SENSORY PROFILES AND HEXANAL CONTENT OF CRACKER-COATED AND ROASTED PEANUTS STORED UNDER DIFFERENT TEMPERATURES

N.R. GROSSO[1], A.V.A. RESURRECCION[2,3], G.M. WALKER[2] and M.S. CHINNAN[2]

[1]*Department of Food Science*
University of Georgia – Griffin Campus
1109 Experiment Street, Griffin, GA 30223-1797

[2]*Becario de CONICET*
Facultad de Ciencias Agropecuarias (UNC)
CC509, 5000 Cordoba, Argentina

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ABSTRACT

Mean values of oxidized and cardboard flavor intensities and hexanal content increased significantly in cracker-coated peanut (CCP) and roasted peanut (RP) samples stored at 23, 30 and 40C, while intensity of roasted peanutty flavor decreased during storage. Prediction models for these sensory attributes from time and temperature variables were developed. Hexanal content could not be predicted from storage time and temperature of CCP and RP. Flushing RP with nitrogen had a protective effect against development of oxidized flavors, not observed in CCP. The coating of CCP contributed to the development of oxidized flavor. When oxidized flavor (= 36.2) was used as an indicator of storage deterioration, CCP had a predicted shelf life of 78, 56 and 32 days at 23, 30 and 40C, respectively, whereas in RP it was 116, 105 and 94 days, respectively. Sensory profiles predicted shelf life of RP and CCP better than hexanal content.

PRACTICAL APPLICATIONS

Roasted peanuts (RPs) are a popular food item consumed as snacks or food ingredients for confections, spreads and other food products. Development of cracker-coated peanuts (CCPs) will result in increased utilization of peanuts, a high-value crop in the U.S.A. New product introductions require

[3] Corresponding author. TEL: 770-412-4736; FAX: 770-412-4748; EMAIL: aresurr@uga.edu

shelf-life assessments. This study not only quantifies the sensory attribute profile and hexanal content of RPs and CCPs under various storage conditions of time and temperature, but also identifies critical measurements to track during storage studies to determine shelf life. The effect of using a nitrogen flush on sensory profiles and hexanal was likewise studied. Finally, the shelf life of RPs and CCPs under various temperature conditions was identified. This information is important to processors of RPs and CCPs.

INTRODUCTION

Roasted peanut flavor is composed of a complex blend of heterocyclic and other volatile compounds which are formed during roasting by thermal degradation reactions, including Maillard reactions between carbohydrate, free amino acid and protein. Lipid oxidation occurs during storage of peanut products and contributes to the development of undesirable flavors in these foods. The oxidation reactions lead indirectly to the formation of numerous aliphatic aldehydes, ketones and alcohols, which are expressed as cardboard or painty flavors (Bett and Boylston 1992). Peanuts contain approximately 50–55% oil with 30% of the oil being linoleic acid, which becomes susceptible to development of rancid and off-flavors through lipid oxidation (St. Angelo 1996). Lipid oxidation is associated with volatile components such as ethanol, pentane, pentanal and hexanal which are indicators of poor peanut quality (Brown *et al.* 1977; Crippen *et al.* 1992). Solid-phase microextraction fibers have been used to measure hexanal in food (Brunton *et al.* 2000; Steenson *et al.* 2002).

Descriptive analysis is one of the most useful tests for sensory profiling and uses trained panels to detect and rate the intensities of sensory attributes in a product (Chambers and Wolf 1996). Descriptive analysis has been used to describe attributes for various peanut products such as tortillas made with peanut and other flours (Holt *et al.* 1992), peanut paste (Muego-Gnanasekharan and Resurreccion 1992), coffee whitener from peanut milk (Abdullah *et al.* 1993), roasted defatted peanuts (Plemmons and Resurreccion 1998) and peanut butter treated with vegetable oils (Gills and Resurreccion 2000).

Roasted peanutty is a desirable flavor in peanuts and is composed of a complex blend of heterocyclic compounds such as pyrazines, thiazoles, thiophenes and other volatile compounds formed during roasting through the Maillard and other thermal degradation reactions between amino acids and sugars. In particular, this desirable flavor has been attributed to alkylpyrazines. This flavor could not be correlated with volatile components obtained by gas chromatographic methods (Crippen *et al.* 1992) but was correlated with pyrazines (Buckholz and Daun 1981; Baker *et al*. 2003). Bett and Boylston (1992) reported a significant reduction in roasted peanutty flavor for roasted peanuts with storage time.

Lipid oxidation during storage increases the amount of hexanal, heptanal, octanal, 2-octenal, nonanal, decanal, 2-decenal, 2-hexanal-1-ol, 2-heptanone, 2-octanone, 3-octenone-2-one, 2-nonanone and 2-pentylfuran (St. Angelo 1996). Hexanal was identified as a product of linoleic acid oxidation (Bett and Boylston 1992).

