Predicting Consumer Acceptance Ratings of Cracker-coated and Roasted Peanuts from Descriptive Analysis and Hexanal Measurements

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ABSTRACT: A consumer test, descriptive analysis, and hexanal measurements were performed in cracker-coated peanuts (CCP) and roasted peanuts (RP) to determine the cut-off point for acceptability of stored CCP and RP. Regression analysis showed that roasted peanutty, oxidized and painty flavors and hexanal content were good predictors ($R^2 \geq 0.70$) of overall acceptance and flavor ratings. A hexanal content higher than 5.39 μg/g in CCP and 7.40 μg/g in RP, and/or an oxidized flavor intensity higher than 27.4 in CCP and 36.2 in RP is expected to have a product unacceptable to consumers (overall acceptance of 5 or lower). These values can likewise be used to determine the endpoint of shelf life of the products.

Keywords: peanut, consumer test, descriptive analysis, hexanal, storage, shelf life

Introduction

PEANUTS CONTAIN ABOUT 50 TO 55% OIL and 25 to 28% protein. Approximately 30% of the oil is linoleic acid, which is responsible for development of off-flavors via lipid oxidation reactions (St. Angelo 1996). These reactions lead indirectly to the formation of numerous aliphatic aldehydes, ketones, and alcohols. One of the most important components in these reactions is hexanal (Bett and Boylston 1992).

The lipid oxidation reactions occur during storage and affect overall flavor quality and the shelf life of the peanut products. Storage time and temperature are the main factors, which affect food quality. Other factors are light and exposure to oxygen. In order to predict the extent of shelf life, and to be able to put an endpoint date on a product, knowledge of the rate of deterioration is necessary (Labuza and Schmidl 1985; Yang 1998). Criteria used to determine a product's shelf life include consumer acceptability, sensory discrimination, and/or specific product attribute measurements (Labuza 1982).

Roasted peanuts possess a unique and widely enjoyed flavor. Roasted peanut flavor is composed of a complex blend of heterocyclic compounds such as alkylpyrazines (St. Angelo 1996). Bett and Boylston (1992) reported that the roasted peanutty flavor intensity and alkylpyrazines decreased during storage. The flavor intensities of lipid oxidation descriptors such as painty and cardboard increased during storage. Lipid oxidation products, such as hexanal and other aldehydes, also increased. Buckholz and Daun (1981) correlated volatile components with hedonic ratings of overall acceptance. They found that the peak identified as pentanal had a negative correlation with flavor preference whereas the peak identified as 2-ethyl-6-methylpyrazine correlated positively with flavor preference.

Consumer perception is an important aspect that needs to be included in the definition of quality of a food product (Munoz and others 1992). Rancidity, the development of off-flavor due to lipid oxidation reactions, makes a food unacceptable to consumers (Labuza 1982; St. Angelo 1996). Oxidized flavor intensity, which is related to degree of product rancidity, was analyzed by descriptive analysis in roasted peanut (Plemmons and Resurreccion 1998), stored peanut pastes (Muego-Gnanasekharan and Resurreccion 1992), and peanut butter with vegetable oils (Gills and Resurreccion 2000). Oxidized flavor intensity as measured through descriptive panels and hexanal content analyzed by gas chromatography could be useful variables for predicting consumer response in stored peanut products.

The objective of this work was to determine the relations between consumer acceptance, descriptive analysis and hexanal measurements in roasted and cracker-coated peanuts to find out the end point of consumer acceptance corresponding to hexanal measurements and sensory descriptive analysis ratings. Specific objectives were to: (1) assess consumer acceptance of peanut samples using a consumer panel, (2) determine intensity of sensory attributes of peanut samples using a descriptive analysis panel, and (3) measure hexanal contents of peanut samples using gas chromatography.

Materials and Methods

Experimental design

Cracker-coated peanuts (CCP) and roasted peanuts (RP) were the samples for this study. The samples were packaged in 12 x 18 inch polyethylene bags (National Bags, Inc., Hudson, Ohio, U.S.A.) using a heat sealer (Model AG500, Multivac, West Germany). The samples were stored in an oven (AMICO, American Instrument Co., Silver Spring, Md., U.S.A.) at 40 °C under accelerated storage condition (Labuza and Schmidl 1985) for varying storage periods up to 110 d to obtain a wide range of difference in peanut flavor. Consumer acceptance tests, descriptive analysis and hexanal measurement were performed in CCP and RP samples. Samples were removed from the oven and were stored in a freezer at –70 °C until all samples for consumer and descriptive tests were collected. Consumer and descriptive tests were performed simultaneously for a period of 4 consecutive days within one week. The samples for hexanal measurements were analyzed on the same day that they were pulled out from the oven. The sampling days were 0, 10, 19, 25, 35, 66, and 110 for consumer tests. In addition, samples were drawn after 13, 16, 22, and 28 d for descriptive sensory tests and hexanal measurements, and after 7, 31, 42, 48, and 81 d for hexanal measurements. The experiment was replicated 3 times.

