idae), Biological Control Candidates for Yellow Starthistle and Diffuse Knapweed. *Environ. Entomol.* **1987**, *16*, 645–648.

Winterhalter, P.; Schreier, P. 4-Hydroxy-7,8-dihydro-β-ionol: Natural Precursor of Theaspiranes in Quince Fruit (*Cydonia oblonga*, Mill.). *J. Agric. Food Chem.* **1988**, *36*, 560–562.

Received for review August 14, 1989. Accepted December 5, 1989.

Registry No. Ethyl acetate, 141-78-6; benzene, 71-43-2; 2-pentanone, 107-87-9; pent-1-en-3-ol, 616-25-1; 3-pentanone, 96-22-0; 2-pentanol, 6032-29-7; pent-3-en-2-one, 625-33-2; 3-methylbutanol, 123-51-3; pentanol, 71-41-0; 2-methylpent-2-enal, 623-36-9; hex-3-en-2-one, 763-93-9; (*E*)-2-hexenal, 6728-26-3; (*Z*)-3-hexenol, 928-96-1; ethylbenzene, 100-41-4; (*Z*)-2-hexenol, 928-94-9; hexanol, 111-27-3; *m*-xylene, 108-38-3; *p*-xylene, 106-42-3; (*E*)-5-methylhex-3-en-2-one, 1821-29-0; *o*-xylene, 95-47-6; (*E*,*E*)-2,4-hexadienal, 142-83-6; benzaldehyde, 100-52-7; (*E*)-2-heptenal, 18829-55-5; octanal, 124-13-0; (*E*,*E*)-2,4-heptadienal, 4313-03-5; (*Z*)-3-hexenyl acetate, 3681-71-8; decane, 124-18-5; benzyl alcohol, 100-51-6; phenylacetaldehyde, 122-78-1; 2-phenylethanol, 60-12-8; nonanal, 124-19-6; methyl salicylate, 119-36-8; (*Z*)-3-hexenyl butyrate, 16491-36-4; decanal, 112-31-2; benzothiazole, 95-16-9; (*Z*)-3-hexenyl 2-methylbutyrate, 53398-85-9; *cis*-theaspirane, 66537-40-4; *trans*-theaspirane, 66537-39-1; α-copaene, 3856-25-5; β-bourbonene, 5208-59-3; caryophyllene, 87-44-5; (*E*)-α-bergamotene, 13474-59-4; (*E*)-β-farnesene, 18794-84-8; humulene, 6753-98-6; *ar*-curcumene, 644-30-4; germacrene D, 23986-74-5; β-selinene, 17066-67-0; 1-pentadecene, 13360-61-7; bicyclogermacrene, 24703-35-3; β-bisabolene, 495-61-4; (*Z*,*E*)-1,3,11-tridecatriene-5,7,9-triyne, 124604-44-0; (*Z*,*Z*,*Z*)-1,8,11,14-heptadecatetraene, 10482-53-8; (*E*,*E*)-1,3,11-tridecatriene-5,7,9-triyne, 50739-51-0; mint sulfide, 72445-42-2.

Interrelationships between Headspace Volatile Concentration, Marketing Grades, and Flavor in Runner-Type Peanuts

Harold E. Pattee,*[,†] Wallace H. Yokoyama,[†] Maureen F. Collins,[‡] and Francis G. Giesbrecht[§]

Department of Botany, U.S. Department of Agriculture—Agricultural Research Service, North Carolina State University, Box 7625, Raleigh, North Carolina 27695-7625, Research and Development, Beatrice/Hunt-Wesson, 1645 West Valencia Drive, Fullerton, California 92633-3899, and Department of Statistics, North Carolina State University, Box 8203, Raleigh, North Carolina 27695-8203

The general quality of the peanut crop within a given year is not static but is dynamic and changes in response to climatic variations and harvesting and handling variations. A quality survey of the 1987 peanut crop marketed in southwest Georgia using the headspace volatile concentration (HSVC) test indicated that sensory quality decreased and immaturity increased as the season progressed. During the first week of the marketing season, the distribution of initial-grade samples into superior, questionable, and inferior sensory quality categories as measured by the HSVC test was 86%, 10%, and 4%, respectively. The last week of the marketing season the distribution was 45%, 21%, and 34%, respectively. Taste panel intensity scoring of selected sensory attributes of roasted peanut paste made from five selected marketing grades and selected HSVC ranges indicated an inverse linear relationship between roasted peanut flavor and fruity off-flavor. There was a decrease of approximately 1 unit in roasted peanut flavor intensity for a 2-unit increase in fruity off-flavor. The data presented confirm previous suggestions that larger seed sizes are generally more flavorful and more resistant to high-temperature damage.