The expected shelf life of a product depends upon the potential environmental conditions of storage (Labuza and Schmidl 1985). One of the major environmental factors that result in decreased quality and nutrition for most food during storage is exposure to increased temperature. In order to predict the extent of food quality, and to be able to put a shelf-life date on a product, knowledge of the rate of deterioration as a function of storage condition, like temperature and time, is necessary (Labuza 1982). Pattee *et al*. (1982) mentioned that cold storage could increase the oxidative stability of raw and roasted peanuts over its storage period, thus reducing the rate of quality deterioration.

The overall objective of this work was to predict the effects of time and temperature on the sensory profiles and hexanal content of stored roasted and cracker-coated peanuts. Specific objectives were to (1) determine the intensity of sensory attributes of stored roasted and cracker-coated peanuts using a descriptive analysis panel, and (2) measure their degree of oxidation using hexanal analysis of headspace volatiles.

MATERIALS AND METHODS

Experimental Design

Two peanut samples, two packaging treatments and four storage temperatures were tested using a $2 \times 2 \times 4$ factorial experimental design. Cracker-coated (CCP) and roasted peanuts (RP) were used as the peanut samples. Nitrogen flush and no nitrogen flush were the two packaging treatments. Finally, the four storage temperatures were −19, 23, 30 and 40C. A total of 16 treatments were studied. The experiment was replicated twice.

Sample Preparation

RP Preparation. Shelled, medium, Florunner peanuts were purchased (1997 crop, Cargill Peanut Products, Dawson, GA). Before processing, the peanuts were manually inspected to remove damaged and bruised kernels. Sound raw kernels were heated in 4-kg batches to 101C for 2.5 min in a rotary gas roaster (Model L5, Probat Inc., Memphis, TN) preheated to 204C to loosen the skins (Plemmons and Resurreccion 1998). The peanuts were then blanched using a dry blancher (Model EX, Ashton Food Machinery Co. Inc., Newark, NJ). Kernels were passed through the blancher three times to remove all remaining testa. After blanching, the peanuts were roasted in 454-g batches at 138C in the electric rotisserie oven (Model 47 R20, General Electric, Ridgeport, CT). The peanuts were roasted to an average Hunter color lightness (*L*) value of 50 ± 1.0 (Johnsen *et al.* 1988). During roasting, a sample was obtained every 5 min and measured for color lightness until the kernels reached the determined roast end point and the roasting time was estimated to be 25 min. After that, all samples were processed using this roasting condition (Plemmons and Resurreccion 1998).

CCP Preparation. Batches of CCP were prepared following the procedure developed by Walker (2000). Each batch of CCP was started with 454 g of raw peanuts. A syrup solution was prepared which consisted of 55% water, 35% sucrose and 10% corn syrup solids. The sucrose and corn syrup solids were dispersed into water and the slurry was heated to 150C. The syrup slurry was cooled to ambient temperature at approximately 23C. A batch of raw peanuts was placed into a stainless steel pan coater (fabricated at the Department of Food Science & Technology, Griffin, GA) and rotated at 20 rpm. A 50:50% (w/w) mixture of starch and wheat flour was poured into the coating pan. Alternate layers of the syrup solution and starch/flour were added in a 1:1.4 (w/w) ratio until a coating of 42% was reached. Immediately after coating, the sample was roasted in an electric rotisserie oven (Model 47 R20, General Electric) at 165 ± 5C for 45 min. Once the CCP reached their roasting end point of Hunter *L* value of 72–73, they were removed from the roasting basket and cooled to room temperature.

Storage Conditions

The prepared samples were packaged either with or without a nitrogen flush (Model AG500, Multivac, Wolfertschwenden, West Germany) and placed into 6 × 10 in., high-density barrier bags made of 0.75 nylon and 2.25 polyethylene (KOCH Supplies Inc., Kansas City, MO). Samples were stored at −19 (control), 23 (ambient storage condition), 30 and 40C (accelerated storage condition) as recommended by Labuza and Schmidl (1985). Samples were stored in either the freezer (Brown, W. A. Brown & Son, Inc., Salisbury, NC) at −19C, or in ovens at 23C (mechanical convection oven Model 645, Precision Scientific, Winchester, VA), 30C (Isotemp Incubator Model 655D, Fisher Scientific, Pittsburgh, PA) or at 40C (AMICO, American Instrumental Co., Silver Spring, MD).

Sampling

Samples were removed from storage on designated days to perform sensory and hexanal evaluations. Generally, 12 to 20 samples per session were evaluated. [These sampling intervals were 0, 7, 14, 21, 28, 35, 42, 56, 70, 84, 98, 112, 126, 133, 140, 154, 168, 182, 196, 217 and 238 days which corresponded to 0, 23, 47, 70, 93, 117, 140, 187, 233, 280, 327, 373, 420, 443, 447, 513, 560, 607, 653, 723 and 793%, respectively, of the expected shelf life of the roasted peanuts.] The testing time for sample evaluations was based on the estimated 30-day shelf life of RPs stored without nitrogen (Clotfelter 1998).

Sensory Methods

Panel. A total of 11 panelists participated in this study. All panelists were selected using the following criteria: natural dentition, no food allergies, nonsmokers, between the ages of 18 and 64, consume RPs and/or products at least once per month, available for all sessions, interested in participating, and able to verbally communicate regarding the product (Plemmons and Resurreccion 1998). Seven of the panelists were previously trained on descriptive sensory analysis of peanut products (Walker 2000) and the remaining four participants had no descriptive sensory analysis experience prior to the training sessions.