Sample preparation

Shelled, medium size Florunner peanuts (1999 crop) were obtained from Golden Peanut Co. (Ashburn, Ga., U.S.A.). Before processing, peanuts were inspected; damaged and bruised kernels were manually removed. Cracker-coated peanuts were prepared following the procedure developed by Walker (2000). Roasted peanuts were prepared by hand sorting to remove any damaged or bruised kernels. After sorting, the raw kernels were heated in 4 kg batches to 101 °C for 2.5 min in a rotary gas roaster (Model L5, Probat Inc., Memphis, Tenn., U.S.A.) at 204 °C to loosen and crack the skins (Plemmons and Resurreccion 1998). Peanuts were then blanched using a dry peanut blancher (Model EX, Ashton Food Machinery Co., Inc., Newark, N.J., U.S.A.). Kernels were passed through the blancher 3 times. Blanched peanuts were roasted in 454 g batches at 138 °C in the electric rotisserie oven. Peanuts were heated to a medium roast or an average Hunter color Lightness (L) value of 50 ± 1.0 (Johnsen and others 1988). During roasting, as peanuts reached their roasting endpoint, a sample was obtained every 5 min and measured for color lightness until the kernels reached their color specification (Plemmons and Resurreccion 1998).

Sensory methods

Consumer analysis panel. Panelists (n = 51) were from Griffin (Ga., U.S.A.) and surroundings were recruited by phone using the following criteria: ages between 18 to 65, non-smokers, no food allergies, eat roasted peanuts and/or products at least twice per week, available for all session, and good dentition. Among the participants a total of 9 panelists were non-food science staff and students from the Georgia Experiment Station in Griffin, Ga., U.S.A. who were screened and qualified for the test.

Sample evaluation. Five grams of the peanut samples were placed into 28.4 g plastic cups with lids (Dixie, James River Corp., Norwalk, Conn., U.S.A.), coded with 3 digit random numbers. Samples consisting of 21 CCP and 21 RP samples (7 periods of time and 3 replications of each one) were prepared for each panelist. Samples were presented to panelists in balanced, random, monadic order during the 4 test days. On the 1st and 2nd day CCP samples were evaluated, and on the 3rd and 4th day RP samples were evaluated. Ten or 11 samples were served each day with a 5 min compulsory break after the 1st 5 samples. Samples were presented with water, spit cup for expectoration, and paper ballots on a stainless steel tray. Each consumer evaluated the samples in individual booths under fluorescent light (illuminated with two 50-watt indoor reflector lamps, which provided 738 lux of light) at room temperature. Panelists were instructed to consume the whole sample, rinse their mouths with water between samples to minimize any residual effect, and were informed they could expectorate if they so desired. A 9-point hedonic scale ranging from 1 = dislike extremely to 9 = like extremely (Peryam and Pilgrim 1957) was used to evaluate overall acceptance and flavor from the CCP and RP samples.

Descriptive analysis. A total of 11 panelists, 9 female and 2 male, were recruited for this study. Panelists were selected on the following criteria: ages between 18 to 65, non-smokers, no peanut allergies, eat roasted peanuts and/or products at least once per mo, available for all sessions, interest in participating, able to verbally communicate about the product, and good dentition (Plemmons and Resurreccion 1998). Prior to the training sessions 7 of the panelists had previous experience on descriptive sensory analysis of storage cracker coated peanut and peanut products (Walker 2000) and the remaining 4 participants had experience on descriptive sensory analysis of peanuts in caramel. Potential panelists had to have a perfect score in a taste sensitivity test and the ability to identify 5 of 7 commonly found food flavors before they qualified as panelists.

Training. All 11 panelists were trained and calibrated for 4 d. Each training session lasted 2 h each day for a total of 8 h. Descriptive analysis test procedures as described by Meilgaard and others (1991) were used to train the panelists. Panelists evaluated samples using a "hybrid" descriptive analysis method (Resurreccion 1998) consisting of the Quantitative Descriptive Analysis (Tragon Corp., Redwood City, Calif., U.S.A.) and the Spectrum™ Analysis Methods (Sensory Spectrum, Inc., Chatham, N.J., U.S.A.) methods.

On the 1st day of training, panelists were given a review of concepts of sensory analysis. Then, they were asked to taste standard solutions of sucrose, sodium chloride, citric acid, and caffeine at varying concentrations and intensities that corresponded to points on a 150 mm unstructured line scale (Plemmons and Resurreccion 1998). After that, all 11 panelists worked together to develop the language to describe perceivable product attributes in cracker-coated peanuts and roasted peanuts. Fresh and rancid samples of CCP and RP were presented to each panelist. Panelists identified appearance, aromatics, tastes, feeling factors, and texture attributes that would be used to describe the product samples. A lexicon for peanut samples (Johnsen and others 1988) was used to provide an initial list of attributes. Panelists decided whether terms were redundant and should be removed or if additional terms should be included in the list of attributes and defined each attribute (Table 1). Panelists also identified references to be used to rate each appearance, flavor, feeling factor, and textural attribute. Each panelist gave an intensity rating of each reference between 0 and 150 for each attribute on Table 2. The mean intensity rating was calculated and used as the attribute intensity rating for that particular reference.

On the 2nd day of training, panelists reviewed descriptors, definitions, and reference standards to describe CCP and RP samples. Panelists tasted each reference and provided a rating for each one. The panel was calibrated by obtaining an average panel rating and panelists not rating within ± 10 points of the mean rating were asked to re-evaluate the sample and adjust their rating until a consensus was reached. Panelists are calibrated if the standard deviation of their scores were within 10 points from the mean attribute rating. After that, medium roasted peanuts were presented as a warm-up sample to be used for each panelist as the initial sample during training and testing sessions (Plemmons and Resurreccion 1998).

On the 3rd day of training, panelists finalized the definitions, descriptors, and reference standard intensities to describe CCP and RP. Then, the lists of the warm-up and reference intensity ratings and definitions were finalized. After that, panelists evaluated the attributes of 4 CCP samples with different degrees of oxidized flavor using computerized ballots (Compusense 5, Version 4.2 Compusense, Inc., Guelph, Ontario, Canada) in order to calibrate themselves. On the last day of training, panelists continued evaluating warm-up, CCP and RP samples using the computer to calibrate themselves within ± 10 points of the mean rating for each attribute of the samples.

