Roasted Peanut Flavor Intensity Variations Among U.S. Genotypes[1]

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ABSTRACT

Roasted flavor should be a critical factor in the acceptance of a peanut cultivar edible use. A 5-yr study was made on variation in roasted peanut flavor intensity of U.S. peanut cultivars and advanced breeding lines. Sixty-one genotypes were evaluated with sufficient location and replication observations (4) to have a 40% chance of detecting a true difference of 0.5 sensory units in flavor score with P = 0.05. Cultivars Florunner, NC 7, and Pronto were used as comparison standards for the roasted peanut attribute in the runner, virginia, and spanish market types, respectively. The adjusted mean difference between control and test germplasm was largest within the virginia type, with an adjusted mean difference of +0.7 units for roasted peanut attribute intensity. Runner types were next with a difference of +0.3 units and spanish types were not different. Broad-sense heritability for the roasted peanut attribute among germplasm sources was 9.3%, which compares favorably with previously published values of 10.6 and 24.3%. Heritability of the sweet sensory attribute was determined to be 25.9%, compared to previously published values of 14.3 and 37.0%. This suggests a potential for improving the roasted peanut and sweet attribute levels through using proper breeding strategies.

Key Words: Roasted flavor, nuttiness, sweetness, *Arachis hypogaea*, groundnut, market types, broad-sense heritability.

For the last 10 yr, over 50% of the edible supply of shelled peanuts in the U.S. has been roasted prior to consumption (Agricultural Statistics, 1992). This roasting process converts the peanut seed from its slightly sweet, green "beany" flavor in the raw state to a flavor that is delicate, uniquely nutty, and widely enjoyed. The specific origin of this delicate, uniquely nutty peanut flavor is not known; but it has been suggested that amino acids, a peptide, and carbohydrates in an oil medium are the precursors to roasted peanut flavor (Mason and Waller, 1964; Newell *et al.*, 1967; Mason *et al.*, 1969). Various aspects of roasted peanut flavor and parameters which affect it have been previously reviewed (Pattee and Young, 1982; Pattee *et al.*, 1985; Ahmed and Pattee, 1987).

The most widely investigated peanut seed components across genotypes are oil and fatty acid compositions (Norden *et al.*, 1987; Pattee and Young, 1987). Varietal differences in stereospecificity of triacylglycerols have been examined (Sanders, 1979; Treadwell and Young, 1982). Genotypic variations in protein and free amino acids contents have been studied also (Holley and Hammons, 1968; Young and Hammons, 1973; Tai and Young, 1975; Young, 1979), as has amino acid composition variation among selected genotypes (Young, 1979) and carbohydrate variation (Young *et al.*, 1974; Basha *et al.*, 1976; Oupadissakoon *et al.*, 1979). Recently, Pattee and co-workers (Pattee and Giesbrecht, 1990; Pattee *et al.*, 1993) studied inheritance of roasted peanut flavor intensity and documented broad-sense heritability estimates for the roasted peanut sensory attribute.

The objective was of this paper to document variability in roasted peanut flavor intensity across a wide range of peanut cultivars and breeding lines using normalized sensory data (Pattee and Giesbrecht, 1994).

Materials and Methods

Genetic Resources

1986-1988. Seed samples for the 1986 crop year were obtained from peanut breeding programs in Florida, Georgia, North Carolina, Oklahoma, Texas, and Virginia and represented nearly all commercially available cultivars within each market type grown in the U.S. Only selected cultivars and breeding lines grown in Georgia and Virginia were used for the 1987 and 1988 crop years. All samples were obtained from plants grown and harvested under standard Extension Service recommended procedures for each location. Replication in this study was obtained by replication of selected entries across locations in 1986. Years were used for replication for selected entries from 1986 in 1987 and 1988 for both locations.

1988M. Thirty virginia-type genotypes were grown in randomized complete block experiments at two locations, Northampton County, NC and Suffolk, VA in 1988 using Extension Service recommended cultural, harvesting, and handling practices. These entries were part of the Virginia-North Carolina germplasm evaluation program.

