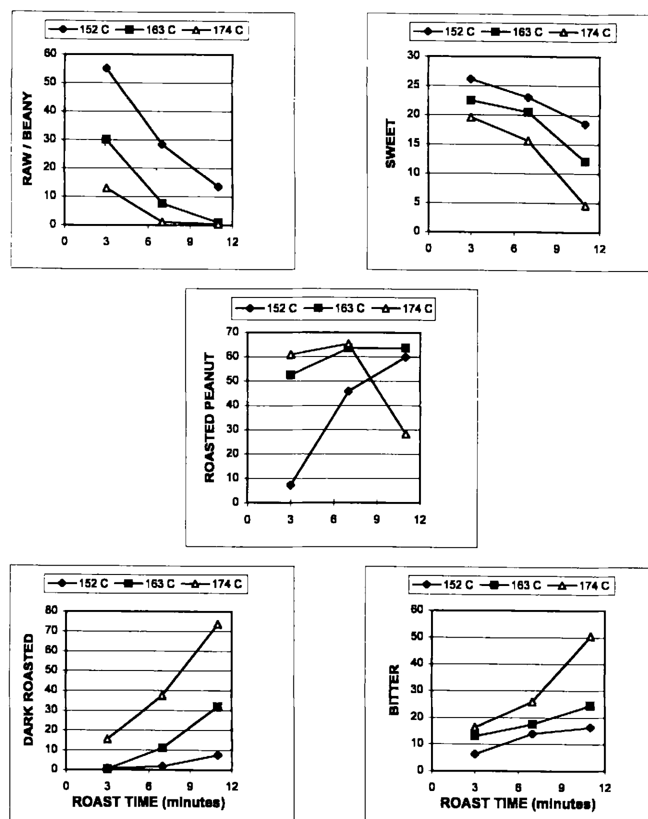

Fig. 4. Changes in flavor intensity of U.S. extra large virginia seeds roasted at different times (3, 7, 11 min) and temperatures (152, 163, 174 C). Seeds were the same ones used for volatile analyses (Fig. 3). The five sensory attributes (raw/beany, sweet, roasted peanut, dark roasted, bitter) are shown based on a 150-unit scale calibrated with intensity standards for each attribute.

the 1993 harvest had 34% linoleic acid versus 30% for U.S. seeds. Roasted product stability was similar for both Argentine and U.S. seeds in an accelerated oxidation test (data not shown).

High oleic acid seeds were evaluated to determine whether a raw material with low polyunsaturated fatty acid content would produce more stable roasted product. High oleic acid cultivars had roasted peanut flavor ratings similar to normal chemistry cultivars (data not shown). Oleic acid, linoleic acid, and palmitic acid contents were 79.56, 3.34, and 5.85%, respectively, for the cultivar SunOleic 95R, whereas the conventional chemistry cultivar Florunner had values of 51.17, 28.38, and 10.08% for the same fatty acids. Cold pressed oil from raw high oleic acid seeds (80% in Fig. 6) was roughly five times more stable than the oil from genotypes with oleic acid content less than 65% from the University of Florida breeding program. The enhanced oxidative stability of the high oleic acid oil also was expressed in roasted seeds. In an accelerated oxidation test (Fig. 7), hexanal production surged after 20 d of storage with the conventional cultivar Florunner, whereas hexanal production was still relatively low after 80 d with the cultivar SunOleic 95R.

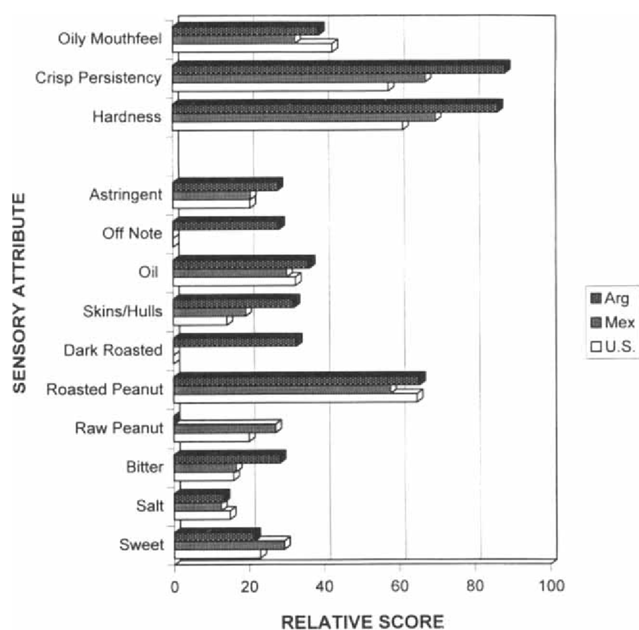

Fig. 5. Descriptive sensory evaluations of roasted jumbo runner seeds grown in different environments (U.S., Mexico, Argentina). Seeds were from the 1993 harvest. Seeds were roasted for 11 min at 157 C. The relative intensity scores for 3 texture attributes and 10 flavor attributes are shown based on a 150-unit scale.

