Sensory Attribute Variation in Low-Temperature-Stored Roasted Peanut Paste[†]

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Length of sample storage can become significant in sensory studies due to panel fatigue limitations and samples needed for a reasonable expectation of finding significant differences. In roasted peanut sensory studies samples are stored between −10 and −23 °C to prevent or retard changes. Studies of up to 13 months' duration have examined stability and slow-rate sensory changes. Sweet taste was relatively stable, whereas bitter and tongue burn attributes increased slightly. Stale taste increased, suggesting lipid oxidation was taking place even at −23 °C. Painty attribute did not increase until stale was >3. An increase in fruity attribute was unexpected. With increases in fruity and stale attributes a decrease in roasted peanut was expected. However, storage at −23 °C seems to stabilize the roasted peanut lability when compared to storage at −10 °C. Fruity and stale interactions with roasted peanut and lability of roasted peanut were shown to be three separate and identifiable effects on roasted peanut.

Keywords: *Flavor intensity; flavor-fade; sensory interactions; stability; staling*

INTRODUCTION

Descriptive sensory analysis protocols limit the number of samples evaluated in a given session due to panelist fatigue. With roasted peanut paste we have found this limit to be four samples per session (Pattee et al., 1995a). Comparative peanut genetic studies (Pattee et al., 1993, 1994, 1995a, 1997) have shown a minimum of two replications at two locations for each entry is needed to give a reasonable expectation of finding significant differences. With studies approaching 60 entries the sensory panel evaluation time can be quite extended. In sensory evaluation studies of roasted peanuts it is a standard practice to store the processed samples at ∼−10 °C to prevent or retard sensory changes over the period of analysis (Oupadissakoon and Young, 1984; Pattee and Giesbrecht, 1990). The primary process of concern is lipid oxidation. In addition to the off-flavors produced, lipid oxidation has been associated with "flavor-fade" in roasted peanut products (Warner et al., 1996). Braddock et al. (1995) found during 6 weeks of storage at 25 and 40 °C that sensory evaluation of peanut flavor and oxidation-derived off-flavors paralleled changes in certain pyrazines and aldehydes in stored peanuts. A number of reviews are available on lipid oxidation in processed peanuts and their products (Ory et al., 1992; Sanders et al., 1993). The Ory et al. (1992) review covers that group's work on peanut lipid oxidation from the late 1960s forward. St. Angelo et al. (1977) reported on development of lipid peroxides in several peanut varieties that had been stored at 4 °C for 12 months as raw and roasted whole peanuts, but no sensory data are reported. Bett and Boylston (1992) studied the effect of lipid oxidation on sensory descriptors by storing whole, roasted peanuts at 37 °C for 12 weeks. Using paste samples from the roasted seed treatments, significant changes in volatile lipid oxidation products, alkylpyrazines, and intensity of sensory descriptors were observed. Studies using low-temperature storage (−10 °C) and of <6 month duration found no sensory instability (Pattee and Giesbrecht, 1990; Pattee et al., 1993, 1995a,b; Pattee and Knauft, 1995). Other sensory studies involving roasted peanut paste samples and low-temperature storage (Oupadissakoon and Young, 1984; Syarief et al., 1985a,b) make no specific mention of evaluation for time length or instability of sensory attributes.

Our interest in examining low-temperature−long-term storage effects arose from a 1993 roasted flavor study that required a 9-month period to complete the sensory evaluation. At about the seventh to eighth months, increases in the sensory attributes related to lipid oxidation were identified. The objectives of this study were to determine the effect of storage time and two different storage temperatures on the instability of flavor attributes and to determine interrelationships between the sensory attributes being evaluated.

MATERIALS AND METHODS

Genetic Resources. Selected germplasm lines were grown at Gainesville, FL, and Lewiston, NC, during 1992 and 1993, and in 1995 a group of F_5 breeding lines and their parents

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were grown at Lewiston, NC, and Rocky Mount, NC. Samples from the 1992 Gainesville, FL, location were lost due to mold contamination during storage in Florida. The 1992−1993 production experimental design was a randomized, complete block design with 60 entries in two replications at each of two locations over 2 years. The 1995 production experimental design was a completely random design with unequal replication at two locations.