1990. Seed samples were obtained from peanut breeding programs in Florida, Georgia, North Carolina, Texas, and Virginia in a study designed to measure the effects of location and genotype on roasted peanut flavor and to evaluate new advanced breeding lines. All samples were obtained from plants grown and harvested under standard Extension Service recommended procedures for the specific location.

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breeding lines for improved roasted peanut flavor quality. All samples were obtained from plants grown and harvested under standard Extension Service recommended procedures for the specific location.

Sample Handling

Following harvesting and shelling each year, a 1000-g sample of the sound mature kernel (SMK) fraction from each entry at each location was shipped to Raleigh, NC in February. Samples were placed in controlled storage at 5 C and 60% RH until roasted.

Sample Roasting and Preparation

Peanut samples from each year were roasted between May and July using a Blue M "Power-O-Matic 60" laboratory oven, ground into a paste, and stored in glass jars at -20 C until they were evaluated. The roasting, grinding, and color measurement protocols were as described by Pattee and Giesbrecht (1990).

Sensory Evaluation

An eight-member trained roasted peanut flavor profile panel at the Food Science Dept., North Carolina State Univ., Raleigh, NC evaluated all peanut paste samples using a 1-14 intensity scale. Panel members were the same from year to year. Panel orientation and reference controls were as described by Pattee and Giesbrecht (1990) and Pattee *et al.* (1993). Two sessions were conducted weekly, but never on consecutive days. Panelists evaluated six samples per session in 1986, five samples per session in 1987 and 1988, and four samples per session in all subsequent years. In 1986-88 and 1990, samples were presented in a randomized order. In the 1988M and 1991 studies, samples were presented in an incomplete block design to monitor variation within and between panel sessions. Sensory evaluation commenced during the middle of June and continued until all samples were evaluated.

Statistical Analysis

Statistical analyses on all data sets used procedures in the SAS (1987) system, Vers. 6, and Giesbrecht's (1989) procedure for analysis of mixed models to estimate the components of variance. Averages of individual panelists' scores on sensory attributes were used in all analyses. Utilizing the findings of Pattee *et al.* (1994) on genotype-by-environmental interaction of roasted peanut flavor, mean values having less than four observations and two locations were not included in this paper, thus providing more reasonable estimates of experimental error. Genotype means for the roasted peanut attribute were adjusted to a common roast color value of 58.3 and common fruity score of 1 (Pattee and Giesbrecht, 1994).

Results and Discussion

Broad-Sense Heritability Estimates

Broad-sense heritability estimates for the sensory attributes roasted peanut, sweet, and nutty were previously shown to be the amenable to genetic improvement (Pattee and Giesbrecht, 1990; Pattee *et al.*, 1993). Because this roasted peanut flavor data set has increased significantly both in numbers of genotypes and observations per entry since these publications, heritability estimates were re-evaluated and compared with previously obtained data. Further, the equation used for determining the broad-sense heritability estimates by Pattee *et al.* (1993) did not include the effects of year, production region, or their interaction with genotype. With these effects included, the appropriate formula for estimating the broad-sense heritability of means calculated from n observations taken in n_y years, n_r regions, n_{yr} year-region combinations, and a total of n_e environments (locations in years and regions) is:

$$H = \frac{S_G^2}{S_G^2 + \frac{S_Y^2}{N_y} + \frac{S_{YR}^2}{N_{yr}} + \frac{S_{E(YR)}^2}{N_e} + \frac{S_{GY}^2}{N_y} + \frac{S_{GR}^2}{N_r} + \frac{S_{GYR}^2}{N_{yr}} + \frac{S_{GR(YR)}^2}{N_e} + S^2} \quad \text{[Eq. 1]}$$

where $S_G^2, S_Y^2, S_{YR}^2, S_{E(YR)}^2, S_{GY}^2, S_{GR}^2, S_{GYR}^2, S_{GR(YR)}^2$ and S^2 are estimates of variance components associated with genotype, year, year-by-region interactions, environments in year-by-region interaction, genotype-by-year interactions, genotype-by-region interactions, genotype-by-year-by-region interactions, genotype-by-environment interactions in years and regions, and residual error, respectively. Table 1 contains the current estimates of variance components as well as previous estimates for comparative purposes. Any variance components estimated in the previous publications, but not in the current analysis, would be confounded with the residual error of this study.