Curing peanuts at temperatures above 35 °C or subjecting them to freezing temperatures before they are cured may cause off-flavors in peanuts (Dickens, 1957; Singleton and Pattee, 1987a). Development of these off-flavors in peanuts is accompanied by an increase in the concentration of alcohols and aldehydes, primarily ethanol and acetaldehyde (Pattee, 1965; Singleton and Pattee, 1987a,b). The increase in concentration of these compounds is thought to result from a change in the respiration process from aerobic to anaerobic (Whitaker and Dickens, 1964; Whitaker et al., 1974). Until recently, a rapid, inexpensive, quantitative method has not been available for detecting quality deficiencies in farmers stock peanut lots (Dickens et al., 1987). The headspace volatile concentration (HSVC) test enables one to detect the presence of high-temperature off-flavor in farmers stock wagon-load lots being graded for marketing at peanut buying stations. The HSVC test was developed to be used as part of the Federal–State Inspection Service (FSIS) grading procedure. Although short-term sampling studies have been conducted (Pattee et al., 1986, 1987), a full marketing season test in which every grade sample at the peanut buying station is tested for quality has not previously been undertaken.

Previous sensory investigations by Pattee and coworkers (1986, 1989) have shown that (a) the sensory character note fruity is the appropriate sensory character note to characterize high-temperature off-flavor, (b) a relationship exists between the intensity of high-temperature off-flavor (fruity flavor) and the meter reading of the HSVC test, and (c) relationships exist between HSVC values, selected seed size ranges, and fruity flavor intensity in large-seeded virginia-type peanuts.

This study, during the 1987 crop year, was undertaken to (1) determine the variation in sensory quality, as determined by the HSVC test, across the entire mar-

[†] USDA—ARS.

[‡] Beatrice/Hunt-Wesson.

[§] North Carolina State University.

Table I. Definition of Sensory Attributes Evaluated at North Carolina State University (NCSU) and Beatrice/Hunt-Wesson (B/HW)

NCSU	B/HW
Roasted Peanut	
a nutty aromatic associated with medium-roast peanuts	flavor associated with the aromatics of sweet, nutty, toasted peanuts
Roast Character	
not evaluated	a continuum of flavor associated with increasing degree of roast, beginning with raw/green, continuing through green/underroast, light roase, roast, overroast, overroast burnt, and concluding with burnt
Overroast	
the aromatic associated with dark-roast or charred peanuts	not evaluated
Underroast	
the aromatic associated with light-roast peanuts and having legumelike character	not evaluated
Fruity	
a sweet aromatic associated with fermented fruit	flavor of overripe fruit, usually sweet fermented, ranging from fermented to rotten, but can also be sour
Bitter	
the basic taste associated with quinine	same
Sweet	
the basic taste associated with sugars but largely aromatic associated with caramel, vanilla, molasses	same
Throat/Tongue Burn	
a burning sensation in the mouth	not evaluated

Table II. Definition of Numeric Sensory Intensity Ratings Used at North Carolina State University

numerical value	definition
1	not detectable
2	threshold, barely detectable
3	
4	barely detectable to slight
5	
6	slight
7	
8	slight to moderate
9	
10	moderate
11	
12	moderate to strong
13	
14	strong

keting season at a given location, (2) determine the interrelationship between flavor quality across selected marketing grades and HSVC, and (3) investigate the relationship between fruity flavor intensity and roasted peanut flavor intensity of roasted peanut paste.

MATERIALS AND METHODS

The peanut buying station selected by the FSIS, Albany, GA, to cooperate in this study was located in the southwest Georgia peanut growing area. It opened on Sept 16, 1987, and closed on Oct 14, 1987. During this time a total of 1377 samples were analyzed by the organic volatile meter as described by Dickens et al. (1987). The meter was standardized at 8 and 10 a.m. and 1 and 3 p.m. each day against 0.08 and 0.32 mL of EtOH/L of distilled H_2O. The standardized meter readings were recorded and used to calculate HSVC values. The FSIS samples analyzed came from farmers stock wagon load lots, usually 3.6–4.5 metric tons, or from regrade farmers stock lots (which are combined initial-grade lots shipped from an external buying point to a shelling plant and regraded) of about 20 metric tons. A 125-g subsample of the split-kernel fraction used for determination of concealed damage was taken for the HSVC test. Form FV-95 or the regrade data sheet for each lot was also collected when available and lot-identified for future reference. Values for sound mature kernels (SMK) and sound splits (SS) were obtained from the FV-95s.