Training. All 11 panelists, two males and nine females, were trained and calibrated according to Grosso and Resurreccion (2002) except that training was conducted for 6 days, 2 h each day for a total of 12 h. Descriptive analysis test procedures as described by Meilgaard *et al.* (1991) were used in training. Panelists evaluated samples using a "hybrid" descriptive analysis method (Resurreccion 1998) consisting of the Quantitative Descriptive Analysis (QDA, Targon Corp., Redwood City, CA) and the Spectrum (Sensory Spectrum, Inc., Chatham, NJ) methods.

Ballot. To develop a ballot, a list of attributes, in order of their appearance in the samples, was identified, and definitions and references for each term were determined by the panel (Table 1). Each panelist gave an intensity rating for each reference between 0 and 150 mm for each attribute, and the mean intensity rating was used as the attribute intensity rating for that reference (Table 1). The sweet, salty, sour and bitter intensity ratings were obtained from published values by Meilgaard *et al.* (1991). A computerized ballot (Compusense Five, Version 2.4, Compusense, Inc., Guelph, Ontario, Canada) was developed and used to evaluate all samples for all 21 attributes.

Sample Evaluation. All samples were evaluated in environmentally controlled partitioned booths illuminated with two 50-W indoor reflector

TABLE 1.
DEFINITIONS AND REFERENCE INTENSITY RATINGS USED IN A DESCRIPTIVE TEST FOR CRACKER-COATED AND ROASTED PEANUTS

Sensory attribute*	Definition	Reference	Intensity† (mm)	Brand/Type/Manufacturer
Appearance				
Brown color	The intensity or strength of brown color from light to dark brown	Cardboard	30	
Roughness	The appearance associated with uneven surface	Burnt peanuts	150	Silver Peak, City of Commerce, CA
Aromatics				
Roasted peanutty	The aromatic associated with medium roasted peanuts	Dry roasted peanuts	75	Planter's Nabisco, East Hanover, NJ
Raw beany	The aromatic associated with raw peanuts	Raw medium Florunner peanuts	30	
Burnt	The aromatic associated with dark roasted peanuts and having very brown or toasted character	Dark roasted peanuts	68	
Woody/hulls/skins	The aromatic associated related to dry wood, peanut hulls, skins	Peanut skins	35	
Earthy	The aromatic associated with wet dirt and mulch	Wet soil	150	
Sweet aromatics	The aromatic associated with material such as caramel, vanilla, molasses and fruit	Milk maid caramels	45	Brach's, Chicago, IL
Oxidized	The aromatic associated with rancid fats and oils	Rancid peanut	83	
Cardboard	The aromatic associated with oxidized fats and oils and reminiscent of cardboard	Moist cardboard	85	
Painty	The aromatic associated with linseed oil	Boiled linseed oil	115	Klean Strip, W.M. Barr & Co, Memphis, TN
Fishy	The aromatic associated with trim ethylamine, cod liver or old fish	Cod liver oil	90	E.R. Squibb & Sons, Princeton, NJ

Tastes				
Sweet	Taste on the tongue associated with sucrose solutions	2.0% sucrose solution	20	
		5.0% sucrose solution	50	
Salty	Taste on the tongue associated with sodium chloride solutions	0.2% NaCl solution	25	
		0.35% NaCl solution	50	
Sour	Taste on the tongue associated with acid agents such as citric acid	0.05% citric acid solution	20	
		0.08% citric acid solution	50	
Bitter	Taste on the tongue associated with bitter solutions such as caffeine	0.05% caffeine solution	20	
		0.08% caffeine solution	50	
Feeling factor				
Astringent	The puckering or drying sensation of the mouth or tongue surface	Grape juice	70	Welch's, Concord, MA
Texture				
Crispness	Force needed and intensity of sound (high pitch) generated from chewing a sample with front teeth	Original corn chips	70	Frito Lay, Plano, TX
Hardness	Force needed to compress a food between molar teeth	Dry roasted peanuts	95	Planters Nabisco, East Hanover, NJ
Crunchiness	Force needed and intensity of sound (lower pitch) generated from chewing a sample with molar teeth	Original corn chips	75	Frito Lay, Plano, TX
Tooth pack	The amount of sample left in or on teeth after chewing	Raw Florunner peanuts	40	

* Attribute listed in order as perceived by panelists.

† Intensity ratings are based on 150-mm unstructured line scales.

lamps, which provided 738 lux of light at the surface of the peanut samples. On the test days, 5 g of the peanuts samples was placed into 1-oz plastic cups with lids (Dixie, James River Corp., Norwalk, CT), coded with three-digit random numbers, and served at ambient temperature. Evaluation procedures were conducted according to Grosso and Resurreccion (2002) except that samples analyzed in this paper were not previously frozen as noted in the "Sampling" section. A list of the warm-up and reference intensity scores and definitions was posted in each booth for all training and test sessions (Plemmons and Resurreccion 1998).