In spite of the variability inherent in the estimate of heritability, the estimates obtained for roasted peanut, nutty, and sweet flavor attributes were fairly consistent across the data sets. Recognizing the importance of year-to-year variation, one would expect the estimates obtained in the earlier studies to be inflated because the year component of variance was omitted from the denominator of the heritability formula. Conversely, the current study included a broader array of genotypes, especially in comparison with the Pattee *et al.* (1993) study which included only virginia-type cultivars obtained from the Virginia-Carolina (VC) production region in a single year. Based on the results of the current study, the roasted peanut and sweet attributes are amenable to improvement through breeding. The nutty attribute exhibited little genotypic variation and improvement of this trait by selection will not be possible.

Comparative Variation of Roasted Peanut Attribute Among Germplasm

To make comparisons among germplasm lines, the widely grown cultivars NC 7 (virginia), Florunner (runner), and Pronto (spanish) were designated as standards for each of the market types. Statistical comparisons were then made within market type. Least-squares means estimates adjusted to roast color of 58.3 and fruity attribute of 1, and common production region (VC) for the roasted peanut attribute were determined for each germplasm line. Both the unadjusted and least-square means are presented for informational purposes but only the least-square means were used to determine differences (Tables 2, 3, and 4). It was previously suggested that the smallest meaningful difference for roasted peanut flavor intensity is 0.5 sensory units on a 1-14 scale (Pattee *et al.* 1993). This criterion should be used by peanut breeders while making decisions regarding the level of improvement needed to significantly affect the commercial product. Virginia market-type germplasm (Table 2) has the highest potential for flavor improve-

Table 1. Estimates of variance components and broad-sense heritabilities for the roasted peanut, nutty, and sweet attributes of roasted peanuts.

	Sensory attribute								
	Roasted peanut			Nutty			Sweet		
Variance components	Curr.	Prev1[a]	Prev2[b]	Curr.	Prev1	Prev2	Curr.	Prev1	Prev2
Genotype (G)	.056	.100	.044	.000	.020	.043	.071	.040	.080
Year (Y)	.294	--	--	.292	--	--	.037	--	--
Y x Region (R)	.000	--	--	.022	--	--	.047	--	--
Environment (E) in Y,R	.021	.020	.000	.073	.080	.000	.038	.080	.036
GxY	.000	--	--	.052	--	--	.003	--	--
GxR	.000	--	--	.000	--	--	.000	--	--
GxYxR	.000	--	--	.000	--	--	.000	--	--
GxE in Y,R	.052	--	.048	.000	--	.005	.000	--	.000
Block	--	.000	.170	--	.000	.124	--	.040	.006
Panel (P)	--	--	.102	--	--	.086	--	--	.016
Within P	--	--	.049	--	--	.101	--	--	.078
Residual	.175	.290	--	.183	.270	--	.078	.120	--
Heritability[c]	.093	.243	.106	.000	.050	.120	.259	.143	.370

[a]Prev1 = Estimates obtained by Pattee and Giesbrecht (1990).
[b]Prev2 = Estimates obtained by Pattee *et al.* (1993).
[c]Heritability estimated for a single plot value in a single environment ($n_y=n_{yr}=n_e=n_r=n=1$).