Sample evaluation. All samples were evaluated in the partitioned booths described previously for the consumer test. Panelists evaluated 10 to 11 samples per d plus a warm-up sample on the test day. 10 g of the peanut samples were placed into 28.4 g plastic cups with lids (Dixie, James River Corp., Norwalk, Conn., U.S.A.) coded with 3 digit random numbers. In order to calibrate panelist evaluations, the final lists of the warm-up and reference intensity ratings and definitions were posted in each booth for all training and test sessions. References and warm up samples were provided for all panelists for all training and test sessions (Plemmons and Resurreccion 1998). Samples were tested using a complete randomized block design using computerized ballots (Compusense, 1998). A randomized block was necessary so that all panelists evaluated all treatment combinations (Lawless and Heymann 1998).

Table 1—Definitions of attributes used by the trained panel to describe cracker coated and roasted peanuts.

Attribute[a]	Definition
Appearance	
Brown Color	The intensity or strength of brown color from light to dark brown.
Roughness	The appearance associated with uneven surface. The overall presence of gritty, grainy, or lumpy particles; lack of smoothness.
Powdery	The appearance associated with uncooked flour on the surface.
Even color	The appearance associated with even color on the surface.
Aromatics	
Roasted Peanutty	The aromatic associated with medium roasted peanuts.
Raw/Beany	The aromatic associated with uncooked or raw peanuts.
Burnt	The aromatic associated with over roasted peanuts.
Woody/Hulls/Skins	The aromatic associated with hulls or skins of roasted peanut.
Earthy	The aromatic associated with wet soil.
Oxidized	The aromatic associated with rancid fats and oils.
Painty	The aromatic associated with linseed oil.
Cardboard	The aromatic associated with wet cardboard.
Flour	The aromatic associated with cooked flour.
Tastes	
Sweet	Taste on the tongue associated with sucrose solutions.
Salty	Taste on the tongue associated with sodium chloride solutions.
Sour	Taste on the tongue associated with acid agents such as citric acid.
Bitter	Taste on the tongue associated with bitter solutions such as caffeine.
Feeling factors	
Astringent	The puckering or drying sensation on the mouth or tongue surface.
Tongue sting	Tingling or burning sensation on the tongue.
Texture	
Hardness	Force needed to compress a food between molar teeth.
Crispness	Force needed and amount of sound (high pitch) generated from chewing a sample with front teeth.
Crunchiness	Force needed and amount of sound (lower pitch) generated from chewing a sample with molar teeth.
Fracturability	Force with which the samples break.
Toothpack	The amount of sample left in or on teeth after chewing.

[a]Attribute listed in order as perceived by panelists

Hexanal analysis

A gas chromatograph (GC) (Varian Star 3400 CX, Sugar Land, Tex., U.S.A.) equipped with Hewlett Packard Ultra 2 (5% Phenyl methylsiloxane) capillary column (length 50 m, dia 320 μm, 0.52 μm film) was used. Helium carrier gas (linear flow velocity 20 cm/sec) was used for analysis of hexanal. The following temperature program was used: initial temperature at 40 °C, rate at 20 °C/min, and final temperature at 250 °C. Injector and detector temperatures were 200 and 275 °C, respectively. The flame ionization detector was used to detect the peaks. Head space volatiles were absorbed by a fiber of Solid Phase Micro Extractor (SPME), 100 μm Polydimethylsiloxane, coated fiber RED (Supelco, Bellefonte, Pa., U.S.A.) (Brunton and others 2000). The fiber was injected into a 5 mL Kimax cylindrical screw-cap vial sealed with a Teflon lined rubber septum (pre-hole) that contained 1g of the ground sample. The sample was spiked with 50 μL of a 0.03 μg/mL solution of 4-heptanone (SIGMA, St. Louis, Mo., U.S.A.) in fresh canola oil (Nifda, Inc., Atlanta, Ga., U.S.A.). Then, the vial was heated at 70 °C for 30 min in a heater (Thermolyne, SYBRON, type 16500 dri-bath, Dubuque, Iowa, U.S.A.). After that, the fiber was removed from the vial and placed into the injector for 5 min for desorption of the volatile components. Hexanal was identified by comparison to retention time of hexanal standard. The 4-heptanone was used as internal standard to calculate the amount of hexanal in the sample using the formula:

$$\mu g \text{ of hexanal} = (1.23\ \mu g \text{ of 4-heptanone} \times \text{hexanal peak area}) / (\text{heptanone peak area})$$

Statistical analysis

The data were analyzed using the Statistical Analysis System (SAS Version 6.12, 1994) software. Means and standard deviations of consumer responses, descriptive analysis attributes ratings and hexanal measurements were calculated. Analysis of variance was used to detect significant differences in consumer responses, sensory attribute ratings, and hexanal measurements between storage day. Pearson correlation coefficients were calculated between all variables.

Regression analyses were used to predict consumer responses using sensory attribute intensity ratings and hexanal measurements (SAS 1985). A second order polynomial regression model was used. The terms in the model are as follows:

$$Y = b_o + b_1X + b_{11}X^2$$

where Y is the value of consumer response; b_o is the intercept when Y = 0; b_1, and b_{11} are parameter estimates; X is the sensory attribute rating from descriptive analysis or hexanal content. Dependent variables, which could be explained by the model using the criterion of an adjusted $R^2 \geq 0.70$, were used to predict consumer responses in CCP and RP.

