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Effect of the High-Oleic Trait on Roasted Peanut Flavor in Backcross-Derived Breeding Lines

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The high-oleic trait of peanut (*Arachis hypogaea* L.) has been suggested to have a positive impact on the roasted peanut sensory attribute. A series of lines derived by backcrossing the high-oleic trait into several existing cultivars were compared with their parent cultivars at locations in Florida, Georgia, North Carolina, and Texas. Breeders grew their high-oleic lines and parents in three-replicate tests at one or two locations. The Florida high-oleic line F435-2-3-B-2-1-b4-B-B-3-b3-b3-1-B was grown at each location. The test included normal- and high-oleic variants of F435, GK 7, NC 7, NC 9, Sunrunner, Tamrun 96, and Tamspan 90. Sound-mature kernel samples were roasted, ground into paste, and evaluated by a sensory panel using a 14-point flavor intensity unit (fiu) scale. Background genotype had an effect ($P < 0.01$) on the heritable sensory attributes roasted peanut, sweet, and bitter. Oleate level had a positive effect on roasted peanut intensity, increasing it by 0.3 fiu averaged across all seven background genotypes. However, the magnitude of improvement varied across background genotypes. The high-oleic trait had no effect or increased the intensity of the roasted peanut attribute in each background genotype. The increase was greatest in Tamrun 96 (+0.6 fiu, $P < 0.05$) and Spanish genotypes Tamspan 90 (+0.4 fiu, $P < 0.05$) and F435 (+0.4 fiu, $P < 0.10$). A change of 0.5 fiu or more should be perceptible to consumers. Interaction between oleate level and background genotype was detected for sweet ($P < 0.10$) and bitter ($P < 0.01$) attributes. The trait had an increasing effect on the bitter attribute only in the background genotype of Tamspan 90 (+0.7 fiu, $P < 0.01$). There was a nonsignificant increase in bitterness in the other Spanish background genotype, F435. Changes in bitterness in runner- and Virginia-type backgrounds were close to zero. Incorporation of the high-oleic trait into peanut cultivars is likely to improve the intensity of the roasted peanut attribute, but it may also increase the bitter attribute in Spanish genotypes.

KEYWORDS: Parentage; roasted peanut attribute; sweet attribute; bitter attribute; *Arachis hypogaea* L.; genotypes

INTRODUCTION

There has been sustained interest in the effect of the high-oleic acid trait of peanuts on various quality factors since discovery of high levels of oleic acid by Norden et al. (*1*) in a breeding population (F435) derived from a natural cross between Florispan and a Spanish parent, provided to the University of Florida by W. K. Bailey of the USDA−ARS (D. A. Knauft, personal communication). This trait is controlled by two recessive genes (*2*), and one of the genes is common in peanut germplasm (*3*). Most U.S. peanut breeding programs have had access to the Florida high-oleic variant F435-2-2-B-2-1-b4-B-B-b3-b3-1-B (abbreviated F435OL-1) and have used the line as a source of the high-oleic trait in backcrossing programs. Some programs have also developed their own independent high-oleic mutants.

Pattee and co-workers have shown certain roasted peanut quality sensory attributes to be heritable traits (*4*−*9*), and significant correlations have been found among genotypic means for the attributes, particularly of bitter with sweet and of roasted

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Table 1. Lines Used and Locations at which Tests Were Conducted in 2000

line	origin	Green Acres Res. Ctr., Gainesville, FL	AgraTech Res. Farm, Ashburn, GA	Peanut Belt Res. Stn., Lewiston, NC	Upper Coastal Plains Res. Stn., Rocky Mt., NC	Western Peanut Growers Res. Farm, Denver City, TX	Frio County, TX
Spanish market type							
F435-Normal[a]		X					
F435OL-1[b]	natural variant in F435	X	X	X	X	X	X
F435OL-2[c]	natural variant in F435	X				X	
Tamspan 90						X	X
OLin	Tamspan 90*2/F435OL-1					X	X
runner market type		X					
Sunrunner		X					
SunOleic 97R	Sunrunner*5/F435OL-1	X					
Tamrun 96						X	X
Tamrun OL 01	Tamrun 96*2/SunOleic 95R[d]					X	X
GK 7			X				
GK 7 (high oleic)	GK 7*3/F435OL-1		X				
Virginia market type							
NC 7				X	X		
N00090ol	NC 7*4/F435OL-1			X	X		
NC 9				X	X		
N00092ol	NC 9*4/F435OL-1			X	X		

