# Trends in Sensory Quality of Roasted Peanuts Across 15 Years (1986-2000)

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## ABSTRACT

Enhancement of flavor of roasted peanut (*Arachis hypogaea* L.) has been a long-standing objective of the peanut industry. Studies relative to roasted peanut flavor variation have separated the effects of genotype, environment, and genotype-by-environment interaction on the sensory attributes roasted peanut, sweet, bitter, and astringent. Much of the focus of these studies has been on the genotypic variation and the possibility of genetic improvement of peanut flavor. However, most of the variation in sensory attributes is caused by non-genetic factors. Years were found to be the largest single source of variation for the sensory attributes roasted peanut and bitter. Because roasted peanut is the sensory attribute most important to the peanut consumer, it is important to know if the observed year effects varied randomly or if there was any directional trend in peanut flavor over time. Examination of a 15-yr data set for directional trends in peanut flavor indicated that all three sensory attributes (roasted peanut, sweet, and bitter) exhibited adverse trends across the span of this study. These trends were independent of whether or not the effects of years were unadjusted for other effects or adjusted for the effects of regions, locations within regions, and the covariates fruity attribute intensity and roast color. The nature of the evident trends, i.e., whether they were linear or curvilinear, was often affected by adjustment. Changes in sensory quality of a single cultivar over time are likely due to changes in prevailing cultural practices such as rotations and chemicals applied to the peanut crop. It was not clear whether consumers would have noticed the change in sensory quality over time because the trends within individual cultivars were confounded with changes in the dominant runner-type cultivars with variable sensory quality marketed over the span of the study.

Key Words: *Arachis hypogaea* L., sensory attributes, flavor, sweet, bitter.

## Introduction

Enhancement of roasted peanut (*Arachis hypogaea* L.) flavor has been a long-standing objective of the peanut industry. In a series of studies, Pattee and coworkers (Pattee and Giesbrecht, 1990; Pattee *et al.*, 1993, 1994, 1995, 1997, 1998; Isleib *et al.*, 2003) separated the effects of genotype, environment, and genotype-by-environment interaction on the sensory attributes roasted peanut, sweet, bitter, and astringent. Much of the focus of subsequent studies has been on the genotypic variation and the possibility of genetic improvement of peanut flavor (Pattee and Knauft, 1995; Pattee *et al.*, 2001, 2002a,c,d; Isleib *et al.*, 1995, 2000, 2003). However, most of the variation in sensory attributes is caused by non-genetic factors. Years were found to be the largest single source of variation for the sensory attributes roasted peanut and bitter, but the nature of year effects, i.e., whether they followed any detectable trends, was not determined. Because roasted peanut is the sensory attribute most important to the peanut consumer, it is important to know if the observed year effects varied randomly or if there was any directional trend in peanut flavor over time. If

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the latter, then future research efforts should be directed toward identifying the causes of these trends. The objective of this study was to determine whether the effect of years on sensory attributes of roasted peanut followed a trend.

## Materials and Methods

***Genotype Resources.*** The data used for this study were gathered over a 15-yr span and include two peanut cultivars: Florunner, the industry standard for the runner market-type, and NC 7, similarly a standard for the virginia market-type. Seed samples of the two cultivars were obtained from all three major peanut production regions, and 17 different locations were represented among the samples. In the data set there were 274 observations, including 141 on Florunner and 133 on NC 7. All samples were obtained from plants grown and harvested under standard recommended procedures for the specific location.

The data set was augmented with data on GK 7 (22 observations acquired in 1986 through 2000) and Georgia Green (40 samples observed in 1990 through 2000) to permit a comparison of sensory quality among the cultivars that dominated the runner market-type sequentially during the course of the 15 yr.

***Sample Handling.*** A 1000-g sample of the sound-mature-kernel (SMK) fraction from each location-entry was placed in controlled storage at 5 C and 60% RH in February following the crop harvest until roasted. The SMK fraction was separated using official grading standards for each market type.

