Relationships of Sweet, Bitter, and Roasted Peanut Sensory Attributes with Carbohydrate Components in Peanuts

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Certain roasted peanut quality sensory attributes have been shown to be heritable. Currently the only means of measuring these traits is the use of a trained sensory panel. This is a costly and time-consuming process. It is desirable, from a cost, time, and sample size perspective, to find other methodologies for estimating these traits. Because sweetness is the most heritable trait and it has a significant positive relationship to the roasted peanut trait, the possible relationships between heritable sensory traits and 18 carbohydrate components (inositol, glucose, fructose, sucrose, raffinose, stachyose, and 12 unknown peaks) in raw peanuts from 52 genotypes have been investigated. Previously reported correlations among sweet, bitter, and roasted peanut attributes were evident in this study as well. Where there was positive correlation of total sugars with sweetness, there also was positive correlation of total sugars with roasted peanut attribute and negative correlation of total sugars with bitterness and astringency. The expected generalized relationship of total sugars or sucrose to sweetness could not be established because the relationship was not the same across all market-types. Further work is needed to determine the nature of the chemical components related to the bitter principle, which appear to modify the sweet response and interfere with the sensory perception of sweetness, particularly in the Virginia market-type. Also, certain carbohydrate components showed significant relationships with sensory attributes in one market-type and not another. These differential associations demonstrate the complexity of the interrelationships among sweet, bitter, and roasted peanut sensory attributes. Within two market-types it is possible to improve the efficiency of selection for sweetness and roasted peanut quality by assaying for total carbohydrates. On the basis of the regression values the greatest efficiency would occur in the fastigiate market-type and then the runner.

Keywords: *Arachis hypogaea L.; flavor; carbohydrate;components; roasted peanut; sweet; bitter*

INTRODUCTION

Certain roasted peanut quality sensory attributes have been shown to be heritable traits (Pattee and Giesbrecht, 1990; Pattee et al., 1993, 1994, 1995; Isleib et al., 1995). The sweet attribute has been shown to have the highest broad-sense heritability ($H = 0.28$); that is, 28% of the total variability in sweet is due to genetic causes. Selection based on the sweet attribute should result in relatively rapid genetic gain in overall flavor quality compared to selection based on the roasted peanut ($H = 0.06$) or bitter attributes ($H = 0.06$) (Pattee et al., 1998). In two separate studies Pattee et al. (1997, 1998), using 17 cultivars and breeding lines in one and 122 genotypes in the other, found correlations among least-squares means for the bitter and sweet attributes to be highly significant and nearly identical ($r = -0.89$ versus -0.80). In the 1998 study the roasted peanut to sweet and bitter correlations were $r = 0.50$ and -0.59, respectively. These results indicate that indirect selection based on the more highly heritable sweet attribute could be more effective than direct selection for increased intensity of the roasted peanut and decreased intensity of the bitter attribute. Sanders et al. (1989a,b) found varying influences of maturity across years on sweet and bitter intensities and that increasing curing temperatures decreased bitter intensity as the maturity level increased but had no effect on sweet intensity across maturity. Muego-Gnanasekharan and Resurreccion (1992) found that sweet and bitter intensities did not change during storage at varying elevated temperatures over storage times of up to 1 year. Earlier, Oupadissakoon and Young (1984) modeled roasted peanut flavor and found the best 10-variable model for predicting roasted peanut flavor used the concentrations of eight different amino acids, sucrose, and total sugars from raw peanuts. However, sucrose and total sugar contents were negatively correlated with the desirability of the roasted peanuts. They reported the sweet attribute to be significantly correlated with maturity and total sugars. The bitter attribute was not considered to be a significant contributor to the roasted peanut flavor

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because of its low intensity, but statistical analysis showed a significant negative correlation to the roasted peanut attribute.

The carbohydrates of peanuts have been identified and quantitated (Newell et al., 1967; Holley and Hammons, 1968; Tharanathan et al., 1975, 1976). They have been shown to be precursors of compounds imparting the roast peanut characteristic (Newell et al., 1967; Mason et al., 1969). Vercellotti et al. (1993) studied peanut mono-, oligo-, and polysaccharide fractions as the origin of intermediates for flavor molecules. The carbohydrate fraction of peanuts has been shown to change during maturation (Pattee et al., 1974; Ross and Mixon, 1989) as well as during curing (Vercellotti et al., 1995). The carbohydrate fraction also changes with seed size and over storage time (Pattee et al., 1981), decreases with higher soil temperatures (McMeans et al., 1990), and varies among genotypes (Basha et al., 1976; Oupadissakoon et al., 1980; Gupta et al., 1982; Gadgil and Mitra, 1983; Pattee et al., 2000).