Flavor quality evaluation samples were collected for preselected HSVC ranges of <3.0, 3.0–5.1, 5.2–8.7, 8.8–14.5, 14.6–24.7, 24.8–41.7, 41.8–69.3, and >69.3 mg of volatiles/kg of air. Each day two FSIS check samples (which are 2.2-kg samples held in reserve for random checks on market grade), if available, were randomly collected for each of the above HSVC ranges below 24.8 mg of volatiles/kg of air. All FSIS check samples from lots testing equal to or greater than an HSVC of 24.8 were collected. Collected check samples were lot-identified and held in cold storage until shelled. Prior to shelling all check samples for each HSVC range were combined. Shelling and segregation of the kernels into Other Edible Quality (5.50–6.35 mm), No. 1 Runner (>6.35–7.14 mm), Medium Runner (>7.14–7.94 mm), Runner Splits (>6.75 mm), and Jumbo Runner (>6.94 mm) marketing grades were done at the National Peanut Research Laboratory, USDA—ARS, Dawson, GA, with use of standard procedures as described by Davidson et al. (1982). Other Edible Quality is a Peanut Administrative Committee Category, while No. 1 Runner, Medium Runner, Runner Splits, and Jumbo Runner are Southeastern Peanut Association grades. Specifications for these designations are published by the USDA (1986). Hereafter these designations will be referred as other edible, no. 1, medium, splits, and jumbo marketing grades. After being shelled and sorted into the marketing grade lots the peanuts were shipped to Raleigh, NC, and stored at 5 °C and 60% RH (relative humidity) until roasted for flavor evaluation. Just prior to being roasted, each lot was sampled and the HSVC value determined for each lot by the prescribed procedure (Dickens et al., 1987).

Peanuts to be made into roasted peanut paste for sensory and objective color measurements were roasted in a Blue M Power-O-Matic 60 laboratory oven. An 800-g roasting sample was equally divided among eight roasting compartments within the oven. Roasting time for each marketing grade was selected by trial roasting and attainment of a butter color of approximately $L^* = 58$. The selected roasting conditions for the five marketing grades were 160 °C and 9.5 min for other edible, 12.5 min for no. 1, 16.5 min for medium, 16 min for splits, and 17.5 min for jumbo. Peanuts were ground in an Olde Tyme peanut butter mill (Olde Tyme Food Products Corp., 143 Shaker Rd., E. Long Meadow, MA 01028). Color measurements were made with a Minolta Chroma Meter II CR-100 on a finely ground paste of peanuts, which had been blanched following roasting. The three color-reflectance parameters, L^*, a^*, and b^*, were read, immediately after the peanuts were ground, using 60 × 15 mm, Falcon No. 1007, disposable Petri dishes as containers.

Sensory Evaluation. A nine-member trained roasted peanut flavor panel at the Food Science Department, North Carolina State University (NCSU) evaluated 25 (5 market grades × 5 HSVC levels) experimental peanut paste samples using 14-point intensity scales. An orientation session was conducted in which a control sample made from the jumbo marketing grade, <3.0 HSVC category, and extremes of the experimental samples were presented and described. A questionnaire was developed containing primary peanut flavor attributes selected during the orientation session (Table I). The control was rated on the above attributes and was available, along with the ratings, at each session for intensity reference. Two sessions were conducted weekly. Panelists evaluated five samples per session presented in an incomplete block design constructed to control carryover effects. The resulting data were converted to 1–14 numerical values (Table II) and statistically analyzed with SAS

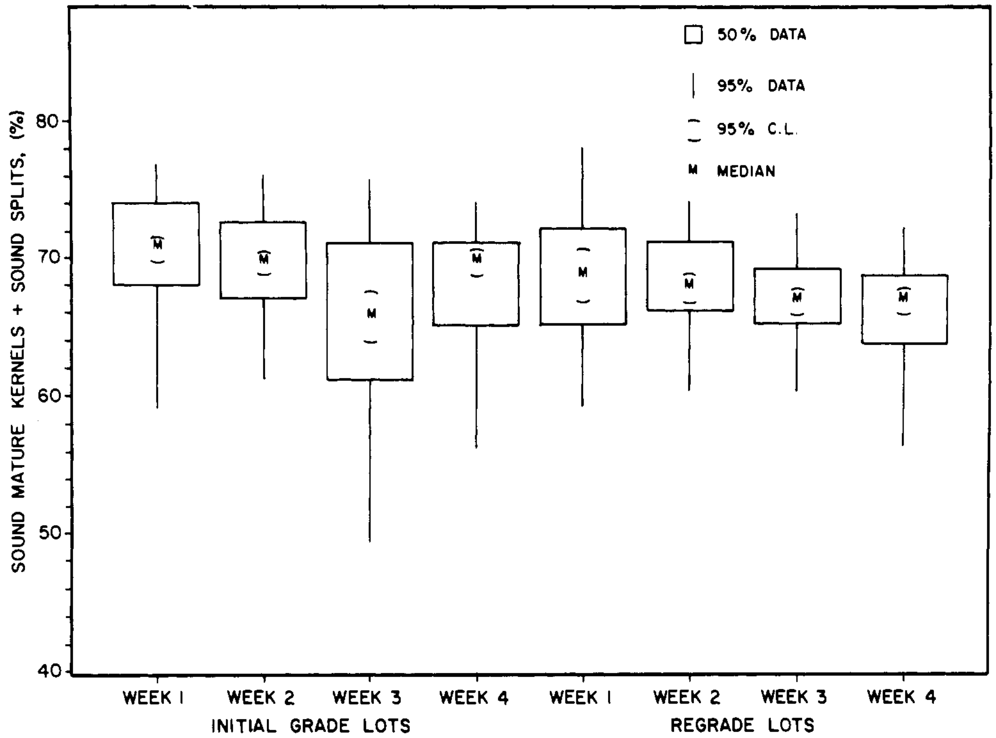

Figure 1. Source and marketing season variation in sound mature kernel plus sound split values of peanuts marketed at a southwest Georgia location.