Samples were evaluated using a complete randomized block design. Due to panelist attrition during the 238-day study, eight remaining panelists participated in the storage study for a total of 21 evaluation sessions.

Hexanal Analysis

A solid-phase microextraction fiber (Supelco, Bellefonte, PA), 100 μm polydimethylsiloxane (Brunton *et al.* 2000), along with a gas chromatograph (Varian Star 3400 CX, Sugar Land, TX) that was equipped with a flame ionization detector and a capillary column composed of 5% phenyl methylsiloxane, length 50 m, diameter 320 μm, 0.52 μm film (Ultra 2, Hewlett Packard, Avondale, PA) was used to determine hexanal (Grosso and Resurreccion 2002). Each sample was spiked with 50 μL of a 24.6 μg/mL solution of 4-heptanone (SIGMA, St. Louis, MO) in fresh canola oil (Nifda, Inc., Atlanta, GA) as an internal standard. Hexanal was identified by comparison with the retention time of the hexanal standard.

Statistical Analysis

The data were analyzed using the Statistical Analysis System (SAS Institute, Cary, NC, Version 6.12, 1994) software. Means and SDs of sensory attribute ratings and hexanal measurement were calculated. Regression analysis (SAS 1985) was used to determine if the independent variables time and temperature had an effect on the descriptive sensory attributes and hexanal content. A second-order polynomial regression model was used:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 + \varepsilon$$

where Y is the value of the response variable; β_0 is the intercept when Y equals 0; β_1, β_2, β_{11}, β_{12} and β_{22} are parameters; X_1 and X_2 are the temperatures and the days, respectively; and ε is the random error.

Each dependent variable, which could be explained by the model using the criterion of an adjusted coefficient of determination (R^2) ≥ 0.50, was examined in reduced models as possible predictors to explain the effect of time and temperature in stored CCP and RP. The adjusted R^2 statistic is an alternative to R^2 that is adjusted for the number of parameters in the model and is calculated as

$$\text{Adjusted } R^2 = 1 - \left(\left[\{n-i\}\{1-R^2\}\right]/[n-p]\right)$$

Where n = number of observations used in fitting the model, and i is an indicator variable that is 1 if the model includes an intercept and 0 otherwise (SAS 1987).

The partial F-statistic between a proposed reduced model and the full second-order polynomial model was calculated as follows:

$$F = \frac{(\mathrm{SSE}_{\mathrm{reduced}} - \mathrm{SSE}_{\mathrm{full}} / \mathrm{df}_{\mathrm{reduced}} - \mathrm{df}_{\mathrm{full}})}{\mathrm{MSE}_{\mathrm{full}}}$$

where SSE is the sum of squares of error; MSE is the mean square error; and df is the degrees of freedom. If the reduced model was not significantly different from the full model ($P \le 0.05$), it was then used as a final model to predict storage changes in CCPs and RPs (Muego-Gnanasekharan and Resurreccion 1992). Analysis of variance (ANOVA) was used to detect significant differences between sampling days in sensory attributes and hexanal measurements.

RESULTS AND DISCUSSION

Descriptive Analysis

The mean values for 0, 154 or 168 and 238 days of storage for the roasted peanutty, oxidized, painty and cardboard attributes for CCPs and RPs are presented in Fig. 1. These attributes were evaluated until 238 days of storage marking significant ($\alpha = 0.05$) changes between the first and the last days of storage time in samples stored at 23, 30 and 40C. The remaining attributes – brown color, roughness, raw beany, burnt, woody/hulls/skins, earthy, sweet aromatics, fishy, sweet, salty, sour, bitter, astringent, crispness, hardness, crunchiness and tooth pack – did not change significantly ($\alpha = 0.05$) during storage; therefore, these attributes were analyzed at shorter storage time. The ratings of 10 of 17 attributes on the first and last storage days of brown color, raw beany, burnt, sweet aromatic, fishy, sweet, bitter, crispness, hardness and crunchiness attributes are presented in Fig. 2. The remaining seven attributes were not influenced by storage temperature or time. Only texture attributes