ment by replacing current cultivars with existing breeding lines. The two virginia-type lines with the highest adjusted roasted flavor scores were 0.7 units higher than the standard, and seven virginia-type breeding lines had scores 0.5 units greater than NC 7. None of the runner or spanish types were 0.5 units superior to their respective standard cultivars (Tables 3 and 4). Potential improvement for the virginia type is largest, and is of interest because previous reports indicated that runner-type peanuts have the highest, and virginia types have the lowest roasted peanut flavor (Pattee and Giesbrecht, 1990). In previously published work (Pattee and Giesbrecht, 1990; Pattee *et al.*, 1993) the comparison control for the virginia type was Florigiant. Since 1986 there has been a shift in the major production cultivars grown in the VC production region. In 1985, Florigiant accounted for about 58%, NC 7 about 27%, and NC 9 (released in 1985) 0% of the production hectareage. In 1988, the percentages had shifted to approximately 24, 33, and 19%, respectively; in 1990 to 9, 38, and 18%; and in 1993 to 0, 37, and 16% in the VC region (Anon., 1989, 1991; G. Sullivan, pers. commun.). NC-V 11, released in 1989, had the largest increase in production percentage, with 3 and 18% of the hectareage in 1990 and 1993, respectively. This shift necessitated replacing the virginia-type control cultivar Florigiant with NC 7 and a concurrent increase in the baseline roasted peanut comparison score of +0.1 unit. The next two major cultivars, NC 9 and NC-V 11, had increases of +0.3 and +0.5 units over Florigiant. This indicates a trend in the North Carolina breeding program towards improvement of the roasted flavor aspects of virginia-type cultivars and release decisions now include roasted flavor considerations. N90010E, with a 0.5 unit improvement over NC 7, is a candidate for cultivar release in the near future. Comparison of the top group of roasted peanut scores for runner and virginia types indicates that they have the same potential levels of roasted peanut attribute. With the release of N90010E, parity between virginia- and runner-type cultivars will be achieved, thus demonstrating the value of obtaining roasted peanut flavor data during cultivar development.

Increased efforts must be put forth to maintain the high roasted peanut attribute intensity in new cultivars as evident in the survey of the runner-type germplasm (Table 3). Florunner is widely recognized as having high intensity roasted peanut flavor and only 11% of the tested germplasm lines equal its level of intensity. Only Langley (released in 1986) and Marc I (released in 1990), of the runner-type cultivars released after Florunner, have a higher roasted peanut attribute intensity even though the ancestral pedigrees are similar in all of the releases. To maintain roasted peanut attribute at the level of Florunner, or to improve upon this intensity, germplasm sources used in breeding programs must be evaluated for this important attribute.

Although hectareage of the spanish-type peanut has decreased since the mid-1970s, it is important for specific peanut commodities. The roasted peanut flavor intensity of the three cultivars was about midway between the virginia- and runner-type controls. However, because of the declining production hectareage, only a limited amount of breeding work is being done on this peanut type. Thus, sufficient germplasm samples were not available to make a more extensive evaluation of its roasted peanut flavor potential.

Conclusions

Estimates of broad-sense heritability for roasted peanut and sweetness were sufficiently high that selection among existing cultivars and breeding lines should result in significant improvement of these traits. There was no genotypic variation for the nutty attribute. The range of adjusted roasted peanut scores for virginias (5.1-6.1) and runners (5.1-6.3) were almost identical. Several virginia

Table 2. Comparative variation in the roasted peanut sensory attribute among virginia-type germplasm.