Results and Discussion

Consumer test

The hedonic scale means of consumer acceptance test for cracker coated and roasted peanuts for overall acceptance and flavor are presented in Table 3. In cracker-coated peanuts, samples at day 0 had the highest rating for overall acceptance and flavor. Means for overall acceptance and flavor were significantly ($\alpha = 0.05$) lower at day 10 through 35 from the rating at day 0. The mean ratings for overall acceptance and flavor decreased further at 66 d and were lowest at 110 d of storage. After 66 d, the mean ratings of overall acceptance and flavor were below 5 (neither like nor dislike) on the hedonic scale. The lowest mean ratings were 3.44 and 3.52 for acceptance of flavor of RP and CCP, respectively, at day 110 of storage time.

During storage, increased oxidized flavor and decreased roasted peanutty flavor were reported in roasted peanuts (Bett and Boyslton 1992), ground roasted peanuts (Warner and others 1996), and peanut paste (Muego-Gnanasekharan and Resurreccion 1992). The decrease of overall acceptance and flavor in CCP and RP is probably related to the increase of oxidized flavor intensity and the decrease of roasted peanutty flavor intensity.

Descriptive analysis

The mean values for the sensory attribute ratings from the descriptive analysis are presented in Table 4 for cracker-coated peanuts and in Table 5 for roasted peanuts. The attributes with intensity ratings that changed significantly ($\alpha = 0.05$) between day 0 and day 110 were roasted peanutty, oxidized, painty, cardboard, sour, bitter, astringent and tongue sting in CCP, and roasted peanutty, woody/hulls/skins, earthy, oxidized, painty, cardboard, sour, bitter, astringent and tongue sting in RP.

In cracker-coated peanuts (Table 4), the intensity of oxidized flavor increased from 12 on day 0 to 35 on day 66 and increased to 49 on day 110. Painty, cardboard, sour, bitter, astringent and tongue sting intensities also increased significantly ($\alpha = 0.05$) during storage. On the other hand, roasted peanutty decreased significantly from 63 on day 0 to 52 on day 110. In roasted peanuts (Table 5), the intensity of oxidized flavor increased from 12 on day 0 to 61 on day 110. Woody/hulls/skins, earthy, painty, cardboard, sour, bitter, astringent and tongue sting intensities also increased during storage. The intensity of roasted peanutty flavor decreased from 67 on day 0 to 46 on day 110 in RP.

Bett and Boyslton (1992) found that roasted peanutty flavor intensity and alkylpyrazines decreased in roasted peanuts stored at 37 °C. Roasted peanutty flavor can be attributed to the presence of pyrazines (Buckholz and Daun 1981; Crippen and others 1992). Warner and others (1996) and Brannan and others (1999) also found that roasted peanutty flavor de-

Table 2—Standard reference intensity ratings used in descriptive tests for cracker coated and roasted peanuts

Attribute	Reference Standards	Intensity[a]
Appearance		
Brown Color	Cardboard (lightness value, L = 47 ± 1.0)	37
Roughness	Burnt peanuts (Silver Peak, City of Commerce, Calif., U.S.A.)	150
Powdery	Baked dough balls[b]	60
Even color	Florunner Peanut blanched 50%	75
Aromatics		
Roasted Peanutty	Dry roasted peanuts (Planter's, Nabisco, East Hanover, NJ)	75
Raw/Beany	Raw medium Florunner Peanuts	50
Burnt	Dark roasted peanuts (lightness value, L = 36 ± 1.0)	70
Woody/Hulls/Skins	Peanut skins	35
Earthy	Wet soil	55
Oxidized	Rancid peanut	83
Painty	Boiled Linseed Oil (Klean Strip, W.M. Barr & Co., Inc., Memphis, Tenn., U.S.A.)	97
Cardboard	Moist cardboard	50
Flour	Tortillas (Kroger, Cincinnati, Ohio, U.S.A.)	50
Tastes		
Sweet	2.0% sucrose solution	20
	5.0% sucrose solution	50
	10.0% sucrose solution	100
Salty	0.2% NaCl solution	25
	0.35% NaCl solution	50
	0.5% NaCl solution	85
Sour	0.05% citric acid solution	20
	0.08% citric acid solution	50
	0.15% citric acid solution	100
Bitter	0.05% caffeine solution	20
	0.08% caffeine solution	50
	0.15% caffeine solution	100
Feeling factors		
Astringent	Grape Juice (Welch's, Concord, Mass., U.S.A.)	65
Tongue sting	Big Red-Cinnamon Gum (Wrigley's, Chicago, Ill., U.S.A.)	57
Texture		
Hardness	Dry roasted peanuts (Planter's, Nabisco, East Hanover, N.J., U.S.A.)	95
Crispness	Lay's Potato Chips (Frito-Lay, Plano, Tex., U.S.A.)	75
Crunchiness	Original Corn Chips (Frito-Lay, Plano, Tex., U.S.A.)	75
Fracturability	Graham Cracker (Nabisco, East Hanover, N.J., U.S.A.)	42
	Melba Toast (Old London Foods, Bronx, N.Y., U.S.A.)	67
Tooth Pack	Graham Crackers (Nabisco, East Hanover, N.J., U.S.A.)	75

[a] Intensity ratings are based on 150 mm unstructured line scales.
[b] 150 g of flour and 15 g of water, mixed with a stainless steel fork in a plastic bowl, shaped into round balls, 2 cm, in dia and placed in stainless steel baking tray, baked for 10 min at 176 °C in electric oven (Model ARR624, Amana Refrigeration, Amana, Iowa, U.S.A.).