Sample Handling, Roasting, and Preparation. Peanuts were shelled in January and February following the growing year, screened to sound-mature-kernel standards, picked for damage, and then placed in controlled storage at 5 °C and 60% relative humidity until roasted. Roasting, beginning in May or June, followed the standard protocol of 165 °C for a variable time to attain a paste color of 58L^* ± 2. Before grinding, the roasted sample was forced-air cooled and blanched. Color of the peanut paste was determined using a Minolta 200 color meter and was the average of three observations on each of two subsamples. The ground samples were placed in 12 oz glass jars and frozen at −10 °C in 1992−1993 and at −23 °C in 1995 until sensory analysis. Twenty-four hours prior to sensory analysis, samples were removed from storage for room temperature equilibration.

Sensory Evaluation. Sensory analysis was done by a six- to eight-member, trained descriptive sensory panel at the Department of Food Science, North Carolina State University, using a 1−14 intensity scale. Panelists were the same in 1992−1993 and in 1995. Panel orientation, sensory attributes, and reference control were as described by Pattee and Giesbrecht (1990) and Pattee et al. (1993, 1995b). Panelists evaluated four samples per session, two sessions per week on nonconsecutive days. Sample assignments to panel sessions were based on incomplete block designs for all three years. Because of the loss of samples from the Florida location in 1992, the length of the sensory evaluation time was reduced to ∼4 months, whereas the full 1993 sample complement required nearly 9 months to evaluate. The 1995 sample set required 13 months to complete the sensory evaluation. Storage days were counted from first sensory evaluation session each year. To provide confirmation of the trends of the general population, samples evaluated on July 25 (2 days), 30 (7 days), Aug. 6 (14 days), 8 (16 days), 13 (21 days), and 15 (23 days), 1996, respectively, were reevaluated on March 24 (244 days), May 8 (289 days), 12 (293 days), 14 (295 days), 20 (301 days), and 22 (303 days), 1997, respectively.

Statistical Analysis. Incomplete block designs with panel sessions as blocks were chosen because with proper statistical analysis they permit us to make interline comparisons based solely on within-panel session information. Differences among panel sessions (blocks) are eliminated from comparisons. Because repeat samples from individual lines appear on various dates in the design, an alternate set of analyses allowed for the removal of genetic effects and the study of storage effects in this paper. The statistical analyses were based on a linear model that included terms for panel sessions, date of test, germplasm, roast color, and the various sensory attributes. Because interest focused on changes in sensory attribute intensity over time [i.e., across panel sessions (date of test)], Procedure MIXED (SAS, 1997), a mixed model analysis, was used (with germplasm treated as a random factor) to adjust for the fact that only sets of four germplasms could be evaluated in a given panel session. Regression analyses were used to measure the sensory analysis−time relationships within attributes. The adjusted values from the Proc Mixed analysis were used to check for year-by-date interactions. Roast color and selected sensory attributes were used as covariates to provide additional adjustments in the various analyses (Pattee and Giesbrecht, 1994).

RESULTS AND DISCUSSION

In this study it is important to determine first the effects of differences in length of time required to perform the sensory evaluations in the three years (∼4 months in 1992 and 9 and 13 months in 1993 and 1995, respectively). A General Linear Model (GLM) analysis of the adjusted values from the Proc Mixed analysis showed highly significant year effects across all peanut sensory attributes. This is in agreement with previous reports (Pattee et al., 1994, 1997). There was statistically significant variation among panel sessions even after adjustment for variety differences. However, this variation [mean squares (MS)] was 1−3 orders of magnitude less than year-to-year variation. Additionally, the variation due to year-by-date interaction was ∼3 orders of magnitude smaller than year-to-year variation. The size of the MS values suggests to us that the differences are too small to be of practical significance and computation of an arithmetic mean across years is justified.