procedures (SAS Institute Inc., 1985). Mean intensity responses were adjusted to remove panel differences and scaled so that the lowest value was equal to 1.

Frozen duplicates of the 25 experimental samples and a control sample were forwarded by Overnight Express to Beatrice/Hunt-Wesson, Fullerton, CA (B/HW), for sensory evaluation. Five trained peanut butter panelists at B/HW evaluated the experimental samples using a 7-point intensity scale. Attributes for evaluation (Table I) were selected to correspond with those used at NCSU. The control was rated on these attributes. A control sample and ratings were available at each session for intensity reference. Samples were evaluated in six sessions with use of a balanced incomplete block design. Statistical analysis of resulting data was performed with an SAS analysis of variance program for a balanced incomplete block design (SAS Institute Inc., 1985).

Although peanut paste resembles commercial peanut butters, the latter usually contains additional flavor ingredients that can affect the perception of fruity and roast peanut flavors. A direct 1:1 correlation cannot be made between paste and peanut butter.

RESULTS AND DISCUSSION

Crop Maturity. The grade factors SMK and SS added together (SMK + SS) provide a general indicator of peanut crop maturity (Pattee et al., 1980, 1982a). Runner-type peanuts, cv. Florunner, would have an SMK + SS value above 72 when a desirable overall maturity has been reached. This SMK + SS value can appropriately be applied to the peanut crop in Georgia, since 78.1% of the crop is Florunner (Anonymous, 1989). In this study the decrease in SMK + SS indicates an increase in immaturity of marketed peanuts as the market season progressed (Figure 1). During the first week of the marketing season at this southwest Georgia location, the average SMK + SS values suggest that the overall maturity of the peanut crop was near a desirable level. By the third and fourth weeks of the marketing season these values had decreased significantly to 64 and 66, respectively. Thus, the general immaturity of the peanut crop is significantly lower. A similar trend is noted in the regrade lots, but the general growing area of these peanuts was not known. These observations are important because the quality of the peanut crop within a given year changes in response to climatic variations and harvesting and handling variations. The more immature the peanut crop, the more dramatic can be the quality responses to climatic, harvesting, and handling variations (Pattee et al., 1989). Immature peanuts have a lower roasted flavor potential (Pattee et al., 1982b), are more susceptible to freeze damage (Singleton and Pattee, 1987b), and are more susceptible to high-temperature off-flavor (Whitaker and Dickens, 1964), whether it be while curing in the windrow or drying in a drying wagon.

Table III. Mean Headspace Volatile Concentration (HSVC) Values for Samples Collected within Each HSVC Range and Projected Quality Level

HSVC range of farmers stock peanuts, mg volatiles/kg air	no. of samples	mean ± SD	quality
1.8	337	1.07 ± 0.40	
1.8–2.99	204	2.28 ± 0.34	superior
3.00–5.19	195	4.02 ± 0.65	
5.20–8.79	151	6.87 ± 0.97	
8.80–14.59	147	11.58 ± 1.71	?
14.60–24.79	111	19.65 ± 2.98	
24.80–41.79	94	32.01 ± 4.66	
41.80–69.30	62	51.15 ± 7.61	inferior
>69.30	76	194.99 ± 185.70	

Headspace Volatile Concentration. The HSVC test provides information on sensory quality. Previous studies (Pattee et al., 1986, 1989) have suggested that peanuts with a HSVC value below 8.8 have superior sensory quality. Those between 8.8 and 24.8 are of questionable quality, and those above 24.8 have inferior sensory quality. A natural logarithmic plot, for statistical purposes, of the median HSVC values (Figure 2) indicates a significantly increasing HSVC value trend across the marketing season in both the initial and regrade lots. This trend is in agreement with the immaturity trend previously discussed. The percentages of initial-grade samples in the <8.8 category (superior sensory quality) dur-