Table 3–Means and standard deviations of hedonic ratings for overall acceptance and flavor from the consumer test of cracker coated (CCP) and roasted peanut (RP) samples stored at 40 °C.

Storage time	Overall acceptance[a]		Flavor[a]	
(d)	CCP	RP	CCP	RP
0	6.12 ± 1.92[a]	6.37 ± 1.60[a]	6.23 ± 1.94[a]	6.44 ± 1.70[a]
10	5.59 ± 1.78[b]	5.97 ± 1.54[b]	5.68 ± 1.87[bc]	5.91 ± 1.60[b]
19	5.71 ± 1.69[b]	6.18 ± 1.44[ab]	5.79 ± 1.72[b]	6.16 ± 1.51[ab]
25	5.66 ± 1.77[b]	6.17 ± 1.32[ab]	5.61 ± 1.77[bc]	6.08 ± 1.45[ab]
35	5.45 ± 1.84[b]	5.89 ± 1.51[b]	5.33 ± 1.90[c]	5.81 ± 1.64[b]
66	4.72 ± 1.84[c]	5.36 ± 1.48[c]	4.56 ± 1.94[e]	5.21 ± 1.57[c]
110	3.90 ± 1.72[d]	3.71 ± 1.84[d]	3.52 ± 1.66[d]	3.44 ± 1.88[d]

[a]Means within the same column not followed by the same letter are significantly different ($\alpha = 0.05$) as determined by the Fisher's least significant difference (LSD) test.

Table 4–Means of sensory attribute ratings from cracker coated peanut samples stored at 40 °C.

Sensory	Storage time (d)[a]										
Attribute	0	10	13	16	19	22	25	28	35	66	110
Appearance											
Brown Color	27cd	31a	30ab	29abc	28abc	28ab	29abc	30abc	27cb	27bc	27c
Roughness	37a	45a	39a	38a	40a	40a	37a	39a	39a	41a	41a
Powdery	21a	23a	21a	23a	23a	23a	22a	22a	25a	24a	23a
Even Color	101a	101a	102a	96a	97a	101a	103a	98a	104a	101a	103a
Aromatics											
R. Peanutty[b]	63abc	65a	59bcd	61abcd	62abc	58bc	63ab	62abcd	61abcd	57d	52e
Raw/Beany	2ab	2ab	1b	4ab	2ab	5ab	2ab	3ab	4ab	5a	4ab
Burnt	23a	19ab	16ab	13ab	15ab	15ab	16ab	13ab	8b	12ab	14ab
Woody[b]	9a	9a	9a	9a	8a	9a	9a	9a	7a	11a	10a
Earthy	3a	4a	4a	4a	4a	5a	3a	3a	3a	5a	5a
Oxidized	12c	6c	7c	10c	11c	11c	10c	12c	9c	35b	49a
Painty	3c	4c	3c	5c	5c	5c	5c	4c	5c	10b	18a
Cardboard	7bc	6c	7bc	6c	8bc	7bc	6c	8bc	7bc	10b	14a
Flour	13a	14a	14a	14a	15a	12a	12a	13a	13a	13a	14a
Tastes											
Sweet	29a	25a	27a	26a	27a	27a	27a	22a	25a	26a	22a
Salty	4a	5a	4a	4a	5a	5a	4a	4a	4a	4a	4a
Sour	2a	2a	2a	1a	3ab	2a	2a	3ab	2a	2a	4b
Bitter	5bcd	5bcd	5bcd	5bcd	5bcd	6bc	3d	5bc	3d	7b	10a
Feeling factors											
Astringent	4d	4d	5bcd	5bcd	5bcd	7bc	5bcd	5bcd	5bcd	8b	11a
Tongue Sting	3c	3c	4bc	4bc	7ab	4bc	3c	3c	3c	7ab	8a
Texture											
Hardness	88a	87a	89a	84a	87a	88a	87a	86a	88a	84a	88a
Crunchiness	58a	56a	57a	56a	58a	56a	56a	56a	55a	54a	57a
Crispness	63a	62a	63a	58a	62a	61a	60a	60a	61a	58a	61a
Fracturability	50a	51a	50a	49a	49a	50a	51a	48a	51a	49a	51a
Tooth Pack	38a	39a	37a	36a	37a	33a	38a	37a	38a	37a	35a

[a]Means within the same row not followed by the same letter are significantly different ($\alpha = 0.05$) as determined by the Fisher's least significant difference (LSD) test.
[b]R. peanutty = roasted peanutty, Woody = woody/hulls/skins.

creased in ground roasted peanuts stored at 65 °C and defatted roasted peanuts stored at 25 and 63 °C, respectively. Bett and Boylston (1992) reported that painty and cardboard flavor intensities increased during storage of roasted peanuts. These flavors are related to lipid oxidation (St. Angelo 1996). Warner and others (1996) found that oxidized flavor increased in roasted peanuts stored at 65 °C. Muego-Gnanasekharan and Resurreccion (1992) also detected that oxidized and cardboard flavors increased in peanut paste stored at 30, 40, and 50 °C. The intensity changes of the attributes oxidized and painty observed in stored peanut products and the significant intensity changes ($\alpha = 0.05$) of these attributes detected in this work over time indicate that these attributes can be good predictors of flavor quality of peanut products. If the effect of these attributes is related to consumer acceptance test results, they can be used to estimate a consumer response in stored peanut products from a consumer acceptance standpoint.