***Sample Roasting and Preparation.*** The peanut samples were roasted in May and June following each crop year using a Blue M "Power-O-Matic 60" laboratory oven, ground into a paste, and stored in jars at -20 C until evaluated. The roasting, grinding, and color measurement protocols were as described by Pattee and Giesbrecht (1990) and modified by Pattee *et al.* (1997).

***Sensory Evaluation.*** A long-standing eight-member trained roasted peanut profile panel at the Food Science Dept., North Carolina State Univ., Raleigh, NC, evaluated all peanut-paste samples using a 14-point intensity scale. Panel orientation and reference control were as described by Pattee and Giesbrecht (1990) and Pattee *et al.* (1993). To maintain consistency of sensory scores across years, calibration of the panel was conducted at the beginning of each year's sample evaluation period using the universal flavor intensity standards (Meilgaard *et al.*, 1999). Two sessions were conducted each week on nonconsecutive days. The averages of individual panelists' scores on sensory attributes were used in all analyses in this study.

***Statistical Analysis.*** Regression analysis was performed using the general linear models procedure (PROC GLM) in the SAS statistical software package (SAS Institute, 2001). Linear and polynomial (quadratic) regression curves of sensory attributes roasted peanut, sweet, and bitter on years were fit separately for the two cultivars. To reduce the distortion of regression parameter estimates due to the scale of the independent variable year, year values were expressed as deviations from 1993, ranging from a value of -7 corresponding to the year 1986 to a value of +7 for 2000. Curves were fit on raw data and also on residuals after adjustment for the effects of region, location within region, and covariates fruity attribute and roast color after the findings of Pattee *et al.* (1991, 1997) and Pattee and Giesbrecht (1994).

A second analysis of flavor of the three most recently dominant cultivars in the runner market-type was performed using the mixed model procedure (PROC MIXED) in the SAS package. Data from Florunner, GK 7, and Georgia Green were included, as was data on the virginia-type cultivar NC 7. For this analysis, the effects of production regions, cultivars, and covariates fruity and roast color were considered to be fixed while those of years and locations within years and regions were considered to be random. Cultivar means were compared by pair-wise t-tests, the standard error of each difference being calculated independently.

## Results and Discussion

Examination of the data set for any trends in peanut flavor over time produced the following results.

All three sensory attributes analyzed (roasted peanut, sweet, and bitter) exhibited trends across the 15-yr span of this study. The existence of these trends was independent of whether or not the effects of years were left unadjusted (Table 1) or adjusted for the effects of regions, locations within regions, and the covariates fruity attribute intensity and roast color (Table 2). The nature of the evident trends, i.e., whether they were linear or curvilinear, was often affected by adjustment for the factors described above which will be referred to below as "other factors".

Before any adjustments were made on the data, years accounted for 73% of the total variation for roasted peanut in Florunner and 63% of the total in NC 7 (Table 1). Partitioning variation among years into components due to linear and quadratic regression and residual, 55% of the total variation in Florunner and 46% in NC 7 were due to trends, that is, changes across years. In both cultivars, the trend was one of decline over the span of these studies with the downward trend leveling off in more recent years (Fig. 1a). As has been previously reported, the mean for roasted peanut intensity of Florunner was higher than that of NC 7 (4.23 vs. 3.85 fiu, $P < 0.01$), but the difference between the two cultivars declined over years. With the adjustment for "other factors," years still accounted for approximately half of the total variation in roasted peanut intensity in either cultivar (Table 2), with