There is, however, little if any information available correlating the response levels of roasted peanut sensory attributes to individual or total carbohydrate concentrations of peanuts. Because certain roasted peanut sensory attributes have been shown to be heritable and sweetness has a significant positive relationship to the roasted peanut trait, we have investigated possible relationships between carbohydrate components in peanuts and selected sensory attributes using the carbohydrate component data of Pattee et al. (2000). Currently the only means of measuring sweet, bitter, and roasted peanut traits is the use of a trained sensory panel, which is a very costly and time-consuming process. It is highly desirable, from a cost, time, and sample size perspective, to find other methodologies for estimating these traits.

MATERIALS AND METHODS

Sample resources, handling, and carbohydrate analysis were as described in Pattee et al. (2000).

Sample Roasting and Preparation. The peanut samples were roasted between May and June using a Blue M Power-O-Matic 60 laboratory oven, ground into a paste, and stored in glass jars at −10 °C until evaluated. The roasting, grinding, and color measurement protocols were as described by Pattee and Giesbrecht (1990).

Sensory Evaluation. A long-standing, six-to-eight-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. Panelists were the same throughout the evaluation. Panel orientation and reference control were as described by Pattee and Giesbrecht (1990) and Pattee et al. (1993). Two sessions were conducted each week on nonconsecutive days. Panelists evaluated four samples per session. Sensory evaluation commenced mid-July and continued until all samples were evaluated. The averages of individual panelists' scores on sensory attributes were used in all analyses in this study.

Statistical Analysis. PROC MIXED in SAS (1997) was used for analysis of the unbalanced data set to estimate the sensory attribute least-squares means for genotypes. Covariates fruity and roast color were used, as needed, on the basis of the findings of Pattee et al. (1997). The fixed effects were genotype, region, genotype-by-region, and covariates fruity and roast color. Each genotype effect was partitioned to reflect the effects of market-type and genotype within market-types. Classification of lines into market-types was based upon branching pattern, pod type, and seed size. Because there was only one Valencia market-type in this study, it was pooled with the Spanish market-type into a single group hereafter called "fastigiate" market-type. Three additional analyses of the sweet attribute were performed, using bitter and astringent attribute scores as covariates individually and together. In each analysis, least-squares means of the individual genotypes were estimated for the purpose of identifying genotypes with superior or inferior flavor characteristics. Least-squares means also were estimated for market-types and test locations. Correlation coefficients were calculated among least-squares means for carbohydrate components and sensory attributes. For each pair of traits, the correlation was computed for each market-type individually as well as for the entire set of peanut genotypes.

RESULTS AND DISCUSSION

Previous studies (Pattee et al., 1997, 1998) have suggested that indirect selection based on the sensory attribute sweetness, which is highly heritable, could be effective in simultaneously enhancing the roasted peanut attribute and decreasing the bitterness attribute in new peanut varieties. However, the use of any sensory attribute requires the use of a trained sensory panel that is both time-consuming and costly. Analysis for carbohydrate composition of raw samples from 52 peanut genotypes (Pattee et al., 2000) and sensory attribute intensities of duplicate samples after roasting permits investigation of the potential to make selections for the improvement of the roasted peanut, sweetness, bitterness, and astringency attributes based on carbohydrate analysis data. The paper by Pattee et al. (1998) discusses the genotypic relationships of the sensory attributes sweet, bitter, and roasted peanut using a 122 peanut genotype data set. The 52 genotypes reported in this study are a subset of that group. The least-squares means for sweet, bitter, and roasted peanut attributes presented in Table 1 were computed from this data subset and are presented for continuity purposes. Correlations among sweet, bitter, and roasted peanut sensory attributes for the subset (Table 2) were very similar to those reported for the full set of 122 genotypes. Therefore, the subset is deemed to be suitable for analysis of the relationships between carbohydrate components and sensory attributes.

There are four different peanut market-types grown in the United States: Virginia, runner, Spanish, and Valencia. The genetic backgrounds of the last two are entirely from the subspecies *fastigiata* Waldron, the Spanish lines are from the botanical variety *vulgaris* Harz, and the Valencia lines are from the botanical variety *fastigiata*. This commonality, along with the low sample number, was the rationale for pooling the four Spanish lines with the single Valencia in this study and designating them as "fastigiate". The Virginia and runner market-types have the alternate branching pattern typical of subspecies *hypogaea* and pod characteristics typical of botanical variety *hypogaea*. Their genetic base is predominantly the *hypogaea* botanical variety, but current cultivars and breeding lines have at least some ancestry from subspecies *fastigiata*. Because the Virginia and runner market-types come from a genetic background distinctly different from that of the fastigiate types, it is conceivable and perhaps likely that there would be differences in the chemical composition of their seeds.