Hexanal measurements

Mean hexanal contents for cracker coated and roasted peanuts are shown in Table 6. In CCP, the hexanal content mean increased from 1.26 μg/g on day 0 to 16.98 μg/g on day 110. These means were significantly different at $\alpha = 0.05$. The hexanal level increased slightly during the first 42 d. After that, the hexanal content showed a marked increase from day 42 to day 110. In RP, the hexanal content mean increased significantly ($\alpha = 0.05$) during

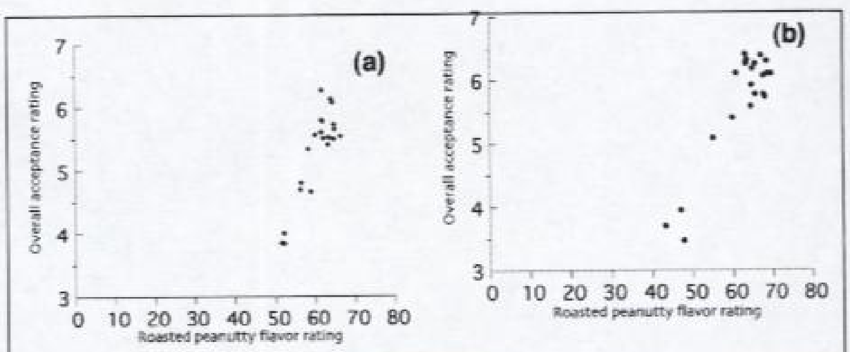

Figure 1–Mean ratings of overall acceptance from consumer tests versus roasted peanutty flavor from descriptive analysis. (a) Cracker-coated peanuts. (b) Roasted peanuts.

Table 5—Means of sensory attribute ratings from roasted peanut samples stored at 40 °C.

Sensory	Storage time (d)[a]											
Attribute	0	10	13	16	19	22	25	28	35	66	110	
Appearance												
Brown Color	29bc	30bc	28c	30bc	28c	30bc	29bc	30bc	32ab	32ab	34a	
Roughness	10a	8a	9a	10a	9a	11a	8a	9a	10a	10a	11a	
Powdery	3ab	3ab	2ab	2ab	5a	2ab	2ab	2ab	2ab	3ab	2ab	
Even Color	90a	97a	97a	96a	95a	94a	95a	101a	95a	93a	88a	
Aromatics												
R. Peanutty[b]	67a	65a	66a	67a	64ab	66a	67a	64ab	67a	60b	46c	
Raw/Beany	2b	8a	4ab	3b	6ab	3ab	2b	4ab	3ab	5ab	4ab	
Burnt	16a	5c	9abc	12abc	6c	11abc	8abc	6c	9abc	14ab	9abc	
Woody[b]	5bc	4c	5bc	6bc	4c	6bc	6bc	5c	5c	8ab	10a	
Earthy	3b	3b	4b	4b	3b	3b	3b	3b	3b	5b	9a	
Oxidized	12bc	6c	12bc	6c	5c	11c	6c	10c	9c	18b	61a	
Painty	4b	2b	4b	3b	3b	4b	3b	4b	5b	6b	18a	
Cardboard	7bc	6bc	6bc	5c	6bc	5c	5c	7bc	6bc	9b	15a	
Flour	2a	2a	4a	4a	2a	2a	3a	3a	3a	4a	3a	
Tastes												
Sweet	7ab	5ab	6ab	7ab	6ab	8a	8a	7ab	5ab	7ab	4b	
Salty	4a	4a	4a	4a	3a	4a	4a	4a	4a	4a	4a	
Sour	2b	2b	3b	2b	2b	3b	3b	3b	2b	4ab	6a	
Bitter	5bc	5bc	5bc	4bc	4bc	5bc	6bc	4c	5bc	8b	11a	
Feeling factors												
Astringent	5bc	3c	4c	4c	2c	4c	4c	3c	3c	7b	11a	
Tongue Sting	5b	2b	4b	4b	3b	3b	5b	3b	4b	5b	9a	
Texture												
Hardness		80a	82a	85a	85a	84a	84a	83a	83a	83a	83a	77a
Crunchiness	33ab	32ab	31ab	30ab	31ab	31ab	30ab	33a	32ab	31ab	29b	
Crispness	45a	47a	45a	45a	46a	46a	45a	48a	47a	46a	44a	
Fracturability	41a	42a	41a	41a	42a	41a	40a	42a	42a	41a	40a	
Tooth Pack	35a	35a	37a	34a	36a	36a	36a	35a	35a	35a	35a	

[a]Means within the same row not followed by the same letter are significantly different ($\alpha = 0.05$) as determined by the Fisher's least significant difference (LSD) test.
[b]R. peanutty = roasted peanutty, Woody = woody/hulls/skins.

storage from day 0 (1.65 μg/g) to day 110 (10.77 μg/g). Roasted peanut also showed a marked increased after day 42.

The polyunsaturated fatty acids of the lipid content in peanuts make them highly susceptible to lipid oxidation. These reactions produce hundreds of compounds, such as aldehydes, ketones, alcohols, acids, or hydrocarbons. Lipid oxidation in peanuts during storage increases the amount of hexanal, heptanal, octanal, 2-octenal, nonanal, decanal, 2-decenal, 2-hexenal-1-ol, 2-heptanone, 2-octanone, 3-octenone-2-one, 2-nonanone, and 2-pentylfuran (Bett and Boylston 1992; St. Angelo 1996). Warner and others (1996) reported that hexanal, heptanal, octanal and nonanal increased in ground roasted peanut stored at 65 °C indicating that off-flavor development in ground peanut during storage occurred, in part, as a result of production of low molecular weight aldehydes from lipid oxidation. The hexanal contents (Table 6) and oxidized flavor intensities (Table 4 and 5) were increasing during the storage time while the consumer acceptance (Table 3) was decreasing. If the effect of the hexanal content is related to consumer acceptance test results then hexanal contents can likewise be used to estimate a consumer response in stored peanut products from a consumer acceptance stand point.