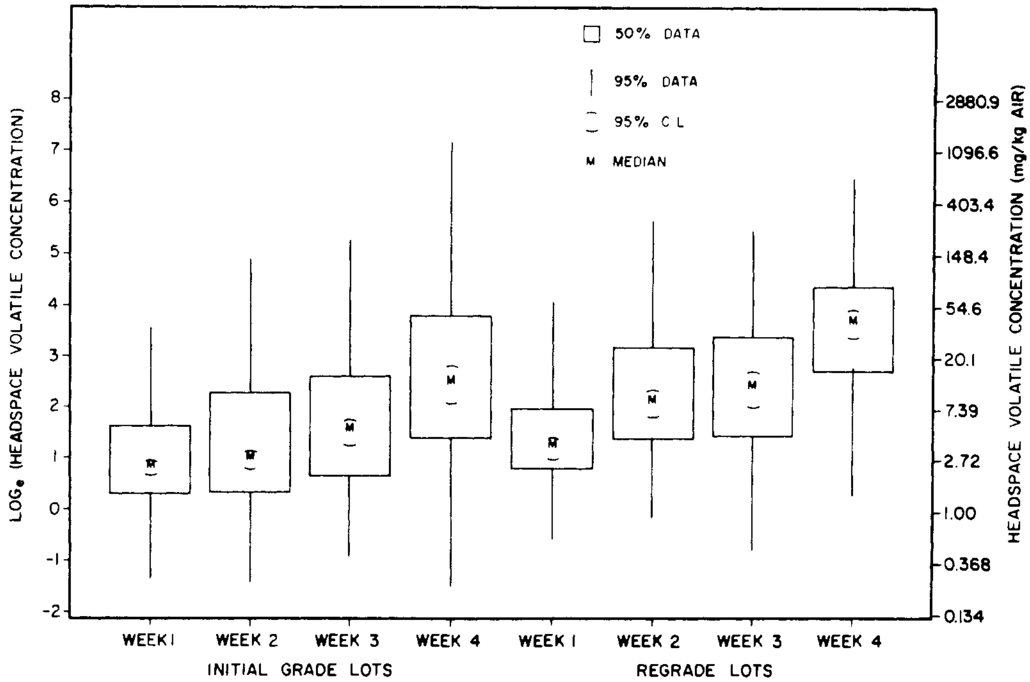

Figure 2. Marketing season variation in headspace volatile concentration values of peanuts marketed at a southwest Georgia location. Note data presented as natural logarithm of headspace volatile concentration in order to accommodate the extreme range of high values.

Table IV. Headspace Volatile Concentration (HSVC) Values for Marketing Grades from within Composited Farmers Stock Grade Samples Collected on the Basis of the Given HSVC Ranges

HSVC range of farmers stock peanuts, mg volatiles/kg air	marketing grade				
	jumbo	medium	splits	no. 1	other edible
<3.0	5.78	8.06	6.76	9.28	10.67
8.8–14.59	7.92	11.06	12.07	20.43	21.16
14.60–24.79	9.44	13.41	16.55	29.02	34.54
24.80–41.79	9.78	19.73	21.92	37.76	48.28
>69.3	13.65	26.58	43.45	73.56	106.34

ing weeks 1–4 were 86, 73, 66, and 46, respectively. The percentages of initial grade samples with a HSVC value >24.8 (inferior sensory quality) during the same 4-week period were 4, 11, 19, and 34. In the regrade lots during this same 4-week period, the percentages in the superior sensory quality category were 79, 52, 43, and 14, and in the inferior sensory category they were 8, 26, 29, and 66. The percent superior sensory quality peanuts in the initial-grade lots during weeks 1 and 2 and during week 1 for the regrade lots probably represents adequate levels to maintain acceptable consumer quality. The percent superior sensory peanuts at week 3 in the initial-grade lots and week 2 in the regrade lots probably represents a questionable level to maintain acceptable consumer quality, and the remaining percentages probably represent an inadequate level to maintain acceptable consumer quality. The number of samples observed within each HSVC category, their mean, and standard deviation for the complete marketing season are presented in Table III. With the above criteria 64.4% of the samples evaluated would have superior quality (HSVC < 8.8), 18.7% questionable, and 16.8% inferior.

Headspace Volatile Concentration Test and Flavor Relationships. The distribution of HSVC values based on marketing grade separation within a given HSVC range has not been previously investigated. Table IV shows the effect on HSVC of shelling and separating farmers stock peanut lots of a given HSVC range into their respective marketing grades. The relationship between HSVC

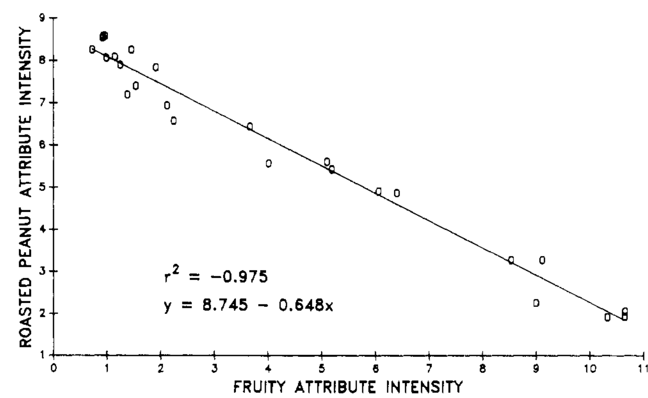

Figure 3. Interrelationship between roasted peanut intensity and fruity intensity using a 14-point intensity scale.