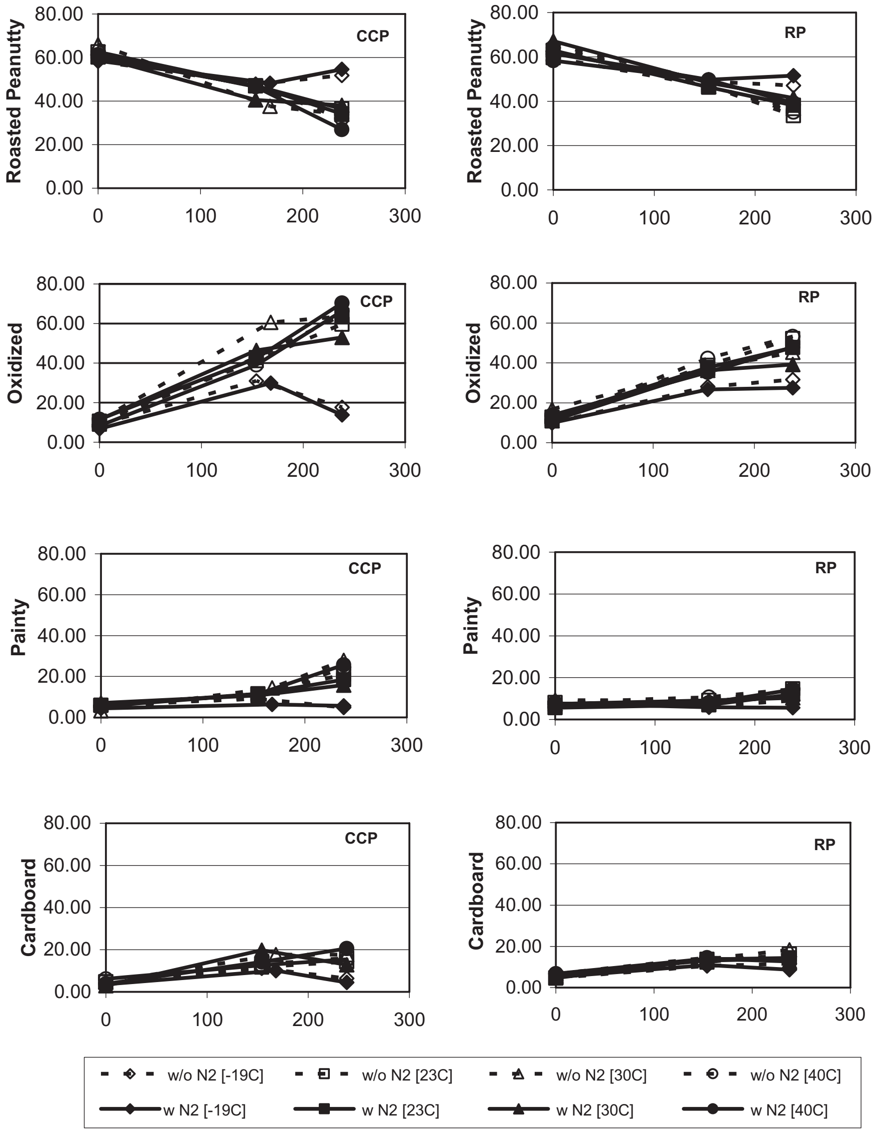

FIG. 1. MEAN RATINGS OF ROASTED PEANUTTY, OXIDIZED, PAINTY AND CARDBOARD FLAVOR FOR CRACKER-COATED PEANUTS (CCP) AND ROASTED (RP) STORED AT DIFFERENT TEMPERATURES