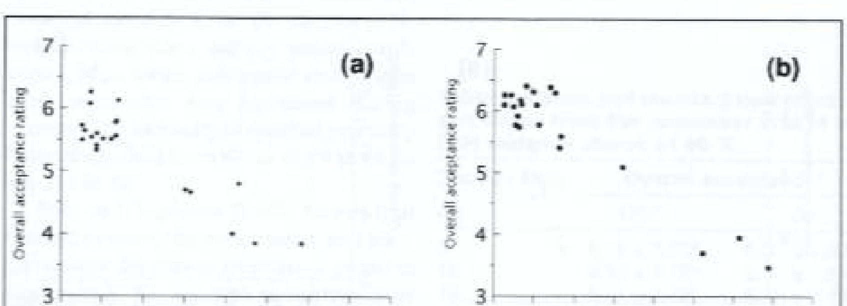

Figure 2—Mean ratings of overall acceptance from consumer tests versus oxidized flavor from descriptive analysis. (a) Cracker-coated peanuts. (b) Roasted peanuts.

Correlation analysis

The variables of interest in this study were overall acceptance, oxidized and roasted peanutty flavors, and hexanal content. The relation between overall acceptance and roasted peanutty, overall acceptance and oxidized flavor, and overall acceptance and hexanal content of CCP and RP are shown in Figure 1, 2 and

3. Similar results were found in the correlation between flavor acceptance and the variable mentioned above (data are not presented in this paper). A positive correlation of 0.90 in CCP (Figure 1a) and 0.95 in RP (Figure 1b) showed that overall acceptance decreased as roasted peanutty flavor intensity decreased. Buckholz and Daun (1981) found that 2-ethyl-6-methyl pyrazine, compound with roasted peanutty flavor, had a positive correlation with sensory preference.

A negative correlation of –0.91 in CCP (Figure 2a) and –0.95 in RP (Figure 2b) indicated that overall acceptance decreased when oxidized flavor intensity increased. Hexanal content had a similar effect on overall acceptance ratings. A negative correlation of –0.92 in CCP (Figure 3a) and –0.97 in RP (Figure 3b) showed that overall acceptance decreased when hexanal content increased. Buckholz and Daun (1981) reported that pentanal, another aldehyde related to lipid oxidation, had a negative correlation with sensory preference. The results consistently showed that overall acceptance rating between 3 to 5 on the 9 point hedonic scale corresponded with higher values of oxidized flavor intensity and hexanal content.

Table 6–Means and standard deviations of hexanal measurements from cracker coated (CCP) and roasted peanut (RP) samples stored at 40 °C.

Storage time	Hexanal content (mg/g)[a]	
days	CCP	RP
0	1.26 ± 0.21f	1.65 ± 0.47f
7	1.63 ± 0.60f	1.82 ± 0.33ef
10	1.65 ± 0.25f	2.55 ± 0.54ef
13	2.37 ± 0.64ef	2.71 ± 1.11edf
16	2.79 ± 1.38edf	2.37 ± 1.04ef
19	2.76 ± 0.58edf	2.37 ± 0.62ef
22	2.74 ± 0.44edf	2.72 ± 0.44edf
25	2.92 ± 0.35edf	2.20 ± 0.39ef
28	3.34 ± 0.80edf	2.39 ± 0.47ef
31	3.21 ± 0.57edf	2.85 ± 0.84edf
35	2.86 ± 0.65edf	2.06 ± 0.34ef
42	3.97 ± 1.66cde	3.06 ± 0.84de
48	4.62 ± 1.39cd	3.92 ± 0.82cd
66	6.01 ± 2.48bc	4.91 ± 1.17bc
81	7.88 ± 2.30b	6.09 ± 1.09b
110	16.98 ± 6.40a	10.77 ± 3.19a

[a]Means within the same column not followed by the same letter are significantly different ($\alpha = 0.05$) as determined by the Fisher's least significant difference (LSD) test.

Regression analysis

Descriptive analysis

The results of regression analysis (regression equations and adjusted R^2) from consumer test as the dependent variables, and from descriptive analysis and hexanal measurements as the independent variables are shown in Table 7. Only those equations with adjusted $R^2 \geq 0.70$ are presented. Overall acceptance could be predicted from roasted peanutty flavor ratings for CCP ($R^2 \geq 0.82$) and RP ($R^2 \geq 0.86$). Similarly overall acceptance could also be predicted from oxidized flavor ratings for CCP ($R^2 \geq 0.78$) and RP ($R^2 \geq 0.87$). Painty flavor ratings could be good predictors of overall acceptance in CCP ($R^2 \geq 0.81$) and RP ($R^2 \geq 0.77$). Astringent and cardboard could also be a good predictor of overall acceptance in CCP ($R^2 \geq 0.72$) and RP ($R^2 \geq 0.72$), respectively.

The prediction equations for flavor acceptance were similar to those of overall acceptance (Table 7). The remaining sensory attributes that had adjusted $R^2 < 0.70$ were not discussed.