**Table 1. Mean squares from analysis of variance from regression of sensory attributes on years, performed by cultivar without adjustments for location effects or covariates fruity and roast color.**

| | Roasted peanut | | | | | | Sweet | | | | | | Bitter | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Florunner | | | NC 7 | | | Florunner | | | NC 7 | | | Florunner | | | NC 7 | | |
| Source | df | SS | MS | df | SS | MS | df | SS | MS | df | SS | MS | df | SS | MS | df | SS | MS |
| | | % of SSTo[a] | fiu[b] | | % of SSTo | fiu | | % of SSTo | fiu | | % of SSTo | fiu | | % of SSTo | fiu | | % of SSTo | fiu |
| Total | 140 | | | 132 | | | 136 | | | 125 | | | 136 | | | 125 | | |
| Year | 12 | 73.1 | 9.0911** | 12 | 63.0 | 3.4034** | 12 | 51.0 | 2.1988** | 12 | 36.5 | 0.7501** | 12 | 73.0 | 6.5469** | 12 | 78.3 | 8.4000** |
| Linear | 1 | 48.9 | 73.0455** | 1 | 44.9 | 29.0857** | 1 | 32.7 | 16.8931** | 1 | 8.7 | 2.1357** | 1 | 0.1 | 0.0745 | 1 | 5.0 | 6.4059** |
| Quadratic | 1 | 5.7 | 8.5023** | 1 | 1.9 | 1.2386* | 1 | 6.2 | 3.1823** | 1 | 10.0 | 2.4693** | 1 | 42.4 | 45.6011** | 1 | 14.2 | 18.2499** |
| Residual | 10 | 18.5 | 2.7545** | 10 | 16.2 | 1.0516** | 10 | 12.2 | 0.6310** | 10 | 17.8 | 0.4397** | 10 | 30.6 | 3.2887** | 10 | 59.1 | 7.6144** |
| Error | 128 | 26.9 | 0.3139 | 120 | 37.0 | 0.1998 | 124 | 49.0 | 0.2040 | 113 | 63.5 | 0.1385 | 124 | 27.0 | 0.2339 | 113 | 21.7 | 0.2474 |

[a]Sum of squares expressed as a percentage of the total sum of squares.
[b]fiu = flavor intensity units.
*,**Denote significance at the 5% and 1% levels of probability, respectively, by F-test.

roughly one third of the total variation due to the trend across years. For both cultivars, the trend in the adjusted data was one of decline over years. While the trend was linear for NC 7, it was curvilinear for Florunner with a curvature similar to that observed for the unadjusted data (Fig. 1b).

For the sweet sensory attribute, years accounted for somewhat less of the total variation unadjusted for "other factors": 51% for Florunner and 36% for NC 7, with 39% and 19%, respectively, attributable to the year effect trends in the two cultivars (Table 1). In both Florunner and NC 7, the curvilinear trend across years unadjusted for "other factors" was generally decreasing and downwardly concave, i.e., the downward slope became steeper with years (Fig. 1c). After adjustment for "other factors," years could account for less than one quarter of the total variation in sweet intensity in either cultivar (Table 2). This is still a large part of the total. For both cultivars, the trend was linear after adjustment for "other factors." Although the year effect trends were statistically significant for both cultivars, the average rate of decline for NC 7 was only 0.008 fiu per year, hardly a dramatic decline. The rate was steeper for Florunner (b = 0.045), suggesting that after 10 or 11 yr, the decline approached the 0.5 fiu level at which sensory panelists can detect a difference in a direct comparison (Pattee *et al.*, 1993).

**Table 2. Partial mean squares from analysis of variance from regression of sensory attributes on years, performed by cultivar with adjustments for region, location within region, and covariates fruity and roast color.**