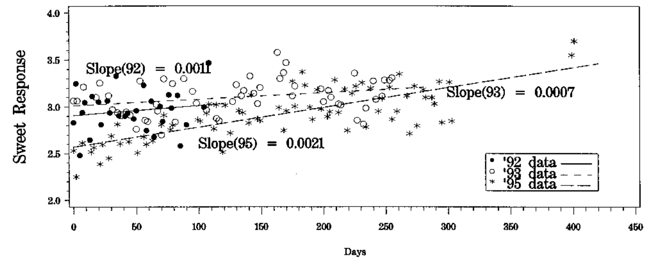

Figure 1. Sweet sensory attribute response versus days from first sensory analysis.

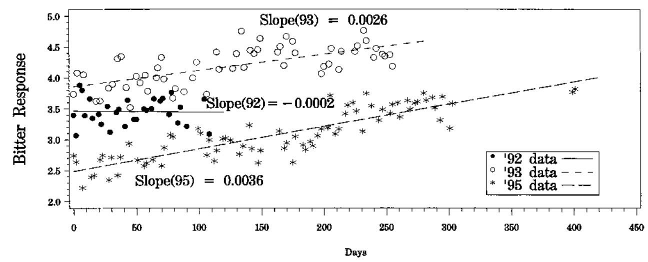

Figure 2. Bitter sensory attribute response versus days from first sensory analysis.

Although no individual statistical test was done on the samples that were evaluated near the beginning and reevaluated near the end of the 1995 storage study, routine comparison of these data suggests that they conform to the standard distribution of the total data set. Thus, the trends and scatter of the data are of chemical and analytical origin rather than biological.

Certain sensory attributes should be constant regardless of other changes over storage time of peanut paste because of the stable nature of the compounds that might produce these sensory responses, for example, sugars for sweetness (Meilgaard et al., 1991) and saponins for bitterness (Dieckert and Morris, 1958). The plot of sensory means versus time and corresponding regression analysis values for sweet (Figure 1) shows the relative stability of sweet with the smallest 3-year average slope value (0.0013) of all attributes. However, bitter (Figure 2) and tongue burn (Figure 3) show similar slope profiles and a larger tendency to change over time than sweet. The slopes for the three attributes were not affected by the lower storage temperature for 1995. The slope values are the estimates of the average change in sensory score per day of storage. A sensory panel value of 1 indicates that the attribute is not detectable, and a value of 2 means that the attribute is barely detectable. The other values are incremental increases toward the most intense sensory level of 14.

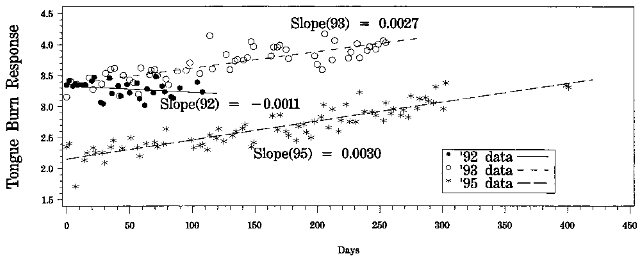

Figure 3. Tongue burn sensory attribute response versus days from first sensory analysis.

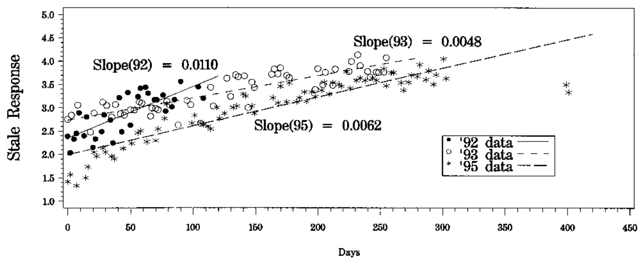

Figure 4. Stale sensory attribute response versus days from first sensory analysis.