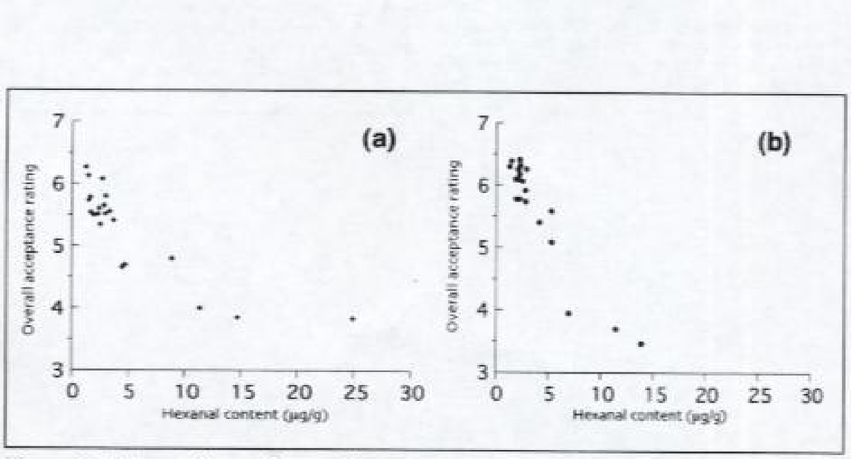

Figure 3–Mean ratings of overall acceptance from consumer tests versus hexanal content. (a) Cracker-coated peanuts. (b) Roasted peanuts.

Bett and Boylston (1992) detected that painty and cardboard flavor intensities had a linear increase across storage time in roasted peanuts while roasted peanutty flavor intensity decreased as storage time decreased. Muego-Gnanasekharan and Resureccion (1992) detected that oxidized and cardboard flavor intensities exhibited a linear increase during storage time in peanut paste. Warner and others (1996) observed that oxidized flavor intensity increased and roasted peanutty flavor decreased during storage time in ground-roasted peanuts, but a regression equation was not presented in their work. All sensory attributes that change in stored peanut products could be used to predict consumer responses if these sensory attributes are related to consumer tests using proper prediction equations like those presented in Table 7.

Hexanal measurements

The adjusted R^2 in the hexanal measurements were 0.83 in CCP and 0.90 in RP (Table 7) indicating that these equations can be used to predict overall acceptance in stored CCP and RP. The prediction equations for flavor acceptance were similar to those of overall acceptance. Hexanal has been identified as a product of linoleic acid oxidation. The content of this compound increased as function of storage time in roasted peanuts (Bett and Boyslton 1992; Braddock and others 1995). Warner and other (1996) indicated that hexanal content changed significantly across the time, but they did not report whether the increase of hexanal during storage time had a linear function.

Conclusions

Predictions of consumer responses

When a food sample has a value of 5 for overall acceptance on the 9 point hedonic scale, it means neither like nor dislike. If a sample food has a value of 4, it means dislike slightly. Therefore, values lower than 5 on a 9-point hedonic scale can be considered as a level to decide if a food is unacceptable for the consumer.

When the oxidized flavor rating of 27.4 and 36.2 is obtained for CCP and RP, respectively, the overall acceptance rating is predicted to be 5. This is the neither like nor dislike (= 5) point on the 9-point hedonic scale and is considered the end point of consumer acceptance of the products. Hexanal measurements of 5.39 μg/g and 5.54 μg/g for CCP and RP, respectively, will result in an overall acceptance rating of 5. These values can like-

Table 7—Significant regression equations ($R^2 \geq 0.70$) from independent variables in descriptive analysis and hexanal measurements for the prediction of overall and flavor acceptance ratings in cracker coated and roasted peanuts.

	Overall acceptance		Flavor acceptance	
Variable	Regression equation	R^2	Regression equation	R^2
Cracker-coated peanuts				
Descriptive analysis				
Roasted peanutty	$-39.06517 + 1.36899X - 0.01045X^2$	0.82	$-46.58504 + 1.59057X - 0.011207X^2$	0.83
Oxidized	$6.01418 - 0.03396X - 0.000114X^2$	0.78	$6.08934 - 0.04004X - 0.00015X^2$	0.77
Painty	$6.62007 - 0.23876X + 0.004945X^2$	0.81	$6.85691 - 0.29449X + 0.006187X^2$	0.82
Astringent	$6.37474 - 0.12687X^2 - 0.00701X^2$	0.72	$6.44656 - 0.12638X - 0.01018X^2$	0.84
Hexanal measurement				
Hexanal	$6.23867 - 0.26704X + 0.006898X^2$	0.83	$6.38293 - 0.32712X + 0.008497X^2$	0.84
Roasted peanuts				
Descriptive test				
Roasted peanutty	$-13.40518 + 0.55629X - 0.00396X^2$	0.86	$-16.69605 + 0.66143X - 0.00481X^2$	0.82
Oxidized	$6.26411 - 0.02664X - 0.00023X^2$	0.87	$6.18789 - 0.02278X - 0.000345X^2$	0.84
Painty	$6.23663 - 0.04538X - 0.00453X^2$	0.77	$6.14039 - 0.02853X - 0.00592X^2$	0.75
Cardboard	$6.41557 - 0.015896X - 0.0088X^2$	0.72	$6.2578 + 0.016915X - 0.011256X^2$	0.70
Hexanal measurement				
Hexanal	$6.9711 - 0.42178X + 0.011875X^2$	0.90	$7.03589 - 0.47278X + 0.013593X^2$	0.90

wise be used to determine the endpoint of consumer acceptance of the product. Similarly, the calculations for flavor acceptance can also be used to determine the endpoint of the product. This study provides the equations needed to define relations between the endpoint of consumer acceptance and flavor acceptance from descriptive analysis and hexanal measurements.

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