[a] F435-normal, abbreviation for F435-2-3-B-2-1-b4-B. [b] F435OL-1, abbreviation for F435-2-3-B-2-1-b4-B-B-3-b3-b3-1-B. [c] F435OL-2, abbreviation for F435-2-3-B-2-1-b4-B-B-3-b3-b3-2-B. [d] SunOleic 95R selected from Sunrunner*3/F435OL-1.

peanut with sweet and bitter (*7*, *10*). Although there have been recent efforts to characterize the sources of variation in sensory attributes in the overall U.S. peanut breeding population (*5*, *10*), the literature is lacking in estimates of the effects of lines as parents in a breeding program. Pattee et al. (*11*, *12*) have provided some insights into the effects of lines as parents in a breeding program on flavor quality. They observed that the group of high-oleic cultivars and breeding lines derived by backcrossing from the Sunrunner cultivar have approximately the same predicted breeding values of the sweet attribute, but they are consistently higher in breeding values for roasted peanut. They had the greatest positive effects on roasted peanut of any of the lines tested. The objective of this study was to investigate the effect of the high-oleic trait on roasted peanut flavor by direct comparison of normal-oleic lines with backcross-derived high-oleic breeding lines.

MATERIALS AND METHODS

Genotype Resources. In 2000 backcross-derived high-oleic lines, parents, associated lines, and mutant lines were grown in the peanut region of their origination (**Table 1**). All plots were irrigated, and recommended procedures for weed and disease control, soil fertilization, digging, and harvesting were followed.

Sample Handling. After harvest, the in-shell sample from each plot was shipped to Raleigh, NC, where it was shelled and screened for its appropriate sound-mature kernel (SMK) fraction. SMK fractions were separated using official grading standards for each market type. The SMK fraction from each location entry was placed in controlled storage at 5 °C and 60% relative humidity until roasted.

Sample Roasting and Preparation. The peanut samples were roasted in June and July 2001 using a Blue M Power-O-Matic 60 laboratory oven, ground into a paste, and stored in glass jars at −20 °C until evaluated. The roasting, grinding, and color measurement protocols were as described by Pattee and Giesbrecht (*13*) and modified by Pattee et al. (*10*).

Sensory Evaluation. A nine-member trained roasted peanut profile panel at the Food Science Department, North Carolina State University, 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 (*13*) and Pattee et al. (*4*). Two sessions were conducted each week on nonconsecutive days. Samples were presented in an incomplete block design with four per session. Sensory evaluation commenced August 20, 2001, and continued until all samples were evaluated. The averages of individual panelists' scores on sensory attributes were used in all analyses in this study.

Table 2. Mean Squares from the Analysis of Variance of the Roasted Peanut, Sweet, and Bitter Sensory Attributes

		flavor intensity units[a]		
source	df	roasted peanut	sweet	bitter
environment	5	0.8756**	0.7079**	0.8686**
rep in environment	15	0.0737	0.1027	0.1340
lines	14	1.1485**	1.0726**	1.2511**
background genotype	6	1.8070**	1.5432**	1.3393**
market type	2	1.2958**	7.3361**	2.7809**
background genotype in market type	4	1.6032**	1.8544**	0.2929*
oleate level	1	1.1629**	0.0790	0.0868
background × oleate	6	0.1232	0.2155†	0.3589**
market type × oleate	2	0.1100	0.6419**	0.5925**
background × oleate in market type	4	0.1165	0.1624	0.1293
line in background, oleate	1	0.1544	0.0892	0.0007
fruity			1.0972**	
roast color linear	1	1.1711**		1.3580**
roast color quadratic	1	1.1541**		
error	59 (60[b])	0.1395	0.1144	0.1148

[a] †, *, and ** denote mean squares significant at the 10, 5, and 1% levels of probability, respectively. [b] Error degrees of freedom for traits analyzed using only one covariate.

Statistical Analysis. Statistical analysis in this study was performed using the mixed model procedure (PROC MIXED) in SAS (*14*) to estimate the design components of variance using restricted maximum likelihood estimation. Covariates fruity and roast color were used, as needed, on the basis of the findings of Pattee et al. (*10*, *15*) and Pattee and Giesbrecht (*16*).