| | Roasted peanut | | | | | | Sweet | | | | | | Bitter | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Florunner | | | NC 7 | | | Florunner | | | NC 7 | | | Florunner | | | NC 7 | | |
| Source | df | SS | MS | df | SS | MS | df | SS | MS | df | SS | MS | df | SS | MS | df | SS | MS |
| | | % of SSTo[a] | fiu[b] | | % of SSTo | fiu | | % of SSTo | fiu | | % of SSTo | fiu | | % of SSTo | fiu | | % of SSTo | fiu |
| Total | 140 | | | 132 | | | 136 | | | 125 | | | 136 | | | 125 | | |
| Region | 2 | 0.0 | 0.0129 | 2 | 0.6 | 0.2023 | 2 | 1.1 | 0.1558 | 2 | 0.9 | 0.1128 | 2 | 1.1 | 0.5870* | 2 | 0.5 | 0.2912 |
| Loc in region | 9 | 3.1 | 0.5125** | 9 | 2.9 | 0.2094 | 9 | 8.7 | 0.4257** | 9 | 7.4 | 0.2023† | 9 | 6.6 | 0.7894** | 9 | 3.3 | 0.4688** |
| Fruity | 1 | 5.1 | 7.5738** | 1 | 5.2 | 3.4007** | 1 | 1.6 | 0.6703* | 1 | 1.9 | 0.4590* | 1 | 0.0 | 0.0351 | 1 | 0.4 | 0.4854† |
| Roast color | 2 | 1.2 | 0.8779* | 2 | 4.7 | 1.5169** | 1 | 2.3 | 1.1832** | 1 | 0.2 | 0.0462 | 2 | 5.7 | 3.0725** | 2 | 3.0 | 1.9165** |
| Linear[c] | 1 | 0.1 | 0.1421 | 1 | 0.3 | 0.1918 | 1 | 2.3 | 1.1832** | 1 | 0.2 | 0.0462 | 1 | 5.7 | 6.1119** | 1 | 2.5 | 3.2457** |
| Quadratic[c] | 1 | 1.1 | 1.6138** | 1 | 4.4 | 2.8421** | | | | | | | 1 | 0.0 | 0.0331 | 1 | 0.5 | 0.5872† |
| Year | 12 | 50.4 | 6.2697** | 12 | 48.8 | 2.6346** | 12 | 24.6 | 1.0616** | 12 | 19.1 | 0.3923** | 12 | 38.5 | 3.4495** | 12 | 34.6 | 3.7157** |
| Linear[c] | 1 | 34.9 | 52.0408** | 1 | 33.6 | 21.8051** | 1 | 14.1 | 7.3131** | 1 | 3.7 | 0.9201** | 1 | 5.0 | 5.3480** | 1 | 6.5 | 8.3763** |
| Quadratic[c] | 1 | 1.5 | 2.2519** | 1 | 0.0 | 0.0074 | 1 | 0.8 | 0.4286 | 1 | 0.9 | 0.2240 | 1 | 10.6 | 11.4322** | 1 | 6.0 | 7.7887** |
| Residual[c] | 10 | 14.0 | 2.0943** | 10 | 15.1 | 0.9803** | 10 | 9.7 | 0.4997** | 10 | 14.5 | 0.3563** | 10 | 22.9 | 2.4614** | 10 | 22.1 | 2.8424** |
| Error | 114 | 14.9 | 0.1956 | 106 | 24.1 | 0.1475 | 111 | 43.2 | 0.1563 | 100 | 42.7 | 0.1055 | 110 | 15.2 | 0.1487 | 99 | 12.1 | 0.1574 |

[a]Sum of squares expressed as a percentage of the total sum of squares.
[b]fiu = flavor intensity units.
[c]Linear, quadratic, and residual components are sequential within the pooled sum of squares for roast color and year, i.e., the linear component is not adjusted for the quadratic, but the quadratic component is adjusted for linear.
†,*,**Denote significance at the 10%, 5%, and 1% levels of probability, respectively, by F-test.