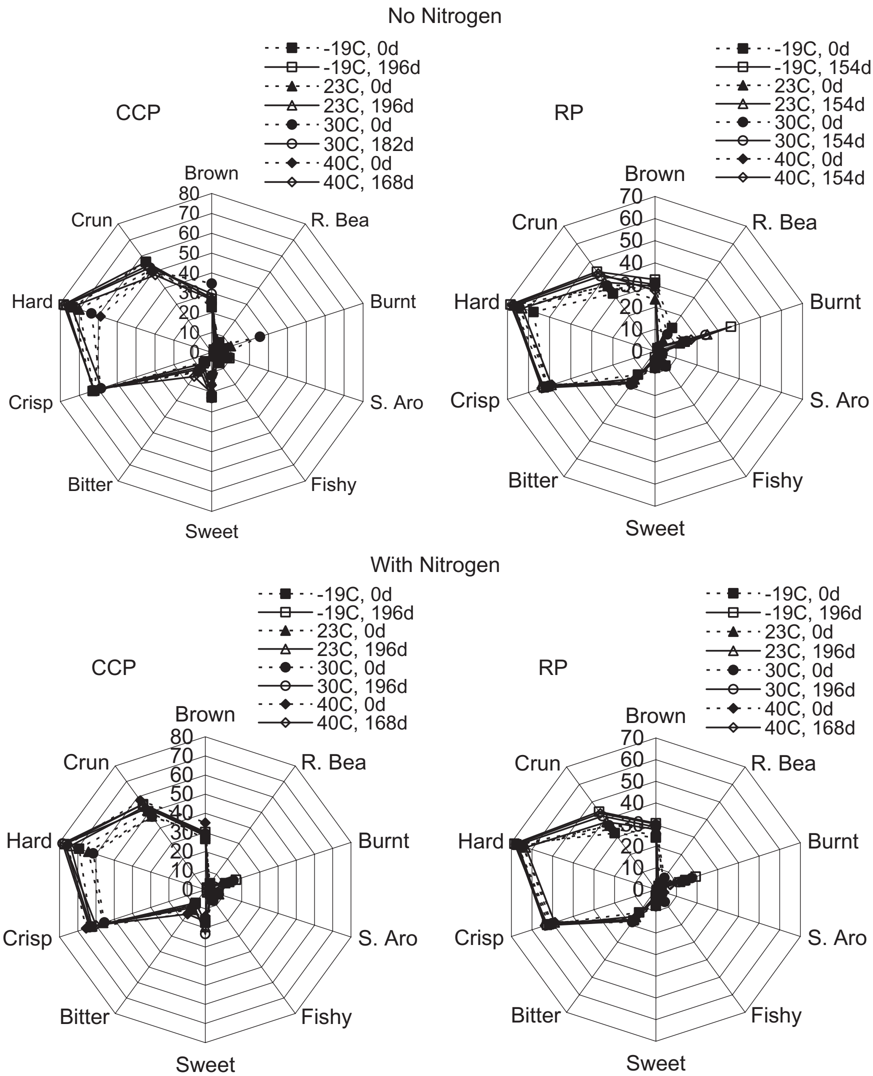

FIG. 2. MEAN RATINGS OF BROWN COLOR, RAW BEANY, BURNT, SWEET AROMATICS, FISHY, SWEET, BITTER, CRISPNESS, HARDNESS AND CRUNCHINESS FOR CRACKER-COATED PEANUTS (CCP) AND ROASTED (RP) STORED AT DIFFERENT TEMPERATURES

crispness, hardness and crunchiness exhibited very slight differences in the samples. Samples held for 0 day (represented by dotted lines) received lower ratings for these attributes compared to those held for longer periods of time.

The roasted peanutty intensity rating decreased during storage. The lowest mean values of this flavor were detected in CCPs packaged with and without nitrogen on day 238 stored at 40C (27 and 32, respectively). In RPs, the roasted peanutty flavor decreased to 39 and 35, with and without nitrogen, respectively. Grosso and Resurreccion (2002) found that after only 110 days, the roasted peanutty flavor of CCP decreased from 63 to 52, whereas in RP the decrease was from 67 to 46. Similarly, the content of heterocyclic compounds and alkylpyrazines diminished during storage in RPs (Buckholz and Daun 1981). A decrease in the content of alkylpyrazines in RP may be attributed to either the degradation by lipid radicals and peroxides or flavor entrainment by complexes between proteins and lipid hydroperoxides or its secondary products (Bett and Boylston 1992). Lee and Resurreccion (2004) found that roasted peanutty flavor of RPs decreased with increasing storage time and temperature. At 23C, samples retained their roasted peanutty flavor longer than those stored at 30C, such that a significant drop from 75 (control) to 65 is predicted to occur after 50 days. They found that RP samples would drop in roasted peanutty flavor intensity to 65 after 20, 10 and 0 days after storage at 30, 35 and 40C, respectively.

The mean intensities of oxidized, cardboard and painty flavors increased significantly for both CCP and RP samples stored at 23, 30 and 40C (Fig. 1). CCP stored at 40C, with or without nitrogen, exhibited the highest increase between day 0 and day 238. Oxidized flavor increased from 11.57 to 70.31 and from 8.35 to 66.28 in CCP, packaged with and without nitrogen, respectively. Oxidized flavor intensity ratings of RP stored at 40C packaged with and without nitrogen at day 0 and day 238 increased from 13.82 to 47.73 and from 11.03 to 53.20, respectively. In previous work, Grosso and Resurreccion (2002) found that oxidized flavor of CCP stored at 40C increased from an intensity of 12 on day 0 to 35 on day 66 to 49 after 110 days. They likewise found that RP stored at 40C resulted in an increase in oxidized flavor from an intensity of 12 on day 0 to 61 after 110 days. Grosso and Resurreccion (2002) published cutoff points for consumer acceptance of CCP and RP based on descriptive panel ratings for oxidized flavor, as 27.4 and 36.2, respectively. A similar increase in flavors related to lipid oxidation during storage was observed in RP (Bett and Boylston 1992), peanut paste (Muego-Gnanasekharan and Resurreccion 1992) and ground roasted peanut (Warner *et al*. 1996). Roasting initiates lipid oxidation and the formation of carbonyl compounds in peanuts (St. Angelo 1996). Lipid oxidation continues during storage at elevated temperatures, resulting in further increases in the content of aliphatic aldehydes, ketones, alcohols and other products of lipid oxidation reactions. These components have been identified as products of linoleic acid and oleic acid oxidation. The formation of these compounds typically has cardboard, painty, rancid and oxidized fat flavor notes (Bett and Boylston 1992).

Painty flavor is associated with lipid oxidation. Painty flavors increased with time and temperature of CCP but only slightly in RP (Fig. 1). Painty intensity increased to a maximum of 26 to 28 after 238 days of storage, with and without nitrogen, respectively. RP exhibited small but significant increases in painty flavor after 238 days, with a maximum of 14 to 15 with and without nitrogen, respectively. All CCP and RP samples stored at −19C, with and without nitrogen showed no significant differences in painty flavor. Grosso and Resurreccion (2002) likewise found significant increases in both CCP and RP, from 3 or 4 initially to 18 after 110 days at 40C. Lee and Resurreccion (2004) found that time, temperature and water activity of storage could not be used a predictors for the painty flavor of RP. Similarly, painty flavor intensity of RP increased with storage time in studies conducted by Bett and Boylston (1992), Braddock *et al*. (1995) and Mugendi *et al*. (1998). Mugendi *et al*. (1998) found that painty flavor was twice as high in runner peanuts compared to high-oleic varieties stored at 40C.