RESULTS AND DISCUSSION

A group of four cultivars and breeding lines derived by backcrossing the high-oleic trait into the Sunrunner cultivar had predicted breeding values for the roasted peanut attribute that were significantly and consistently higher than all 246 other breeding lines and cultivars tested (*11*, *12*), suggesting that the high-oleic trait may have a positive effect on flavor. Previous comparisons of the sensory attribute intensity of high-oleic with

Table 3. Main-Effect Means for Background Genotype of Sets of Normal- and High-Oleic Variants

background	flavor intensity units[a] roasted peanut	sweet	bitter
Spanish	3.03 ± 0.11β	2.08 ± 0.10β	2.98 ± 0.10α
F435	2.50 ± 0.15d	1.75 ± 0.14d	3.19 ± 0.13a
Tamspan 90	3.56 ± 0.14b	2.41 ± 0.13bc	2.77 ± 0.13b
runner	3.65 ±0.12α	2.88 ± 0.11α	2.04 ± 0.11β
GK-7	4.17 ± 0.24ab	2.90 ± 0.22b	1.67 ± 0.22d
Sunrunner	2.52 ± 0.28cd	2.21 ± 0.25bcd	2.54 ± 0.25bc
Tamrun 96	4.25 ± 0.19a	3.54 ± 0.18a	1.93 ± 0.18cd
Virginia	3.04 ± 0.15β	2.02 ± 0.13β	2.73 ± 0.13α
NC 7	3.03 ± 0.17c	2.08 ± 0.15cd	2.76 ± 0.15ab
NC 9	3.04 ± 0.17c	1.97 ± 0.15cd	2.70 ± 0.15b

[a] Background genotype means followed by the same English letter are not different ($P < 0.05$) from the other such means within a column by *t* test. Market-type means followed by the same Greek letter are not different ($P < 0.05$) from the other such means within a column by *t* test.

normal-oleic lines (*17*, *18*) confounded the effect of the trait with that of the background genotype into which the trait had been inserted. In our study, high-oleic lines were compared directly with the lines and cultivars most closely related to them. It is not possible to claim that these groups of lines constitute near-isogenic sets. "Near-isogenic" implies a nearly complete coancestry between lines. In contrast with lines developed by point mutagenesis, which is expected to change only a single gene in the mutated line, lines derived by selection following hybridization may differ at numerous genetic loci despite relatively close relationships. F435OL-1 and F435OL-2 trace to the same F_6 plant as F435-Normal and are expected to share 63/64 common ancestry with that line, but the other high-oleic lines were developed by backcrossing. In the case of OLin and Tamrun OL 01, there was only a single backcross to the recurrent parent before initiation of the process of selfing and selection, so those two lines are expected to retain one-fourth of their genes from F435. The other lines were developed with two or more backcrosses, eliminating more of the genetic contribution of F435OL-1 to their genomes but hardly conforming to a narrow definition of near-isogenic lines. Nevertheless, these high-oleic lines are actual cultivars or candidates for release and are therefore representative of high-oleic derivatives that might be used by the peanut industry in the future.

The results of sensory evaluation of these lines are best understood by considering separately the main effect of background genotype, that of the high-oleic trait, and the interaction between the two. Variation among diverse genotypes for sensory attributes has been consistently reported (*4*−*7*, *10*, *13*). In this study, effects associated with the background genotype of the high- and normal-oleic lines were detected for all three sensory attributes (**Table 2**). In previous studies, the runner market type has been consistently superior in its general flavor profile compared with either the Spanish or Virginia market type. In this study, the same result was obtained for the small sample of lines evaluated (**Table 3**). The runner cultivars GK-7 and Tamrun 96 had the best overall profiles—high values for roasted peanut and sweet and low for bitter attribute—but the runner-type cultivar Sunrunner had one of the poorest. The improved Spanish-type cultivar Tamspan 90 had a more intense roasted peanut attribute than the two Virginia-type cultivars, NC 7 and NC 9, but it was not different from NC 7 in sweet or from NC 9 in bitter. Tamspan 90 had a better flavor profile than the other Spanish-type line studied, F435, which had a high-oleic variant F435OL-1 that was the source of the trait for the other high-oleic lines tested.

In direct comparison of high-oleic backcross-derived lines and mutants with their recurrent parents or source cultivars, there was an effect of the high-oleic trait ($P < 0.01$) on the roasted peanut attribute but not for the sweet or bitter attributes (**Table 2**). The magnitude of the change in roasted peanut across all background genotypes was 0.28 flavor intensity unit (fiu) (**Table 4**). Although this average improvement in roasted peanut