Table V. Influence of Selected Headspace Volatiles Concentration (HSVC) Ranges and Marketing Grades on the Mean Intensity Responses for the Sensory Attributes Roasted Peanut Flavor (RSTFL) and Fruity[a]

HSVC range of farmers stock peanuts, mg volatiles/kg air	sensory attribute	marketing grade				
		jumbo	medium	splits	no. 1	other edible
<3.0	RSTFL	8.85[b]	8.36	8.17	6.85	5.18
	fruity	1.20[c]	1.42	1.52	2.51	6.32
8.8–14.59	RSTFL	8.53	8.82	8.11	5.84	2.53
	fruity	1.73	1.19	2.18	4.28	9.26
14.6–24.79	RSTFL	8.53	8.86	7.21	5.13	2.19
	fruity	1.00	1.24	2.39	6.66	10.59
24.8–41.79	RSTFL	8.32	7.47	6.71	3.55	2.33
	fruity	1.26	1.65	3.93	8.79	10.92
>69.3	RSTFL	7.67	5.70	5.88	3.55	2.20
	fruity	1.81	5.45	5.36	9.37	10.91

[a] Mean intensity values scaled so lowest value equals 1. [b] RSTFL LSD (0.05) = 1.21. [c] Fruity LSD (0.05) = 1.48.

values and marketing grades is probably due to maturity. The same general interrelationship between HSVC range and marketing grade is observable throughout all the observations; i.e., as you go from the large-seeded marketing grade, jumbo, to the small-seeded marketing grade, other edibles, the HSVC values increase. The HSVC values also increase with increasing HSVC range levels within a marketing grade. However, it is observable that the HSVC values obtained within the <3.0 HSVC range are consistently elevated above expected levels for all marketing grades. Retesting of the samples verified the obtained HSVC values. The reason for these consistent elevated HSVC values is not known. However, a very reasonable explanation is that a minor blending contamination of the <3.0 HSVC range lot with material from a higher HSVC range occurred prior to screening into the marketing grades. Thus, the absolute values are not correct, but the trend of the values is correct. This minor contamination of the <3.0 HSVC range does not appear to have any significant impact on the intensity responses for the sensory attributes (Table V).

Although a relationship between roasted peanut flavor and fruity flavor has previously been observed (Pattee et al., 1989), sufficient observations have not been available to describe this relationship statistically. Figure 3 provides the linear equation describing this relationship. Roughly, the inverse relationship is an increase in fruity off-flavor of 2 units resulting in a decrease in roasted peanut flavor of 1 unit. This result can occur because the presence of an undesirable off-flavor suppresses the roasted peanut flavor perception or because there is reduced production of the roasted peanut attribute in peanuts, subjected to high-temperature curing.

Previous studies (Pattee et al., 1986) have also shown that HSVC values of farmers stock peanuts at the buying point are good predictors of peanut flavor as measured by trained sensory panels tasting medium-sized roasted peanuts. This study extends the conclusion to marketing grades. The data (Table IV) confirm the previous suggestions that larger sizes are generally more flavorful and more resistant to high-temperature curing damage. All jumbo grade peanuts contained less than 24.8 mg of volatiles/kg of air. The mediums and splits grades contained less than 24.8 mg of volatiles/kg of air with the exception of the >69.3 category. This categories of mediums and splits have HSVC values of 25.68 and 43.45, respectively. The corresponding fruity off-flavor adjusted scores were 5.45 and 5.36. The >69.3 category of farmers stock peanuts represented only 5.5% of the total samples and upon combination with the other categories would not be detectable.

The no. 1 peanuts represent a grade size in which there exists a wide range of HSVC and sensory values depending upon the HSVC values of the farmers stock peanuts. The HSVC values range from 9.28 to 73.56 with corresponding fruity values of 2.51–9.37. Of the no. 1 samples 64% have an HSVC of <24.8 and a fruity value of <4.28. The remaining 36% have extremely high HSVC and sensory values and contribute significantly to the decrease in quality of the overall combined grade. The other edibles grade represents generally inferior-quality peanuts. The fruity sensory values range from 6.32 to 10.91 with corresponding HSVC values of 10.67 to 106.34. It has been shown that immature peanuts do not have the necessary precursors for optimal production of roasted peanut flavor (Pattee et al., 1982a,b). A close comparison of the other edibles HSVC and fruity values with the other marketing grades shows that this category has significantly higher fruity values for the same HSVC value. For example, splits and no. 1 have a fruity range of 1.52–4.28 for an HSVC range of 6.76–20.43. The other edibles has a fruity value of 6.32 for an HSVC of 10.67.