Cardboard flavor, another indicator of lipid oxidation, increased significantly in CCP and RP stored for 238 days to a maximum of 20 and 18, respectively, with and without nitrogen (Fig. 1). In CCP and RP samples stored at −19C, no significant differences in cardboard flavor were observed. Grosso and Resurreccion (2002) observed significant increases from 7 to 14 and 7 to 15 in cardboard flavor of CCP and RP stored at 40C, respectively. Lee and Resurreccion (2004) predicted an increase in cardboard flavor intensities to a maximum intensity of 40, after 45 days at 40C at a water activity of 0.50 and above. For shorter periods, increasing storage temperatures above 23C are predicted to have a cardboard intensity greater than 10. Mugendi *et al*. (1998) likewise found that cardboard flavor intensity of RP increased with storage time. Braddock *et al*. (1995) concluded that cardboard flavor intensity of normal peanuts increased to twice as high as in high-oleic peanuts stored at 25C. Bett and Boylston (1992) determined that all peanut samples, regardless of crop year or seed size became more cardboardy as storage time progressed.

Final oxidized, painty and cardboard flavors in CCP were higher in intensity than in RP. Nitrogen had a protective effect on the formation of oxidized flavors in RP but not in CCP. This may be attributed to oxygen trapped between the layers of the cracker coating and the peanut kernels, and the inability of the nitrogen to penetrate the cracker coat in CCP, and exert a protective effect.

Hexanal Measurements

Mean values of hexanal level increased between 0 and 154 or 168 days of storage time for both the CCP and RP stored at 23, 30 and 40C (Fig. 3). At

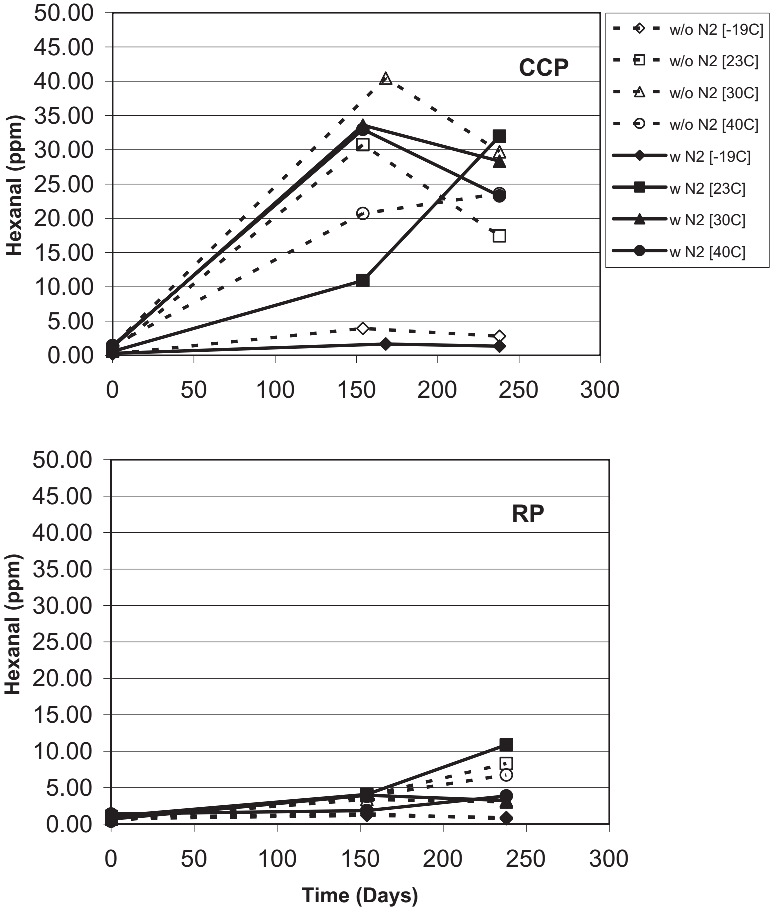

FIG. 3. CHANGES IN HEXANAL LEVELS FOR CRACKER-COATED PEANUTS (CCP) AND ROASTED (RP) STORED AT DIFFERENT TEMPERATURES

–19C only CCP packaged without nitrogen showed a significant increase in the hexanal level. However, as storage time increased to 238 days, the results were variable with unexplainable increases or decreases in hexanal over time. In RP hexanal increased at all storage temperatures, from 0 to 154 days, with and without nitrogen. As in the CCP, storage up to 238 days produced variable results (Fig. 3). While Grosso and Resurreccion (2002) observed that CCP and RP had increases in hexanal from 0 to 110 days, Warner *et al.* (1996) found that hexanal content increased until day 55 then decreased on day 68 in ground roasted peanuts stored at 65C.