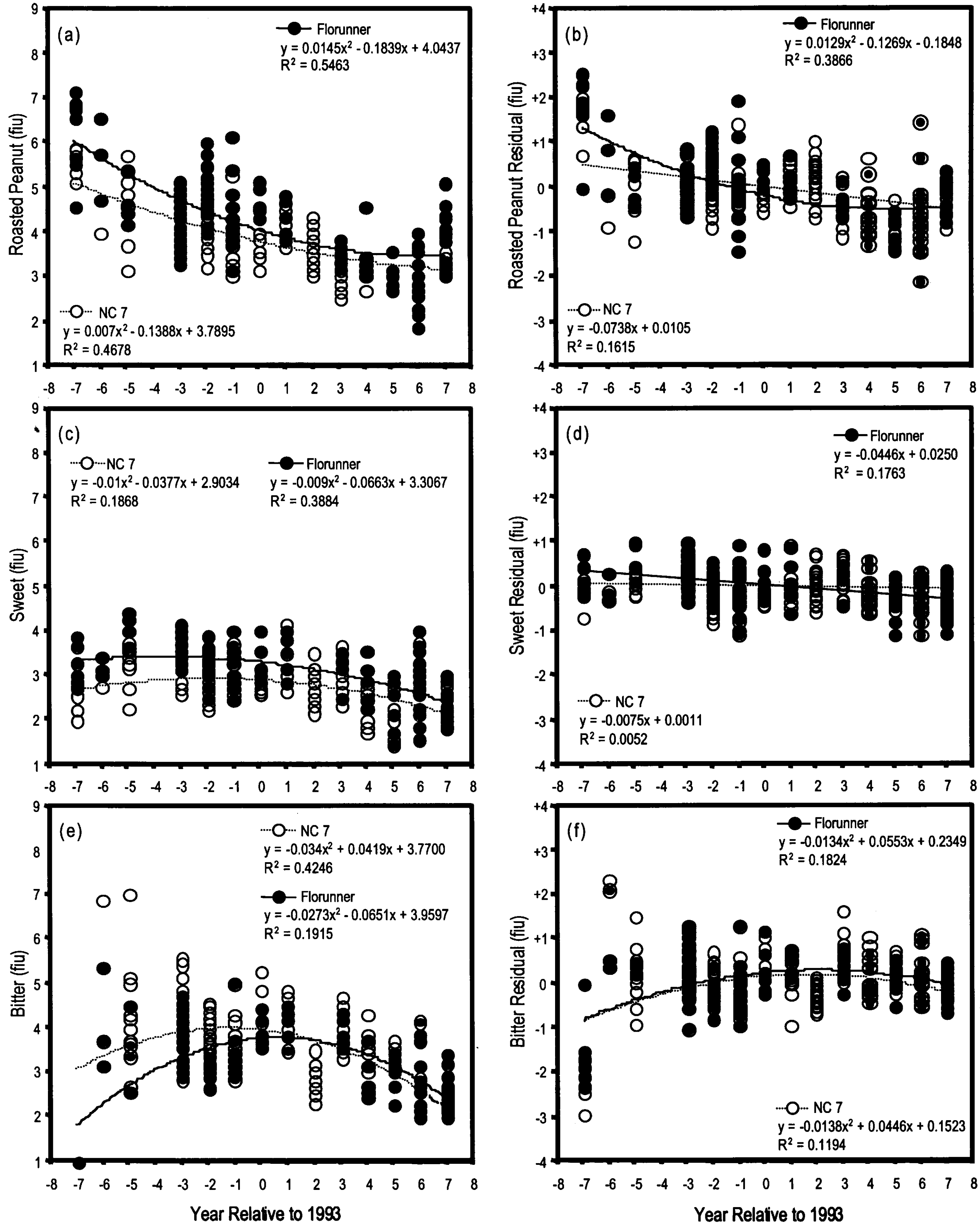


**Fig. 1. Distributions of points and regression lines for sensory attributes roasted peanut (1a, 1b), sweet (1c, 1d) and bitter (1e, 1f) regressed on years. Figs. (1a), (1c), and (1e) show regression of sensory attributes on years without adjustment for location effects or for covariates; Figs. (1b), (1d), and (1f) show regression with adjustment.**

Because the decline was so gradual, it is doubtful whether or not it would be noticed by consumers, and within limits, processors should be able to compensate for declining intensity of the sweet attribute by the addition of sweeteners to their products.