Germplasm	No. obs.	Roasted peanut attribute Mean	Adjusted mean[a]	SE diff. from NC 7
NC 7	50	4.3	5.4	
NC Ac 18457	6	5.0	6.1**	0.25
VA830516-1	5	5.3	6.1**	0.26
VP8407	4	4.8	6.0*	0.28
NC Ac 18431	10	4.8	5.9**	0.20
NC Ac 18456	5	5.0	5.9*	0.26
NC Ac 18460	5	5.1	5.9	0.26
N90010E	6	4.3	5.9*	0.24
NC-V 11	26	4.3	5.8	0.13
NC Ac 18423	10	4.9	5.8*	0.20
NC Ac 18455	6	5.0	5.8	0.25
NC Ac 18464	5	4.9	5.7	0.26
VA-C 92R	6	5.0	5.7	0.24
VP8420	5	4.5	5.7	0.26
AgraTech VC-1	14	4.8	5.7*	0.17
NC 9	25	4.2	5.6	0.14
NC Ac 18424	5	4.9	5.6	0.25
NC Ac 18426	5	5.1	5.6	0.25
NC Ac 18449	4	4.8	5.6	0.28
NC Ac 18451	4	4.7	5.6	0.28
NC Ac 18454	5	4.6	5.6	0.26
N90009	4	4.9	5.6	0.28
N90017	7	4.3	5.6	0.23
NC Ac 18462	5	4.8	5.6	0.26
NC Ac 18463	4	4.5	5.6	0.28
NC Ac 18452	6	4.5	5.5	0.25
NC Ac 18459	6	4.4	5.5	0.25
NC Ac 18450	4	4.8	5.4	0.28
NC Ac 18469	4	4.5	5.4	0.33
N90016	4	4.5	5.4	0.28
N88003	4	4.3	5.4	0.28
VA830215-1	6	4.3	5.4	0.26
VA830416-1	4	4.4	5.4	0.28
VP8417	5	4.8	5.4	0.26
UF82107	6	4.0	5.4	0.26
Florigiant	33	4.4	5.3	0.12
N90013	7	4.1	5.2	0.23
NC 10C	11	4.5	5.1	0.18

[a]Mean adjusted to common levels of fruity attribute and roast color and predicted for the Virginia-Carolina production region.

*,** Denote means significantly different from NC 7 at the 0.05 and 0.01 levels of probability, respectively.

Table 3. Comparative variation in the roasted peanut sensory attribute among runner-type germplasm.

Germplasm	No. obs.	Roasted peanut attribute Mean	Adjusted mean[a]	SE diff. from Florunner
Florunner	58	4.9	6.0	
Marc I	9	4.8	6.3	0.19
Langley	8	5.8	6.1	0.20
Okrun	8	5.4	5.9	0.20
UF90106	9	4.5	5.9	0.23
GA T-2637	4	5.2	5.9	0.28
GA901104	6	4.6	5.9	0.25
Andru 93	8	4.5	5.8	0.24
GA T-2648	4	5.0	5.8	0.28
GA901111	9	4.5	5.8	0.23
GA Runner	7	4.4	5.7	0.23
Sunrunner	10	5.4	5.7	0.18
Tamrun 88	10	4.3	5.7	0.22
UF86107	7	4.4	5.7	0.24
GK-7	8	5.0	5.6	0.23
GA T-2645	4	5.0	5.6	0.28
GA901112	6	4.2	5.4*	0.25
Southern Runner	14	4.7	5.3**	0.30
Sunbelt Runner	5	4.9	5.2**	0.25
GA911108	7	4.0	5.1**	0.24

[a]Mean adjusted to common levels of fruity attribute and roast color and predicted for the Virginia-Carolina production region.

*,** Denote means significantly different from Florunner at the 0.05 and 0.01 levels of probability, respectively.

Table 4. Comparative variation in the roasted peanut sensory attribute among spanish-type germplasm.

Germplasm	No. obs.	Roasted peanut attribute Mean	Adjusted mean[a]	SE diff. from Pronto
Pronto	21	4.5	5.6	
Spanco	9	4.0	5.6	0.22
Starr	10	3.9	5.5	0.21

[a]Mean adjusted to common levels of fruity attribute and roast color and predicted for the Virginia-Carolina production region.

genotypes were superior to the standard NC 7, while none of the runner genotypes were significantly better than Florunner. Thus, the opportunity for improvement in roasted peanut flavor is greater in the virginia than in runner types.

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