The flavor panel results from the Beatrice/Hunt-Wesson evaluation confirm in all aspects the results from NCSU Food Science flavor panel but are not presented for proprietary reasons. Similar sensory values from two independently trained flavor panels reinforce, we feel, the proposed relationships between HSVC values and sensory values for market-grade peanuts as well as the farmers stock peanuts.

SUMMARY

This survey of southwest Georgia farmers stock peanuts marketed throughout the 1987 season has shown that the general sensory quality of the peanut crop, as measured by the HSVC test, is related to the general maturity of the crop as indicated by SMK + SS values. The more immature the peanut crop, the more susceptible it is to sensory quality deterioration by environmental factors and improper handling factors, such as high-temperature curing. Sensory scoring of roasted peanut paste samples has reaffirmed the strong relationship between HSVC values, sample seed size, high fruity values, and low roasted peanut flavor values. Use of the HSVC test throughout the entire marketing season as a part of the FSIS grading procedure (USDA, 1988) without encumbering the present procedure indicates that the HSVC test can be successfully incorporated by FSIS if desired by the peanut industry. If the HSVC test is used as a part of the FSIS grading procedure, we recommend its use as a pass/fail test, with the limits to be set by agreement within the peanut industry buying groups.

LITERATURE CITED

Anonymous. 1987 Cultivar census. *Peanut Res.* **1989**, *27* (110), 2.

Davidson, J. I., Jr.; Whitaker, T. B.; Dickens, J. W. Grading, Cleaning, Storage, Shelling, and Marketing of Peanuts in the United States. In *Peanut Science and Technology*; Pattee, H. E., Young, C. T., Eds.; American Peanut Research and Education Society: Yoakum, TX, 1982.

Dickens, J. W. Off-flavor in Peanuts. *Res. Farming NC Agric. Exp. Stn.* **1957**, *16* (1), 5.

Dickens, J. W.; Slate, A. B.; Pattee, H. E. Equipment and Procedures to Measure Peanut Headspace Volatiles. *Peanut Sci.* **1987**, *14*, 97–100.

Pattee, H. E.; Beasley, E. O.; Singleton, J. A. Isolation and Identification of Volatile Components from High-Temperature Cured Off-Flavor Peanuts. *J. Food Sci.* **1965**, *30*, 388–392.

Pattee, H. E.; Wynne, J. C.; Sanders, T. H.; Schubert, A. M. Relation of the seed/hull ratio to yield and dollar value in peanut production. *Peanut Sci.* **1980**, *7*, 74–77.

Pattee, H. E.; Giesbrecht, F. G.; Dickens, J. W.; Wynne, J. C.; Young, J. H.; Mozingo, R. W. The seed hull maturity index as an estimator of yield and value of virginia-type peanuts. *Peanut Sci.* **1982a**, *9*, 27–30.

Pattee, H. E.; Pearson, J. L.; Young, C. T.; Giesbrecht, F. G. Changes in Roasted Peanut Flavor and Other Quality Factors with Seed Size and Storage Time. *J. Food Sci.* **1982b**, *47*, 455–456, 460.

Pattee, H. E.; Dickens, J. W.; Singleton, J. A.; Slate, A. B. Peanut Quality Evaluation Based on Sensory and Analytical Data Correlation. Symposium presented at the 192nd National Meeting of the American Chemical Society, Anaheim, CA, Sept 1986; American Chemical Society: Washington, DC, 1986; AGFD 53.

Pattee, H. E.; Dickens, J. W.; Singleton, J. A.; Slate, A. B. Peanut Quality Evaluation Using the Alcohol Meter. *Proc. Am. Peanut Res. Educ. Soc.* **1987**, *19*, 21.

Pattee, H. E.; Rogister, E. W.; Giesbrecht, F. G. Interrelationships Between Headspace Volatile Concentration, Selected Seed-Size Categories and Flavor in Large-Seeded Virginia-Type Peanuts. *Peanut Sci.* **1989**, *16*, 38–42.

SAS Institute Inc. *Sas User's Guide: Statistics, Version 5 Ed.*; SAS: Cary, NC, 1985.