For the bitter sensory attribute, years accounted for an even larger proportion of the total variation unadjusted for "other factors" than they did for the roasted peanut attribute: 73% for Florunner and 78% for NC 7 with 42% and 19%, respectively, attributable to the year effect trends in the two cultivars (Table 1). In both Florunner and NC 7, the curvilinear trend across years unadjusted for "other factors" was generally flat and downwardly concave (Fig. 1e). After adjustment for "other factors," years could account for just over one third of the total variation in bitter intensity in either cultivar (Table 2). For both cultivars, the trend was curvilinear after adjustment for "other factors," exhibiting a slight upward trend over all 15 yr but leveling off or even declining slightly in recent years (Fig. 1f). As was the case for the sweet attribute, the magnitude of the change in bitter attribute over the period of this study was small. In contrast to the results for the sweet attribute, it does not appear that the change in bitter attribute would be perceptible to consumers over the period of the study.

In 1986, the first year of the study, all samples of both cultivars scored 1, i.e., no perceptible sensory value, for the bitter attribute. This was an unusual event, and one might ascribe it to a problem of calibration of the sensory panel were it not for a concomitant elevation of the roasted peanut scores for the two cultivars in the same year. Previous work has consistently shown that scores for the roasted peanut and bitter attributes are negatively correlated (Pattee *et al.*, 1995, 1997, 1998, 2001, 2002). However, the data points for 1986 are outliers in the trend figures for bitter attribute (Figs. 1e and 1f). The regression for bitter was recalculated after removing the data for 1986. Prior to adjustment for "other factors," the response equations were curvilinear for both cultivars, $y = -0.0089x^2 - 0.0634x + 3.5126$ ($R^2 = 0.31$) for Florunner and $y = 0.0042x^2 - 0.1661x + 3.7746$ ($R^2 = 0.34$) for NC 7, where "x" represents year expressed as a deviation from 1993, indicating a slightly declining trend in bitter attribute for Florunner and a somewhat more sharply declining trend for NC 7. This contrasts with the generally flat response observed when the 1986 data were included in the analysis, but it is consistent with the downward concavity of the previously calculated regression curve that showed a decreasing trend in more recent years. After adjustment for "other factors," both responses were linear with slopes of $b = 0.016$ for Florunner and $b = -0.014$ for NC 7. Although both slopes reached the level of statistical significance, their magnitudes were very small. These values are consistent with the relatively flat response observed when the data from 1986 were included in the analysis with adjustment for "other factors."

Of the responses observed in this study, the primary concern to the peanut industry should be the apparent decline in intensity of roasted peanut attribute over years. As previously stated, declining sweetness can be offset to some extent by the addition of sweeteners to products containing peanuts as their primary ingredient. Levels of bitterness appear to have changed little, if at all. However, the roasted peanut attribute is the one that distinguishes peanut products from others, and a decline in its intensity is likely to be noticeable to consumers, especially a decline of two or more flavor intensity units as found in this study. Future research should be focused on identifying the underlying causes of the observed decline. Because the same two genotypes were monitored for the duration of this study, the decline in roasted peanut flavor cannot be ascribed to genetic change in the peanuts. Use of the same sensory panelists for the duration of the study and annual calibration of the panelists to the universal flavor intensity standards should have minimized the influence of the panel across years. This leaves environmental influences on the peanuts themselves as the most likely causes of the observed adverse changes in flavor.

Over the period from 1986 through 2000, there have been several major changes in the general crop environment in which peanuts are grown in the U.S. The array of herbicides, fungicides, and insecticides applied to peanuts is constantly changing. For example, in 1986, the most widely used leafspot control program in peanuts was multiple applications of chlorothalonil. By the late 1990s, "block" application of tebuconazole had become the most widely used leafspot control program. In addition to the potential effects of agrichemicals applied directly to the peanut crop, one should also consider the effect of previous crops in peanut rotations. Throughout the peanut producing regions, the 1990s brought more frequent insertion of cotton (*Gossypium hirsutum* L.) and less of corn (*Zea mays* L.) into peanut crop rotations. It is conceivable that agrichemicals applied to cotton or other crops may have an impact on the flavor of a following peanut crop. Comparison of past with current cultural practices should provide insights as to possible causes of the decline in sensory quality. Ongoing programs of pathology, weed science, and agronomy should include monitoring of sensory quality of peanuts to prevent the adoption of cultural practices detrimental to quality in the same way that breeding programs have adopted monitoring to prevent the release of new cultivars with inferior flavor.