It is a reasonable expectation that the concentration of sugars in peanuts be directly related to the sensory perception of sweetness. In the present study, there was a positive correlation between total sugars and sweetness within each of the three market-types ($P < 0.05$)

Table 1. Least-Squares Means for Sensory Attributes

genotype	flavor intensity units (fiu)						
	sweet attribute	sweet adj for bitter	sweet adj for astringent	sweet adj for bitter and astringent	bitter attribute	astringent attribute	roasted peanut attribute
large-seeded Virginia market-type							
Early Bunch	2.7 ± 0.2	2.8 ± 0.2	2.7 ± 0.2	2.8 ± 0.2	4.7 ± 0.2	4.0 ± 0.1	3.7 ± 0.2
Early Bunch Component 1	2.7 ± 0.2	2.7 ± 0.2	2.6 ± 0.2	2.7 ± 0.2	4.6 ± 0.2	3.5 ± 0.1	4.1 ± 0.2
Early Bunch Component 2	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	4.6 ± 0.2	3.7 ± 0.1	3.9 ± 0.2
Early Bunch Component 3	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	4.2 ± 0.2	3.8 ± 0.1	4.3 ± 0.2
Early Bunch Component 4	2.6 ± 0.2	2.8 ± 0.2	2.6 ± 0.2	2.8 ± 0.2	4.9 ± 0.2	3.8 ± 0.1	3.8 ± 0.2
Early Bunch Component 5	2.8 ± 0.2	3.0 ± 0.2	2.9 ± 0.2	3.0 ± 0.2	4.9 ± 0.2	4.0 ± 0.1	3.9 ± 0.2
Florigiant	2.8 ± 0.1	2.8 ± 0.1	2.8 ± 0.2	2.8 ± 0.1	4.5 ± 0.1	4.0 ± 0.1	3.9 ± 0.2
GA 119-20	3.2 ± 0.2	3.1 ± 0.2	3.2 ± 0.2	3.1 ± 0.2	4.0 ± 0.2	3.7 ± 0.1	3.9 ± 0.2
Holland Virginia Jumbo	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	4.1 ± 0.2	3.5 ± 0.1	4.3 ± 0.2
Jenkins Jumbo	3.3 ± 0.2	3.2 ± 0.2	3.2 ± 0.2	3.1 ± 0.2	3.7 ± 0.2	3.4 ± 0.1	4.3 ± 0.2
NC 2	3.3 ± 0.2	3.4 ± 0.2	3.3 ± 0.2	3.4 ± 0.2	4.7 ± 0.2	3.7 ± 0.1	4.4 ± 0.2
NC 4	3.3 ± 0.2	3.3 ± 0.2	3.3 ± 0.2	3.3 ± 0.2	4.1 ± 0.2	3.7 ± 0.1	4.1 ± 0.2
NC 7	2.7 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	4.4 ± 0.2	3.9 ± 0.1	3.6 ± 0.2
NC 9	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	4.3 ± 0.2	3.5 ± 0.1	4.2 ± 0.2
NC Ac 17921	2.9 ± 0.2	2.9 ± 0.2	2.9 ± 0.2	2.9 ± 0.2	4.3 ± 0.2	3.8 ± 0.1	4.0 ± 0.2
NC Ac 18016	2.5 ± 0.2	2.5 ± 0.2	2.5 ± 0.2	2.5 ± 0.2	4.6 ± 0.2	3.7 ± 0.1	3.9 ± 0.2
NC Ac 18423	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	4.4 ± 0.2	3.9 ± 0.1	4.1 ± 0.2
NC Ac 18431	3.0 ± 0.2	3.0 ± 0.2	3.0 ± 0.2	3.0 ± 0.2	4.2 ± 0.2	3.6 ± 0.1	4.0 ± 0.2
White's Runner	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	4.0 ± 0.2	3.5 ± 0.1	4.4 ± 0.2
runner market-type							
Basse (NCSU collection)	3.4 ± 0.2	3.3 ± 0.2	3.3 ± 0.2	3.3 ± 0.2	3.9 ± 0.2	3.5 ± 0.1	4.7 ± 0.2
Basse (PI 229553)	3.6 ± 0.2	3.5 ± 0.2	3.6 ± 0.2	3.5 ± 0.2	3.9 ± 0.2	3.6 ± 0.1	4.6 ± 0.2
Basse 32-15 (PI 237511)	3.5 ± 0.2	3.4 ± 0.2	3.5 ± 0.2	3.4 ± 0.2	3.8 ± 0.2	3.7 ± 0.1	4.3 ± 0.2
Bradford Runner	3.2 ± 0.2	3.2 ± 0.2	3.1 ± 0.2	3.2 ± 0.2	4.6 ± 0.2	3.3 ± 0.1	4.4 ± 0.2
Dixie Runner	3.0 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	3.0 ± 0.2	4.5 ± 0.2	3.7 ± 0.1	4.4 ± 0.2
Early Runner	3.0 ± 0.2	3.0 ± 0.2	3.0 ± 0.2	3.0 ± 0.2	4.1 ± 0.2	3.6 ± 0.1	4.4 ± 0.2
Early Runner Component 1	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	4.2 ± 0.2	3.8 ± 0.1	3.8 ± 0.2
Early Runner Component 2	3.0 ± 0.2	2.9 ± 0.2	3.0 ± 0.2	2.9 ± 0.2	4.1 ± 0.2	3.7 ± 0.1	4.1 ± 0.2