Singleton, J. A.; Pattee, H. E. Effects of Induced Low-Temperature Stress on Raw Peanuts. *J. Food Sci.* 1987a, *52*, 242–244.
Singleton, J. A.; Pattee, H. E. Effects of Maturity and Storage on Freeze Damaged peanuts. *Abstracts of Papers*, 194th National Meeting of the American Chemical Society, New Orleans, LA, Sept 1987; American Chemical Society: Washington, DC, 1987; AGFD 40.
USDA. *Milled Peanuts (Shelled Stock and Cleaned Virginia Type in the Shell) Inspection Instructions*; U.S. Department of Agriculture, Agricultural, Marketing Serive, Fruit and Vegetable Division, Fresh Products Branch: Washington, DC, 1986; 138 pp.
USDA. *Farmers Stock Peanuts Inspection Instructions*; U.S. Department of Agriculture, Agricultural Marketing Service, Fruit and Vegetable Division, Fresh Products Branch: Washington, DC, 1988; 146 pp.
Whitaker, T. B.; Dickens, J. W. The Effects of Curing on Respiration and Off-Flavor in Peanuts. Proceedings of the Third National Peanut Research Conference, Auburn University, Auburn, AL, 1964; pp 71–80.
Whitaker, T. B.; Dickens, J. W.; Bowen, H. D. Effects of Curing on the Internal Oxygen Concentration of Peanuts. *Trans. ASAE* 1974, *17*, 567–569.

Received for review August 7, 1989. Revised manuscript received November 9, 1989. Accepted November 20, 1989. Paper No. 12127 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, NC 27695-7643. The use of trade names in this publication does not imply endorsement by the U.S. Department of Agriculture or the North Carolina Agricultural Research Service of the product named or criticism of similar ones not mentioned.

Headspace Examination of Volatile Emissions from Ripening Papaya (*Carica papaya* L., Solo Variety)

Robert A. Flath,*[,†] Douglas M. Light,[†] Eric B. Jang,[‡] T. Richard Mon,[†] and Janie O. John[†]

Western Regional Research Center, USDA—ARS, Albany, California 94710, and Tropical Fruit and Vegetable Research Laboratory, USDA—ARS, Hilo, Hawaii 96720

Organic compounds released from intact papayas at each of four ripeness stages were concentrated by Tenax trapping–ether desorption and were identified by capillary gas chromatography–mass spectrometry. Linalool, benzyl isothiocyanate, and phenylacetonitrile were released in significant amounts at all four ripeness stages, but linalool production increased dramatically as the fruit progressed from one-fourth to full ripeness. Free benzyl isothiocyanate levels also increased with fruit ripening, but phenylacetonitrile release fluctuated across the four fruit stages, showing no clear correlation with ripeness. Numerous esters and monoterpenes were only detected in emissions from fully ripe fruit. In initial flight tunnel bioassays with Oriental fruit flies, ripe papaya emissions were found to enhance significantly the attractiveness and oviposition stimulation of a perforated yellow sphere fruit model.

Effective attractants for females of the various tephritid fruit flies would be useful tools in monitoring fly populations, in determining female mating levels in sterile mass release or male annihilation projects, and in directly suppressing population levels. One promising source of such attractants is the mix of volatile compounds released by plant hosts of such flies, particularly that part of the host which is the preferred oviposition site for gravid females.

Papaya fruit (*Carica papaya* L.) is readily infested by several of the Hawaiian tephritids, especially the Oriental fruit fly *Dacus dorsalis* Hendel and the Mediterranean fruit fly *Ceratitis capitata* Wiedmann. The melon fly *Dacus cucurbitae* Coquillet will also infest papaya when given no choice of other host but is less of a problem under field conditions (Liquido et al., 1989). Infestation levels in Hawaiian papaya orchards have been shown to be directly related to the ripeness stage of the individual fruit (Seo et al., 1982, 1983; Liquido et al., 1989). Seo and co-workers attributed this relationship to the deterrent effect of benzyl isothiocyanate released from unripe fruit latex when the skin is punctured by the female fly's ovipositor. They suggested that ripe fruit are more heavily infested because the riper portions of the fruit release less benzyl isothiocyanate producing latex when punctured and because other attractive compounds produced by riper fruit may override the deterrent effect of whatever benzyl isothiocyanate is still released. Liquido et al. (1989) suggested that the greater attractiveness of riper fruit, rather than a decrease in the deterrent properties of ripening fruit, is the key factor in explaining the variation of infestation rates with fruit ripeness. This preference for riper post color break fruit is supported by recent field observations of *D. dorsalis* adult fly distribution among papaya fruit at various ripeness stages in an unharvested orchard near Hilo (D.M.L.). Liquido and co-workers (Liquido, N. J., Chan, H. T., 1989, personal communication; Liquido and Cunningham, 1990) have also studied the correlation between physical and chemical properties of ripening papayas and infestation rates by oriental and melon fruit flies.

The commercial quarantine commodity treatment procedure for Hawaiian papayas involves both a fruit selection procedure and treatment of harvested fruit in a two-stage hot water bath sequence (Couey and Hayes, 1986). Proper application of this procedure reduces fruit fly infestation to Probit 9 levels, or no more than 3 survivors/100 000 treated insects at the 95% confidence level. An important parameter in this procedure is stage of fruit

[†] Western Regional Research Center, USDA—ARS.
[‡] Tropical Fruit and Vegetable Research Laboratory, USDA—ARS.