The intensities observed for the three attributes are in the normal range for peanut paste. Thus, these results confirm the expected stability of the sweet attribute over time but suggest a slight but detectable positive change in the constituents responsible for the bitter and tongue burn responses. These results also indicate that the sensory panel members were consistent in their scoring of these attributes over the analysis period.

The sensory attribute that first suggested an instability over storage time was stale. Stale is the sensory term used to describe light lipid oxidation and the sensory characteristics that result from its onset. This characteristic may be further described as an "old, cardboardy, straw-like note" (Pattee et al., 1995b). As lipid oxidation progresses the characteristics intensify and change. These are described by the sensory attribute "painty". The description of the painty characteristics is "painty aromatic note as from an old paint can or linseed oil; includes rancid" (Pattee et al., 1995b). The plot of stale attribute means over days (Figure 4) shows that the intensity values are increasing, albeit at a slow rate with a 3-year average of 0.0073. An initial intensity near 1.5 for stale observed during 1995 is more the normal range. The initial values of 2.5−3 for 1992 and 1993 might be considered slightly high. Regardless of the starting stale attribute intensities of the three years, the changes observed over a standard 6-month evaluation would not be statistically discernible by this taste panel. In the extended storage time of 1993 and 1995, the changes in stale intensity reached a discernible level, thus alerting us to a slow rate of oxidation taking place during low-temperature storage. The lower storage temperature for 1995 had no effect in retarding the process producing the stale attribute. This might be anticipated due to the autoxidative nature of the oxidation process. This slow rate of oxidation may progress to the detectable level of the painty attribute under extended storage conditions (Figure 5) as observed in the 1993 data, in which the painty intensity reached 2, the threshold level after 7 months. In the 1992 data, painty intensity does not reach the barely detectable level because of the limited storage time. The 1995 data suggest that the progression of the autoxidative pro-

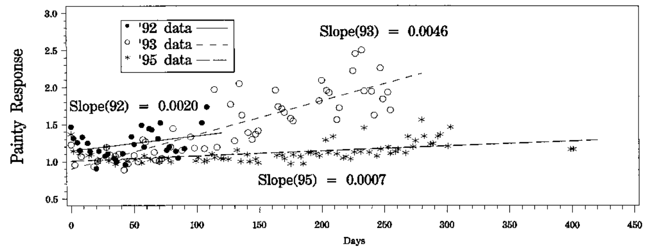

Figure 5. Painty sensory attribute response versus days from first sensory analysis.

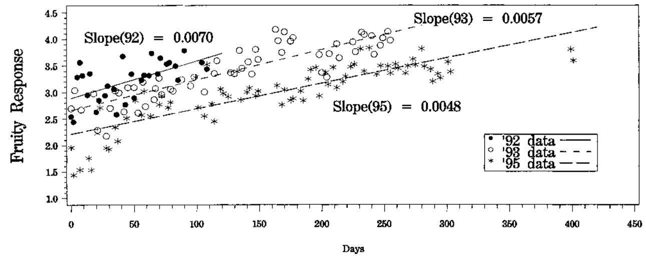

Figure 6. Fruity sensory attribute response versus days from first sensory analysis.

cesses which produce the more intense painty attribute are retarded by the −23 °C storage temperature in contrast to the stale attribute. However, further comparison of the 1993 and 1995 stale and painty plots could suggest that the lower initial intensity of the stale attribute in 1995 produced a longer time frame to reach the 3 intensity level, at which the 1993 data suggest that the painty attribute became perceptible in relation to stale. The possible impact these changes have on other attributes will be discussed later.