Table 4. Mean Flavor Attribute Scores with Standard Errors and Differences between Backcross-Derived High-Oleic Lines and Their Recurrent Parents

	flavor intensity units[a]					
	roasted peanut		sweet		bitter	
market type or line	mean ± SE	diff[b]	mean ± SE	diff	mean ± SE	diff
Spanish, normal	2.81 ± 0.16		2.20 ± 0.14		2.72 ± 0.14	
Spanish, high	3.25 ± 0.12	+0.45*	1.96 ± 0.11	-0.24	3.23 ± 0.10	+0.51**
F435 (normal)	2.27 ± 0.27		1.78 ± 0.25		3.04 ± 0.24	
F435OL-1	2.81 ± 0.09	+0.54†	1.66 ± 0.08	-0.12	3.34 ± 0.08	+0.29
F435OL-2	2.63 ± 0.15	+0.36	1.80 ± 0.15	+0.02	3.33 ± 0.14	+0.28
Tamspan 90	3.34 ± 0.17		2.62 ± 0.15		2.40 ± 0.15	
OLin	3.78 ± 0.19	+0.44*	2.20 ± 0.17	-0.42*	3.14 ± 0.17	+0.74**
runner, normal	3.52 ± 0.15		2.80 ± 0.14		2.09 ± 0.14	
runner, high	3.77 ± 0.15	+0.26	2.97 ± 0.14	+0.17	2.00 ± 0.14	–0.09
GK-7	4.15 ± 0.28		2.86 ± 0.26		1.72 ± 0.25	
GK-7 (high-oleic)	4.19 ± 0.29	+0.04	2.93 ± 0.27	+0.07	1.61 ± 0.27	–0.11
Sunrunner	2.45 ± 0.32		2.09 ± 0.29		2.50 ± 0.29	
SunOleic 97R	2.59 ± 0.32	+0.13	2.34 ± 0.29	+0.25	2.57 ± 0.29	+0.08
Tamrun 96	3.95 ± 0.26		3.44 ± 0.23		2.04 ± 0.23	
Tamrun OL 01	4.55 ± 0.23	+0.61*	3.63 ± 0.21	+0.19	1.81 ± 0.21	–0.23
Virginia, normal	2.96 ± 0.17		1.90 ± 0.15		2.79 ± 0.15	
Virginia, high	3.11 ± 0.17	+0.15	2.15 ± 0.15	+0.25†	2.67 ± 0.15	–0.13
NC 7	3.05 ± 0.20		2.02 ± 0.18		2.73 ± 0.18	
N00090ol	3.02 ± 0.20	–0.03	2.14 ± 0.18	+0.12	2.78 ± 0.18	+0.05
NC 9	2.88 ± 0.20		1.77 ± 0.18		2.85 ± 0.18	
N00092ol	3.20 ± 0.20	+0.33	2.16 ± 0.18	+0.39†	2.55 ± 0.18	–0.30
normal	3.16 ± 0.08		2.37 ± 0.07		2.47 ± 0.07	
high	3.44 ± 0.08	+0.28**	2.45 ± 0.07	+0.08	2.54 ± 0.07	+0.07

[a] †, *, and ** denote differences significantly different from zero at the 10, 5, and 1% levels of probability, respectively. [b] Difference between high-oleic line and its recurrent parent.

intensity is less than the minimum 0.5 fiu needed to be detectable by an individual consumer, the magnitude of the improvement was larger in some background genotypes: 0.45 ($P < 0.05$) in F435, 0.44 ($P < 0.05$) in Tamspan 90, and 0.61 ($P < 0.05$) in Tamrun 96.

The effect of the high-oleic trait on sweet and bitter was inconsistent as indicated by the detection of interaction between background genotype and the trait for sweet ($P < 0.10$) and bitter ($P < 0.01$) (**Table 2**). For sweet and bitter, the interaction was manifested as a difference in the direction of the effect depending on the background genotype. In the background of Tamspan 90, the high-oleic trait reduced the sweet attribute by 0.42 fiu ($P < 0.05$), whereas the effect in other backgrounds was neutral or weakly positive (**Table 4**). Conversely, bitter was increased by 0.74 fiu ($P < 0.01$) in the high-oleic Tamspan 90 derivative, whereas the difference in all other backgrounds was not significant.

The general effect of the high-oleic trait in this study was to increase the intensity of the roasted peanut attribute while not affecting the sweet and bitter attributes. The occurrence of interaction between background genotype and the trait for the sweet and bitter attributes, primarily a result of a differential effect in the background of Tamspan 90, underscores the importance of obtaining sensory data on high-oleic lines derived by backcrossing prior to their release as replacements for normal-oleic cultivars. This may be more important in Spanish-type lines than in runner- or Virginia-type lines. On the basis of these results, incorporation of the high-oleic trait provides a slight improvement in the flavor profile of most cultivars in addition to improving their shelf life by retarding the autoxidation process (*18*−*20*).

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