Another potential environmental cause of the change observed in sweet and bitter scores over years is the gradual increase in incidence of tomato spotted wilt virus (TSWV) across the peanut-growing states during the 15-yr span of the survey. TSWV has been demonstrated to have an adverse effect on sweet and bitter attributes (Pattee *et al.*, 2002b). However, based upon that study, one would not expect the viral epiphytotic to cause the pronounced effect observed in roasted peanut attribute.

Because the observed decline in roasted peanut flavor has been gradual over a period of 15 yr, it might not have been detected by the peanut-consuming public. In addition to the gradual nature of the decline in roasted peanut intensity, there have been other shifts in average peanut flavor profiles as a result of the changing array of cultivars deployed in the marketplace. No single cultivar has dominated the runner or virginia market-type over the entire 15-yr span of this study. Florunner was the dominant runner-type cultivar at the beginning of the test period, then the proprietary cultivar GK 7 became more widely grown, surpassing Florunner in 1996. In response to the gradual spread of TSWV that occurred across the runner-type peanut production area in the mid to late 1990s, TSWV-resistant Georgia Green became the most commonly grown runner-type cultivar, occupying more than three quarters of the runner acreage in the Southeast by 1999. The flavor profiles of these three cultivars (Table 3) suggest that any changes processors or consumers might have detected could have been attributed to the sequence of cultivars being marketed. The average roasted peanut intensity of GK 7 was somewhat inferior to that of the Florunner it replaced, but the difference was less than the threshold of 0.5 flavor intensity units regarded as detectable by consumers (Pattee *et al.*, 1993). Replacement of GK 7 by Georgia Green resulted in an average increase of roasted peanut intensity of approximately 0.5 fiu, a detectable improvement.

Given the gradual decline of roasted peanut intensity over years, breeders must continually improve flavor in successive releases simply to maintain it at a constant level in the commodity if flavor is to be preserved through genetic improvement alone. However, the results of this study suggest that production practices or peanut diseases also influence flavor and that the average roasted peanut intensity of the U.S. peanut crop can return to or exceed levels achieved in the mid-1980s if cultural practices causing the observed decline can be identified and eliminated and flavor-enhancing practices identified and implemented.

**Table 3. Mean sensory attribute intensities of runner-type cultivars Florunner, GK 7, and Georgia Green, and virginia-type cultivar NC 7.**

| Cultivar | Roasted peanut | Sweet | Bitter |
|---|---|---|---|
| | ------------- flavor intensity units (fiu) ------------- | | |
| Florunner | 4.30 ± 0.26 ab[a] | 3.13 ± 0.09 b | 3.07 ± 0.24 b |
| Georgia Green | 4.45 ± 0.27 a | 3.41 ± 0.12 a | 2.97 ± 0.26 b |
| GK 7 | 3.92 ± 0.30 bc | 3.27 ± 0.16 ab | 2.72 ± 0.28 b |
| NC 7 | 3.76 ± 0.28 c | 2.56 ± 0.13 c | 3.76 ± 0.26 a |

[a]Means followed by the same letter are not significantly different at the 5% level of probability by t-test.

## Literature Cited


Isleib, T.G., H.E. Pattee, and F.G. Giesbrecht. 1995. Ancestral contributions to roasted peanut attribute. Peanut Sci. 22:42-48.

Isleib, T.G., H.E. Pattee, and F.G. Giesbrecht. 2003. Narrow sense heritability of selected sensory descriptors in virginia-type peanut (*Arachis hypogaea* L.). Peanut Sci. 30:65-67.