The fruity attribute in roasted peanut paste arises from abusive environmental and handling exposures during fruit development, harvesting, and curing. Background information on the fruity attribute can be found in Sanders et al. (1995). A plot of this important off-flavor attribute (Figure 6) shows that it also increases over low-temperature storage time. This has not been previously documented. The normal intensity range of fruity is 2−3. All three years' data are initially in this range, with 1992 tending to be higher than 1993 and 1995. Comparison of the slopes (0.0070, 0.0057, and 0.0048) indicates approximately the same rate change occurring over all years. The causes of this increase are not known. Because the fruity attribute is caused by uncontrollable environmental influences and its presence has a significant negative effect on the roasted peanut attribute intensity, it is a standard practice to include a covariate adjustment for fruity attribute in all statistical analyses on peanut sensory data (Pattee and Giesbrecht, 1994). This standard covariate adjustment permits observation of the experimental design effects free of the confounding influence of the fruity attribute and roast color variation.

To determine if a linear relationship exists between stale and fruity, stale with fruity as a covariate and fruity with stale as a covariate were examined (Figures 7 and 8). In neither case was a covariate effect observed, thus suggesting that the changes in these two sensory attribute over time may be independent processes. This observation permits the separation of their effects on roasted peanut attribute into independent factors, which will be done in the roasted peanut attribute section.

Table 1 summarizes the results of a statistical examination of possible interactive effects between changes

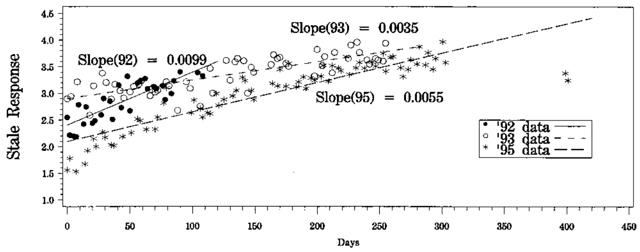

Figure 7. Stale sensory attribute adjusted for fruity versus days from first sensory analysis.

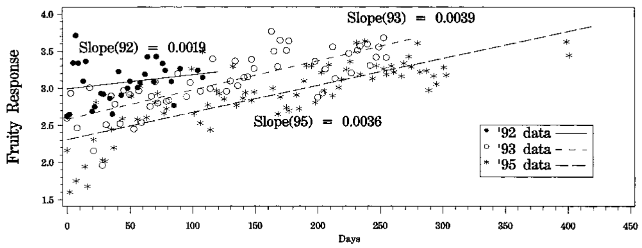

Figure 8. Fruity sensory attribute adjusted for stale versus days from first sensory analysis.

over time in the sensory attributes sweet, bitter, and tongue burn, and the attributes roast color, fruity, stale, and fruity plus stale. There appear to be no significant interactive effects between any of the above variables.

The sensory attribute roasted peanut is the attribute that provides added economic value to roasted peanut products. In studies to understand the importance of genetic factors on roasted peanut enhancement, roast color was observed to be a significant covariate factor (Pattee et al., 1991; Pattee and Giesbrecht, 1994). This interaction results from the simultaneous effects of the roasting process on both color and flavor generation and is discussed in detail by Sanders et al. (1995). However, when roast color was used as a covariate on roasted peanut in this study, no significant effects were observed (Table 1). Thus, any changes in roasted peanut intensity over time were not related to variations in roast color.

The components responsible for the sensory attribute roasted peanut are highly labile; thus, it is not unexpected to observe some decline in this attribute with low-temperature storage time (Figure 9). Comparison of the slopes from the three years shows that 1992 had a reduction rate 2.4 times that of 1993 and that 1995 was 2.4 times less than 1993. It can be observed that there is a close agreement between the rate of change observed in the stale attribute for 1992 and 1993 and that for roasted peanut. This might be taken as evidence for a cause and effect relationship between the two attributes. However, in 1995, with a −23 °C storage condition, there is no relationship between increase in stale intensity and roasted peanut decline. This relationship further supports the suggestion that the lower storage temperature stabilizes the roasted peanut attribute lability. By comparing the plots of roasted peanut (Figure 9) and roasted peanut adjusted for stale (Figure 10), that part of the slope decrease in roasted peanut attribute caused by staling can be calculated [(1992) −0.0090 to −0.0043 = −0.0047; (1993) −0.0038 to −0.0020 = −0.0018; (1995) −0.0016 to −0.0009 = −0.0007]. Note, these slope values are the estimates of the average daily changes in values for roasted peanut attribute. Similarly, by comparing the plots of the roasted peanut (Figure 9) and roasted peanut adjusted for fruity (Figure 11), that part of the decreasing slope