Early Runner Component 3	3.1 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	3.0 ± 0.2	4.2 ± 0.2	3.5 ± 0.1	4.4 ± 0.2
Early Runner Component 4	3.1 ± 0.2	3.0 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	3.8 ± 0.2	3.5 ± 0.1	4.4 ± 0.2
Early Runner Component 5	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	4.1 ± 0.2	3.6 ± 0.1	4.6 ± 0.2
Florispan Component 1	3.0 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	2.9 ± 0.2	4.1 ± 0.2	3.7 ± 0.1	4.3 ± 0.2
Florispan Component 2	3.1 ± 0.2	2.9 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	4.1 ± 0.2	3.9 ± 0.1	3.9 ± 0.2
Florispan Component 3	2.8 ± 0.2	3.0 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	4.1 ± 0.2	3.9 ± 0.1	3.8 ± 0.2
Florispan Component 4	3.1 ± 0.2	2.7 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	4.0 ± 0.2	3.7 ± 0.1	3.9 ± 0.2
Florispan Component 5	3.1 ± 0.2	3.0 ± 0.2	3.1 ± 0.2	3.1 ± 0.2	4.2 ± 0.2	3.8 ± 0.1	4.1 ± 0.2
Florunner	3.4 ± 0.2	3.1 ± 0.2	3.4 ± 0.2	3.3 ± 0.2	4.0 ± 0.2	3.6 ± 0.1	4.4 ± 0.2
Florunner Component 1	3.6 ± 0.2	3.3 ± 0.2	3.6 ± 0.2	3.5 ± 0.2	3.9 ± 0.2	3.8 ± 0.1	4.2 ± 0.2
Florunner Component 2	3.6 ± 0.2	3.5 ± 0.2	3.6 ± 0.2	3.5 ± 0.2	3.9 ± 0.2	3.8 ± 0.1	4.7 ± 0.2
Florunner Component 3	3.7 ± 0.2	3.5 ± 0.2	3.6 ± 0.2	3.5 ± 0.2	3.8 ± 0.2	3.6 ± 0.1	4.4 ± 0.2
Florunner Component 4	3.4 ± 0.2	3.5 ± 0.2	3.3 ± 0.2	3.2 ± 0.2	3.9 ± 0.2	3.6 ± 0.1	4.1 ± 0.2
F439-17-2-1-1 (Florunner sister line)	3.2 ± 0.2	3.3 ± 0.2	3.2 ± 0.2	3.1 ± 0.2	3.9 ± 0.2	3.6 ± 0.1	4.1 ± 0.2
GA 207-2	2.9 ± 0.2	2.9 ± 0.2	2.9 ± 0.2	2.9 ± 0.2	4.4 ± 0.2	3.7 ± 0.1	4.2 ± 0.2
GA 207-3-4	2.7 ± 0.2	2.9 ± 0.2	2.7 ± 0.2	2.8 ± 0.2	4.8 ± 0.2	3.7 ± 0.1	4.2 ± 0.2
NC 3033	2.7 ± 0.2	2.8 ± 0.2	2.7 ± 0.2	2.8 ± 0.2	4.6 ± 0.2	3.7 ± 0.1	4.0 ± 0.2
PI 109839	3.1 ± 0.2	3.2 ± 0.2	3.1 ± 0.2	3.2 ± 0.2	4.4 ± 0.2	3.7 ± 0.1	4.3 ± 0.2
Small White Spanish (PI 264180)	2.8 ± 0.2	2.7 ± 0.2	2.8 ± 0.2	2.8 ± 0.2	4.4 ± 0.2	3.8 ± 0.1	4.2 ± 0.2
Southeastern Runner 56-15	2.7 ± 0.2	2.8 ± 0.2	2.7 ± 0.2	2.7 ± 0.2	4.4 ± 0.2	3.8 ± 0.1	4.0 ± 0.2
fastigiate market-type							
Improved Spanish 2B	2.3 ± 0.2	2.6 ± 0.2	2.3 ± 0.2	2.6 ± 0.2	5.3 ± 0.2	3.8 ± 0.1	3.7 ± 0.2
Pearl	3.7 ± 0.2	3.5 ± 0.2	3.6 ± 0.2	3.5 ± 0.2	3.6 ± 0.2	3.5 ± 0.1	4.6 ± 0.2
PI 337396	3.6 ± 0.2	3.6 ± 0.2	3.6 ± 0.2	3.6 ± 0.2	4.2 ± 0.2	3.6 ± 0.1	4.1 ± 0.2
Small White Spanish (NCSU collection)	3.1 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	3.0 ± 0.2	4.3 ± 0.2	3.5 ± 0.1	4.6 ± 0.2
Spanette (Spanish 18-38-42)	2.7 ± 0.2	2.8 ± 0.2	2.7 ± 0.2	2.8 ± 0.2	4.8 ± 0.1	3.9 ± 0.1	3.7 ± 0.2
av standard error	0.2	0.2	0.2	0.2	0.2	0.1	0.2
mean for Virginia market-type	2.9 ± 0.1	2.9 ± 0.1	2.9 ± 0.1	2.9 ± 0.1	4.4 ± 0.0	3.7 ± 0.0	4.0 ± 0.1
mean for runner market-type	3.1 ± 0.0	3.1 ± 0.0	3.1 ± 0.1	3.1 ± 0.0	4.1 ± 0.0	3.7 ± 0.0	4.3 ± 0.1
mean for fastigiate market-type	3.1 ± 0.1	3.1 ± 0.1	3.1 ± 0.1	3.1 ± 0.1	4.5 ± 0.1	3.7 ± 0.1	4.1 ± 0.1
mean for Gainesville, FL, location	3.0 ± 0.0	3.0 ± 0.0	3.0 ± 0.1	3.0 ± 0.0	4.3 ± 0.0	3.7 ± 0.0	4.2 ± 0.1
mean for Lewiston, NC, location	3.0 ± 0.1	3.1 ± 0.0	3.1 ± 0.1	3.1 ± 0.0	4.4 ± 0.0	3.7 ± 0.0	4.1 ± 0.1