Isleib, T.G., H.E. Pattee, D.W. Gorbet, and F.G. Giesbrecht. 2000. Genotypic variation in roasted peanut flavor quality across 60 years of breeding. Peanut Sci. 27:92-98.

Meilgaard, M., G.V. Civille, and B.T. Carr. 1999. Sensory Evaluation Techniques, 3rd Ed. CRC Press, Boca Raton, FL.

Pattee, H.E., and F.G. Giesbrecht. 1990. Roasted peanut flavor variation across germplasm sources. Peanut Sci. 17:109-112.

Pattee, H.E., and F.G. Giesbrecht. 1994. Adjusting roasted peanut attribute scores for fruity attribute and non-optimum CIELAB $L^*$ values. J. Sensory Studies 9:353-363.

Pattee, H.E., F.G. Giesbrecht, and T.G. Isleib. 1995. Roasted peanut flavor intensity variation among U.S. genotypes. Peanut Sci. 22:158-162.

Pattee, H.E., F.G. Giesbrecht, and R.W. Mozingo. 1993. A note on broad-sense heritability of selected sensory descriptors in virginia-type *Arachis hypogaea* L. Peanut Sci. 20:24-26.

Pattee, H.E., F.G. Giesbrecht, and C.T. Young. 1991. Comparison of peanut butter color determination by CIELAB $L^*a^*b^*$ and Hunter color-difference methods and the relationship of roasted peanut color to roasted peanut flavor response. J. Agric. Food Chem. 39:519-523.

Pattee, H.E., T.G. Isleib, and F.G. Giesbrecht. 1994. Genotype-by-environmental interaction in roasted peanut flavor. Peanut Sci. 20:94-99.

Pattee, H.E., T.G. Isleib, and F.G. Giesbrecht. 1997. Genotype-by-environment interaction in sweet and bitter sensory attributes of peanut. Peanut Sci. 24:117-123.

Pattee, H.E., T.G. Isleib, and F.G. Giesbrecht. 1998. Variation in intensity of sweet and bitter sensory attributes across peanut genotypes. Peanut Sci. 25:63-69.

Pattee, H.E., T.G. Isleib, D.W. Gorbet, and F.G. Giesbrecht. 2002a. Selection of alternative genetic sources of large seed size in virginia-type peanut—Evaluation of sensory, composition and agronomic characteristics. J. Agric. Food Chem. 50:4885-4889.

Pattee, H.E., T.G. Isleib, D.W. Gorbet, and F.G. Giesbrecht. 2002b. Sensory quality evaluation of market-grade-sized red-testa seed associated with TSWV infection from peanut genotypes of varying resistance levels. Peanut Sci. 29:110-115

Pattee, H.E., T.G. Isleib, D.W. Gorbet, F.G. Giesbrecht, and Z. Cui. 2001. Parent selection in breeding for roasted peanut flavor quality. Peanut Sci. 28:51-58.

Pattee, H.E., T.G. Isleib, D.W. Gorbet, F.G. Giesbrecht, and Z. Cui. 2002c. Prediction of parental genetic compatibility to enhance flavor attributes of peanuts, pp. 217-230. *In* K. Rajasekaran, T.J. Jacks, and J.W. Finley (eds.) Crop Biotechnology. ACS Symposium Series 829. Amer. Chem. Soc., Washington, DC.

Pattee, H.E., T.G. Isleib, D.W. Gorbet, K.M. Moore, Y. Lopez, M.R. Baring, and C.E. Simpson. 2002d. Effect of the high-oleic trait on roasted peanut flavor in backcrossed-derived breeding lines. J. Agric. Food Chem. 50:7362-7365.

Pattee, H.E., and D.A. Knauft. 1995. Comparison of selected high oleic acid breeding lines, Florunner and NC 7 for roasted peanut, sweet and other sensory attribute intensities. Peanut Sci. 22:26-29.

SAS Institute, Inc. 2001. SAS/STAT Software: Changes and Enhancements, Release 8.2. SAS Institute, Inc. Cary, NC. 332 pp.