Table 1. Effect of Roast Color, Fruity, Stale, and Stale plus Fruity as Covariates on Time Trends of Selected Sensory Attributes

sensory attribute	covariate	slope	95% confidence interval[a]
sweet	roast color[b]		
	1992	0.0004	(−0.0012, +0.0019)
	1993	0.0007	(+0.0003, +0.0011)
	1995	0.0021	(+0.0018, +0.0025)
	fruity		
	1992	0.0012	(−0.0004, +0.0027)
	1993	0.0010	(+0.0005, +0.0014)
	1995	0.0010	(+0.0006, +0.0015)
	stale		
	1992	0.0023	(+0.0007, +0.0039)
	1993	0.0013	(+0.0009, +0.0018)
	1995	0.0024	(+0.0019, +0.0029)
	stale + fruity		
	1992	0.0024	(+0.0008, +0.0039)
	1993	0.0014	(+0.0009, +0.0018)
	1995	0.0017	(+0.0012, +0.0021)
bitter	roast color[b]		
	1992	0.0007	(−0.0012, +0.0026)
	1993	0.0026	(+0.0020, +0.0031)
	1995	0.0033	(+0.0028, +0.0039)
	fruity		
	1992	−0.0003	(−0.0022, +0.0016)
	1993	0.0017	(+0.0011, +0.0023)
	1995	0.0022	(+0.0016, +0.0028)
	stale		
	1992	−0.0004	(−0.0023, +0.0016)
	1993	0.0018	(+0.0012, +0.0024)
	1995	0.0011	(+0.0005, +0.0017)
	stale + fruity		
	1992	−0.0005	(−0.0025, +0.0014)
	1993	0.0012	(+0.0006, +0.0018)
	1995	0.0004	(−0.0002, +0.0011)
tongue burn	roast color[b]		
	1992	−0.0008	(−0.0024, +0.0008)
	1993	0.0026	(+0.0022, +0.0031)
	1995	0.0029	(+0.0024, +0.0034)
	fruity		
	1992	−0.0015	(−0.0031, 0.0000)
	1993	0.0019	(+0.0014, +0.0024)
	1995	0.0015	(+0.0010, +0.0020)
	stale		
	1992	−0.0022	(−0.0038, −0.0006)
	1993	0.0020	(+0.0015, +0.0025)
	1995	0.0007	(+0.0001, +0.0013)
	stale + fruity		
	1992	−0.0022	(−0.0039, −0.0006)
	1993	0.0016	(+0.0011, +0.0021)
	1995	−0.0001	(−0.0007, +0.0005)
roasted peanut	roast color[b]		
	1992	−0.0096	(−0.0115, −0.0077)
	1993	−0.0038	(−0.0043, −0.0033)
	1995	−0.0017	(−0.0021, −0.0014)

[a] If the confidence interval includes zero, then we conclude that there is no evidence that the slope differs from zero. [b] The roast color attribute was used as a linear and quadratic covariate. Fruity and stale were used as linear covariates.

value for roasted peanut attribute caused by the fruity attribute can be calculated [(1992) −0.0090 to −0.0073 = −0.0017; (1993) −0.0038 to −0.0024 = −0.0014; (1995) −0.0016 to −0.0014 = −0.0002]. When the roasted peanut is adjusted for both stale and fruity attributes (Figure 12), a remaining negative slope [slope (1992) −0.0040; slope (1993) −0.0013; slope (1995) −0.0008] in roasted peanut can be observed. We suggest that this remaining negative slope can be attributed to the lability of the roasted peanut components. This is the first time that these three components have been separated as independent factors and observed as independent components affecting the intensity of roasted