(Table 3). The strongest correlation ($r > 0.9$) was found in the fastigiate market-type. Despite the generally positive correlation within market-types, the overall correlation between total sugars and sweetness was not significant because a corresponding positive correlation was not seen for the market-type means. The means for the runner and fastigiate market-types were nearly identical [28971 versus 28842 ppm of total sugars and 3.1 versus 3.1 flavor intensity units (fiu) for sweetness, respectively], whereas the Virginia market-type had more total sugars (35057 ppm) and slightly lower sweetness (2.9 fiu) (Pattee et al., 2000; Table 3). Adjustment of sweet scores for astringency had little effect on the observed correlations. However, adjustment of sweetness for bitterness reduced its correlation with total sugars in the Virginia and fastigiate market-types

Table 2. Correlations among Sensory Attributes

		sweet adj for bitter	sweet adj for astringent	sweet adj for bitter and astringent	bitter attribute	astringent attribute	roasted peanut attribute
sweet attribute (fiu)	overall	0.974**	0.996**	0.975**	−0.765**	−0.432**	0.641**
	Virginia	0.956**	0.991**	0.949**	−0.618**	−0.391	0.595**
	runner	0.980**	0.996**	0.983**	−0.737**	−0.305	0.514**
	fastigiate	0.991**	0.999**	0.991**	−0.939*	−0.795	0.737
sweet attribute adj for bitter (fiu)	overall		0.975*	0.999**	−0.600**	−0.377**	0.611**
	Virginia		0.970**	0.998**	−0.360	−0.222	0.533*
	runner		0.972**	0.999**	−0.587**	−0.335	0.548**
	fastigiate		0.992**	1.000**	−0.885*	−0.760	0.667
sweet attribute adj for astringent (fiu)	overall	0.975**		0.979**	−0.750**	−0.351*	0.601**
	Virginia	0.970**		0.970**	−0.553*	−0.266	0.537*
	runner	0.972**		0.981**	−0.746**	−0.221	0.466*
	fastigiate	0.992**		0.993**	−0.934*	−0.771	0.713
sweet attribute adj for bitter and astringent (fiu)	overall	0.999**	0.979**		−0.605**	−0.337*	0.591**
	Virginia	0.998**	0.970**		−0.342	−0.167	0.503*
	runner	0.999**	0.981**		−0.607**	-0.288	0.521**
	fastigiate	1.000**	0.993**		−0.886*	-0.749	0.658
bitter attribute (fiu)	overall	−0.600**	−0.750**	−0.605**		0.458**	−0.532**
	Virginia	−0.360	−0.553*	−0.342		0.652**	−0.471*
	runner	−0.587**	−0.746**	−0.607**		0.103	−0.227
	fastigiate	−0.885*	−0.934*	−0.886*		0.821	−0.858
astringent attribute (fiu)	overall	−0.377**	−0.351*	−0.337*	0.458**		−0.666**
	Virginia	−0.222	−0.266	−0.167	0.652**		−0.602**
	runner	−0.335	−0.221	−0.288	0.103		−0.660**
	fastiagate	−0.760	−0.771	−0.749	−0.821		−0.958*

*, **, correlations significant at the 5 and 1% levels of probability, respectively.