Discussion

The finding (9, 18, 20, 23) that roasting within a specific range of CIELAB L* roast colors maximizes the roasted peanut character of peanut seeds makes this quick color measurement a valuable quality test. The limitation of CIELAB L* values as a control parameter is the minimum color change shown at thermal energy inputs (Fig. 1) which are generating the optimum mix of key flavor attributes such as roasted peanut, dark

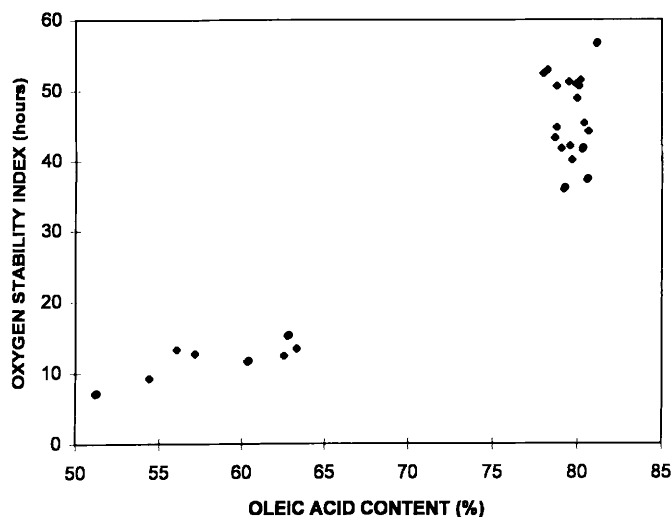

Fig. 6. Relative stability of oils extracted from different genotypes with variable oleic acid content used in the University of Florida Peanut Breeding Program. Seeds were grown in Florida in 1993.

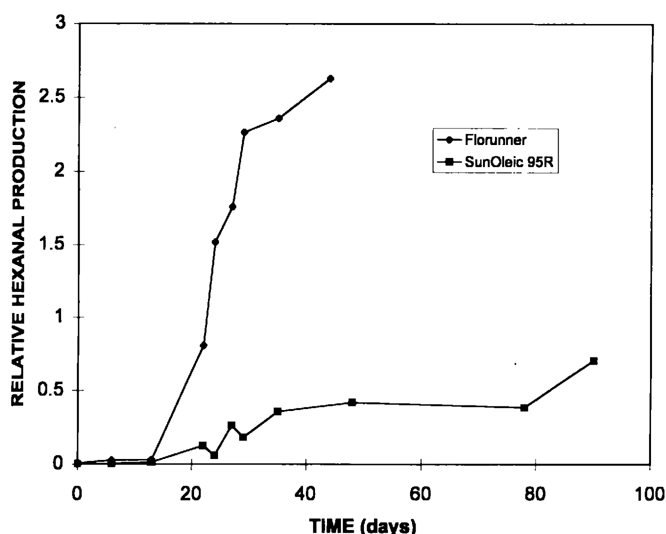

Fig. 7. Comparison between roasted seed stability of cultivar Florunner and a high oleic acid cultivar (SunOleic 95R). Seed were sound mature kernels from the University of Florida Peanut Breeding Program. Seeds were oil roasted for 9.3 min at 157 C, and then stored at 64 C and ambient air. Relative hexanal production was used as a marker for lipid oxidation.

roast, and sweet (Fig. 4). Roast times of 8 to 11 min at typical temperatures had limited effects on roast color, but generated significant changes in flavor balance of the finished product. Seed moisture content can be used to optimize roasting conditions, but it also changes little during the critical roasting period when optimal flavor develops (Fig. 2).

The possibility of using the concentration of potential flavor compounds such as pyrazines as markers for optimizing roast conditions has appeal. Several simple and portable instruments for measuring volatile compounds are available. Research on the generation of roasted peanut flavor (13, 20, 22, 27) has shown the concentration of pyrazines generally increases with longer roast time. These compounds are associated with both roasted peanut and general roast character (8, 13), but in high concentrations may lead to bitter flavor and excessive dark roast character (27). Perhaps other volatiles among the many compounds already reported (1) are more directly linked to roasted peanut character, and thus better analytical targets for roaster control. The present information on the concentration of volatile compounds in roasted seeds is probably not sufficient to allow any further fine tuning of roaster conditions beyond what conventional markers such as roast color or seed moisture accomplish.

The roasting experiments with Argentine seeds illustrate how a raw material difference such as country of origin can have dramatic impact on a roaster operation trying to produce uniform finished product. Argentine seeds can roast to a darker roast color than U.S. seeds under constant conditions (Fig. 1, 6). The higher sugar content of Argentine seeds compared to U.S. seeds (6) may be at least partially responsible because sugars are reactants in the Maillard reaction pathway and browning reactions (1, 20, 22). Roasted Argentine seeds can have a harder texture (Fig. 5). Roasted Argentine seeds are more likely to have higher fruity/fermented sensory scores (6) or off flavor (Fig. 5) than U.S. seeds, even though the Argentine seeds may have large amounts of flavor volatiles (6), or high roasted peanut sensory scores (Fig. 5). Blending seeds with different composition can further complicate the selection of appropriate roast conditions because of the potential for greater heterogeneity in quality traits such as roast color, flavor, and texture.

Oxidation can be an important limiting factor for the storage of roasted seeds (5, 22). High oleic acid content of peanut seeds is one compositional factor that leads to greater stability in the flavor profile after roasting. Roasted seeds with 80% oleic acid content resist rancidity (Fig. 7; 7) and maintain roasted peanut character longer (7) than conventional 50% oleic acid seeds. Pressed oil from peanut breeding lines with only minor increases in oleic acid content (<65%) was only slightly more stable to oxidation than conventional 50% oleic acid oil (Fig. 6). Consequently, peanut products requiring the oxidative stability of the high (80%) oleic acid trait would need fatty acid profile analyses, or accelerated oxidation tests, to ensure raw material purity.

In conclusion, roast color remains a key test for roast optimization. Sensory assessment of the roast peanut attribute also appears necessary because of the diverse nature of the raw seeds used in the snack food industry. The optimal flavor profile found immediately after roasting will last longer using the high oleic acid trait in peanut seeds.

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