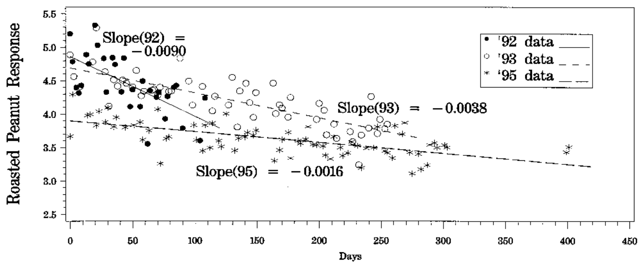

Figure 9. Roasted peanut sensory attribute response versus days from first sensory analysis.

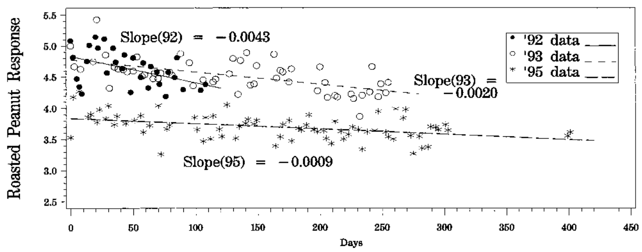

Figure 10. Roasted peanut sensory attribute adjusted for stale versus days from first sensory analysis.

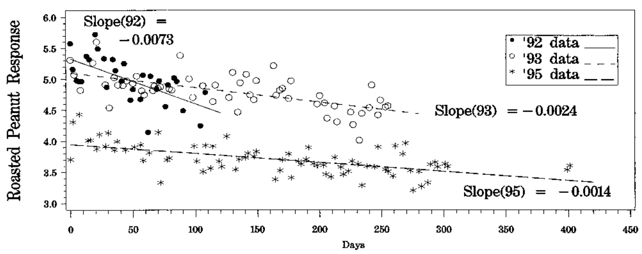

Figure 11. Roasted peanut sensory attribute adjusted for fruity versus days from first sensory analysis.

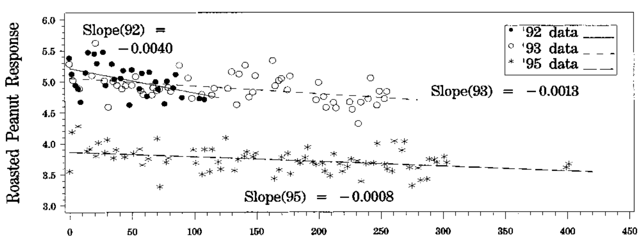

Figure 12. Roasted peanut sensory attribute adjusted for fruity and stale versus days from first sensory analysis.

peanut attribute in peanut paste. The capability of separating these three components will enable researchers to design experiments in which these flavor loss processes can be independently studied and methods found by which they can be controlled and the original intensity of roasted peanut attribute maintained, thus enhancing the economic value of peanut products.

SUMMARY AND CONCLUSIONS

The sensory attribute sweet was shown to be stable over storage periods of up to 13 months, whereas the attributes bitter and tongue burn were shown to increase slightly over observed storage time. The attribute stale showed an increase over time, indicating that oxidation of the lipid components was taking place even under −23 °C storage conditions. The painty attribute intensity is related to stale and did not begin to increase until stale had reached an intensity >3. The observed increase in fruity attribute over time was unexpected, and the reasons for its increase are not known. With the increase in both the fruity and stale attributes, a decrease in the intensity of the roasted peanut attribute over time could be anticipated. However, storage at −23 °C seems to stabilize the roasted peanut lability. We have shown, for the first time, fruity, stale, and lability of roasted peanut attribute to be three separate and independent functions.

Additionally, the above observations bring forth two major points:

1. Storage at −10 or −23 °C over extended time periods does not prevent oxidative changes from occurring in roasted peanut paste samples.

2. In extended sensory panel studies it is imperative that appropriate incomplete block statistical sampling and testing designs be used.

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