Table 3. Correlation of Known Carbohydrate Components with Sensory Attributes

carbohydrate component	market-type	sweet attribute	sweet adj for bitter	sweet adj for astringent	sweet adj for bitter and astringent	bitter attribute	astringent attribute	roasted peanut attribute
total sugar content	overall	0.248	0.230	0.229	0.221	−0.228	−0.293*	0.196
	Virginia	0.506*	0.397	0.476*	0.386	−0.548*	−0.383	0.390
	runner	0.457*	0.509**	0.432*	0.493**	−0.135	−0.393*	0.501**
	fastigiate	0.917*	0.859	0.907*	0.857	−0.991**	−0.878	0.915*
inositol content	overall	−0.152	−0.108	−0.158	−0.115	0.225	−0.002	−0.116
	Virginia	−0.063	−0.071	−0.072	−0.074	0.004	−0.046	0.047
	runner	−0.015	0.042	−0.030	0.029	0.199	−0.154	0.247
	fastigiate	0.119	0.229	0.130	0.226	0.173	0.086	−0.322
glucose content	overall	0.163	0.151	0.146	0.143	−0.147	−0.230	0.277*
	Virginia	0.022	−0.026	−0.010	−0.039	−0.121	−0.201	0.165
	runner	0.157	0.206	0.175	0.213	0.060	0.164	0.030
	fastigiate	0.504	0.400	0.479	0.393	−0.731	−0.803	0.935*
fructose content	overall	0.164	0.151	0.146	0.142	−0.153	−0.243	0.268
	Virginia	0.182	0.106	0.143	0.090	−0.281	−0.308	0.258
	runner	0.020	0.084	0.039	0.089	0.199	0.205	−0.036
	fastigiate	0.520	0.416	0.495	0.409	−0.745	−0.807	0.939*
sucrose content	overall	0.235	0.224	0.217	0.214	−0.202	−0.285*	0.367
	Virginia	0.497*	0.394	0.471*	0.385	−0.530*	−0.357	0.367
	runner	0.453*	0.512**	0.424*	0.494**	−0.105	−0.430*	0.520**
	fastigiate	0.927*	0.873	0.918*	0.871	−0.990**	−0.873	0.903*
raffinose content	overall	−0.023	−0.028	−0.028	−0.031	−0.003	−0.047	0.014
	Virginia	0.077	0.000	0.059	−0.004	−0.242	−0.148	0.181
	runner	0.163	0.222	0.170	0.222	0.086	0.033	0.189
	fastigiate	0.729	0.659	0.704	0.650	−0.849	−0.955*	0.994**
stachyose content	overall	0.309*	0.235	0.297*	0.235	−0.420**	−0.243	0.241
	Virginia	0.446	0.340	0.402	0.322	−0.497*	−0.443	0.421
	runner	0.337	0.285	0.347	0.296	−0.400*	0.015	0.126
	fastigiate	0.434	0.373	0.441	0.382	−0.548	−0.236	0.343

*, **, correlations significant at the 5 and 1% levels of probability, respectively.

sufficiently to make it nonsignificant with or without adjustment for astringency. The nonsignificance of these correlations in the fastigiate market-type is probably due to the small sample size; the estimated correlation coefficients were large in magnitude ($r > 0.85$). The Virginia and fastigiate market-types had higher average bitterness scores than the runner market-type (Table 1). These observations suggest that there may be a bitter principle in the Virginia and possibly the fastigiate market-types masking the sensory perception of sweetness. Walters and Roy (1996) review the taste interaction between sweet and bitter compounds.

Table 4. Correlation of Unknown Carbohydrate Components with Sensory Attributes

carbohydrate component	market-type	sweet attribute	sweet adj for bitter	sweet adj for astringent	sweet adj for bitter and astringent	bitter attribute	astringent attribute	roasted peanut attribute
total unknowns	overall	0.231	0.203	0.196	0.186	−0.239	−0.445**	0.326*
	Virginia	0.303	0.128	0.232	0.102	−0.616**	−0.590**	0.256
	runner	0.308	0.277	0.280	0.266	−0.309	−0.379*	0.445*
	fastigiate	−0.226	−0.239	−0.263	−0.260	0.170	−0.392	0.346
unknown 1	overall	0.098	0.158	0.088	0.148	0.099	−0.149	0.159
	Virginia	0.227	0.196	0.243	0.206	−0.203	0.022	0.108
	runner	0.283	0.322	0.257	0.306	−0.062	−0.348	0.366
	fastigiate	−0.564	−0.579	−0.591	−0.595	0.474	0.016	−0.012
unknown 2	overall	0.273	0.216	0.262	0.215	−0.342*	−0.213	0.112
	Virginia	0.252	0.160	0.185	0.130	−0.363	−0.544*	0.285
	runner	0.319	0.244	0.333	0.258	−0.463*	0.063	−0.075
	fastigiate	−0.311	−0.283	−0.289	−0.272	0.361	0.587	−0.585
unknown 3	overall	−0.315*	−0.316*	−0.330*	−0.325*	0.212	−0.038	−0.135
	Virginia	−0.126	−0.183	−0.148	−0.190	−0.089	−0.116	0.013
	runner	−0.333	−0.259	−0.357	−0.280	0.469*	−0.176	0.044
	fastigiate							
unknown 4	overall	0.220	0.189	0.190	0.175	−0.241	−0.386**	0.236
	Virginia	0.612**	0.468*	0.550*	0.443	−0.688**	−0.626**	0.565*
	runner	0.032	0.040	0.014	0.029	0.001	−0.213	0.277
	fastigiate	0.507	0.617	0.516	0.613	−0.184	−0.240	−0.019
unknown 5	overall	0.123	0.058	0.094	0.047	−0.265	−0.338*	0.128
	Virginia	0.272	0.138	0.201	0.109	−0.494*	−0.581**	0.303
	runner	0.010	−0.039	0.000	−0.041	−0.166	−0.119	−0.019
	fastigiate	−0.266	−0.293	−0.252	−0.283	0.177	0.425	−0.322
unknown 6	overall	0.331*	0.311*	0.312*	0.302*	−0.285*	−0.323*	0.365**
	Virginia	0.219	0.086	0.194	0.083	−0.447	−0.224	−0.061
	runner	0.374*	0.322	0.355	0.317	−0.430*	−0.311	0.447*
	fastigiate	0.251	0.230	0.218	0.212	−0.290	−0.708	0.663
unknown 7	overall	0.304*	0.271	0.282*	0.262	−0.301*	−0.343*	0.364**
	Virginia	0.258	0.135	0.228	0.127	−0.441	−0.278	0.061
	runner	0.194	0.136	0.171	0.128	−0.330	−0.315	0.372
	fastigiate	0.492	0.489	0.464	0.472	−0.464	−0.828	0.734
unknown 8	overall	−0.167	−0.172	−0.190	−0.184	0.095	−0.168	−0.029
	Virginia	0.159	0.041	0.104	0.020	−0.410	−0.441	0.272
	runner	0.021	0.076	0.003	0.062	0.168	−0.194	0.362
	fastigiate	−0.465	−0.555	−0.478	−0.556	0.196	0.158	0.039
unknown 9	overall	−0.093	−0.115	−0.117	−0.126	−0.005	−0.203	−0.001
	Virginia	0.136	−0.017	0.061	−0.046	−0.489*	−0.574*	0.320
	runner	0.162	0.238	0.155	0.229	0.149	−0.106	0.373
	fastigiate	−0.362	−0.376	−0.334	−0.358	0.301	0.712	−0.579
unknown 10	overall	−0.227	−0.223	−0.238	−0.229	0.163	−0.033	−0.129
	Virginia	−0.065	−0.106	−0.092	−0.117	−0.098	−0.193	−0.003
	runner	−0.075	−0.042	−0.106	−0.062	0.160	−0.321	0.386*
	fastigiate	−0.428	−0.315	−0.404	−0.309	0.684	0.730	−0.890*
unknown 11	overall	−0.246	−0.265	−0.278*	−0.282*	0.108	−0.239	0.169
	Virginia	−0.051	−0.167	−0.125	−0.197	−0.295	−0.515*	−0.039
	runner	−0.336	−0.224	−0.353	−0.244	0.602**	−0.092	0.029
	fastigiate							
unknown 12	overall	0.024	0.012	0.012	0.007	−0.047	−0.127	0.000
	Virginia	0.320	0.271	0.294	0.259	−0.285	−0.279	0.292
	runner							
	fastigiate							

*, **, correlations significant at the 5 and 1% levels of probability, respectively.

The previously reported correlations among sweet, bitter, and roasted peanut attributes (Pattee et al., 1998) were evident in this study as well. Where there was positive correlation of total sugars with sweetness, there also was positive correlation with roasted peanut attribute and negative correlation with bitterness (Table 3). These correlations were strongest in the fastigiate market-type, for which increases in total sugars should result in increased sweetness ($r = 0.917$, $P < 0.05$) and roasted peanut attribute ($r = 0.915$, $P < 0.05$) and decreased bitterness ($r = -0.991$, $P < 0.01$). For the runner market-type, selection for increased total sugars should result in somewhat smaller increases in sweetness and roasted peanut attribute but no substantial change in bitterness. For the Virginia market-type, one would expect some reduction in bitterness and some increase in sweetness but no substantial increase in roasted peanut attribute. This is in contrast to the findings of Oupadissakoon and Young (1984), who reported significant negative correlation between total sugar content and roasted peanut attribute in a limited sample of Virginia-type genotypes. Correlations of total sugars with the astringent attribute were similar to those with bitterness. Because sucrose accounts for most of the total sugars in the peanut genotypes evaluated, the associations of sucrose with sensory attributes were very similar to those of total sugars.

It is of interest to note that the Virginia market-type had the highest levels of total sugars of any of the market-types (Pattee et al., 2000). If the relationships between sugar content and flavor attributes were as strong in the Virginia market-type as in the fastigiate, then one would expect to find Virginia lines with outstanding flavor profiles. Similarly, if the range of sugar content in the fastigiate market-type extended as high as it does in the Virginia market-type, then one would expect to find superior flavor profiles in the fastigiate. In fact, the highest sweetness score and lowest bitter score reported by Pattee et al. (1998) among 122 lines were in the Valencia-type New Mexico Valencia C.

The other known carbohydrate components of peanut varied in their degree of association with sensory attributes (Table 3). Inositol content was not significantly correlated with any attribute in any market-type. Glucose and fructose contents were associated with the roasted peanut attribute in the fastigiate market-type but not with any other sensory attribute in that group or with any attribute in the Virginia and runner market-types. Raffinose content had a significant negative correlation with astringency ($r = -0.955$, $P < 0.05$) and, similar to glucose and fructose contents, was positively correlated with roasted peanut attribute ($r = 0.994$, $P < 0.01$) in the fastigiate market-type only. In contrast, stachyose content was negatively correlated with bitterness in the Virginia ($r = -0.497$, $P < 0.05$) and runner ($r = -0.400$, $P < 0.05$) market-types but not with any other attribute in those market-types or with any attribute in the fastigiate market-type.

Like the known carbohydrate components of raw peanuts, the unknown components (Pattee et al., 2000) varied in their degree of association with sensory attributes (Table 4). The total of the unknowns was negatively associated with bitterness and astringency and positively associated with the roasted peanut attribute in the Virginia and runner market-types but not in the fastigiate market-type. Unknowns 1 and 8 were not associated with any sensory attribute in any market-type. Unknown 2 was negatively correlated with bitterness in the runner market-type and with astringency in the Virginia market-type. Unknown 3 did not occur in the fastigiate market-type—at least its observed levels were not significantly greater than background noise—but it was negatively associated with sweetness in both Virginia and runner market-types and positively correlated with bitterness in the runner market-type. In contrast, unknowns 4, 5, and 9 were associated with several sensory attributes in the Virginia market-type but not with any attribute in any other market-type. Increased levels of unknown 4 were associated with increased sweetness and roasted peanut attribute and reduced bitterness and astringency in the Virginia market-type. Unknowns 5 and 9 were associated with reduced bitterness and astringency. Similarly, unknown 6 was associated with superior flavor profiles (increased sweetness and roasted peanut attributes and reduced bitter and astringent attributes) in the runner market-type but not in the others. Unknown 7 had no significant correlation with any sensory attribute within a market-type, but across all 52 genotypes, it was associated with superior flavor. Unknowns 10 and 11 were unusual in terms of their relationships to flavor in this sample of genotypes because each was associated with a positive aspect of flavor in one market-type and a negative aspect in another. Unknown 10 was positively correlated with roasted peanut attribute in the runner market-type and negatively associated with the same attribute in the fastigiate market-type. Unknown 11 was not found in the fastigiate market-type, but in the runner market-type it was positively correlated with bitterness, whereas in the Virginia market-type it was negatively correlated with astringency. These are interesting associations in light of the generally positive correlation between bitterness and astringency in peanuts ($r = 0.459$, $P < 0.01$), especially in the Virginia market-type ($r = 0.652$, $P < 0.01$). It must be noted that bitterness and astringency are not significantly correlated in the runner market-type ($r = 0.103$, ns). Unknown 12 was not measurable in the runner and fastigiate market-types, and it was not associated with any sensory attribute in the Virginia market-type.

In summary, the expected relationship of total sugars or sucrose to the sweet sensory attribute was found within individual peanut market-types. However, because the relationship was not the same across all market-types, a generalized relationship cannot be established. In the Virginia market-type, further work is needed to determine the nature of the chemical components related to the bitter principle, which appear to modify the sweet response and interfere with the sensory perception of sweetness. Also, certain carbohydrate components showed significant relationships with sensory attributes in one market-type and not another. These differential associations demonstrate the complexity of the interrelationships among sweet, bitter, and roasted peanut sensory attributes. Within two market-types it is possible to improve the efficiency of selection for sweetness and roasted peanut quality by assaying for total carbohydrates. On the basis of the regression values the greatest efficiency would occur in the fastigiate market-type and then the runner.

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