Regression Analysis and Prediction Equations

Regression analysis resulted in an $R^2 \geq 0.50$ for the sensory attributes visual roughness, roasted peanutty, oxidized, cardboard and crunchiness sensory attributes in RP packaged without nitrogen; roasted peanutty, oxidized and sweet attributes of RP packaged with nitrogen; and roasted peanutty, oxidized and cardboard attributes of CCP packaged with and without nitrogen (Table 2). These sensory attributes, especially roasted peanutty ($R^2 =$ 0.79–0.87), oxidized ($R^2 = 0.68$–0.74) and cardboard ($R^2 = 0.58$–0.67) flavors, were predicted by storage time and temperature using reduced second-order polynomial models. In sensory evaluation, a value of R^2 greater than 0.50 indicates that 50% of the variance in Y is attributable to the variance in X (O'Mahony 1986). As a result, an R^2 greater than 0.50 is needed before an equation can be considered acceptable for prediction. The remaining attributes, brown color, raw beany, burnt, woody/hulls/skins, earthy, sweet aromatic, painty, fishy, salty, sour, bitter, astringent, crispness, hardness, crunchiness and tooth pack did not have an $R^2 \geq 0.50$ and were not considered further.

In reference to hexanal analysis, the regression equation for the dependent variable hexanal resulted in an R^2 less than 0.50. Therefore, storage time and temperature could not be used to predict hexanal content.

Contour plots of selected significant sensory attributes show the predicted effects of storage, time and temperature. The CCP attributes, roasted peanutty, oxidized and cardboard flavors, stored with and without nitrogen are shown in Fig. 4, and RP attributes, roasted peanutty and oxidized, with and without nitrogen are shown in Fig. 5. Contour plots of CCP, packaged without nitrogen, show the results of the effect of time and temperature on the attributes roasted peanutty ($R^2 = 0.84$), oxidized ($R^2 = 0.68$) and cardboard ($R^2 = 0.61$) in Fig. 4A,B,C, respectively. Roasted peanutty ($R^2 = 0.79$), oxidized ($R^2 = 0.71$) and cardboard ($R^2 = 0.67$) in CCP, packaged under nitrogen, are shown in Fig. 4D,E,F.

The intensity of roasted peanutty flavor of CCP decreased as storage time and temperature increased in samples stored without (Fig. 4A) and with (Fig. 4D) nitrogen. Without nitrogen, roasted peanutty flavor continued to decrease at the low storage temperatures of −5C and below, whereas when nitrogen was present, a slight to almost negligible decrease in roasted peanutty intensity will result during storage from −5 to −20C. Predicted roasted peanutty intensities of peanuts stored without nitrogen are 53 and 51 after 90 days of storage at 23 and 40C, respectively. Under nitrogen, the roasted peanutty flavor intensities of CCP were 51 and 52, when stored for 90 days at 23 and 40C, respectively.

Predicted oxidized ratings for CCP increased as storage time and temperature increased without (Fig. 4B) and with (Fig. 4E) nitrogen. Without

TABLE 2.
SELECTED REGRESSION EQUATION FOR THE PREDICTION OF EFFECT TIME (X_1) AND TEMPERATURE (X_2) IN ROASTED (RP) AND CRACKER-COATED PEANUTS (CCP)

Sample	Treatment	Attribute	Prediction equation	Equation #	R^2
RP	Without N_2	Roughness	$9.2783 - 0.0169X_1 + 0.0003X_1^2$	1	0.54
		Roasted peanutty	$65.2435 - 0.1386X_1 + 0.0001X_1^2$	2	0.87
		Oxidized	$7.4653 + 0.2856X_1 - 0.0118X_2 - 0.0008X_1^2 + 0.0025X_1X_2$	3	0.74
		Cardboard	$3.1608 + 0.1182X_1 - 0.0003X_1^2$	4	0.58
		Crunchiness	$35.5155 - 0.0032X_1 + 0.0240X_1^2$	5	0.53
RP	With N_2	Roasted peanutty	$64.7972 - 0.1103X - 0.2145Y + 0.0001X^2 + 0.0079X_2^2 - 0.0017X_1X_2$	6	0.79
		Oxidized	$-2.4129 + 0.1777X_1 + 0.3678X_2 - 0.0001X_1^2$	7	0.67
		Sweet	$5.8527 - 0.0028X_1 - 0.0001X_1^2$	8	0.52
CCP	Without N_2	Roasted peanutty	$62.4838 - 0.0735X_1 + 0.0025X_2 - 0.0015X_1X_2$	9	0.84
		Oxidized	$6.3497 + 0.0944X_1 + 0.3513X_2 + 0.0031X_1X_2$	10	0.68
		Cardboard	$3.8305 + 0.0261X_1 - 0.0049X_2 + 0.0008X_1X_2$	11	0.61
CCP	With N_2	Roasted peanutty	$58.9249 - 0.0552X_1 - 0.0393X_2 + 0.0001X_1^2 + 0.0054X_2^2 - 0.0026X_1X_2$	12	0.79
		Oxidized	$3.7028 + 0.1564X_1 + 0.1618X_2 - 0.0002X_1^2 + 0.0037X_1X_2$	13	0.71
		Cardboard	$4.7445 + 0.0556X_1 - 0.0977X_2 - 0.0001X_1^2 + 0.0016X_1X_2$	14	0.67

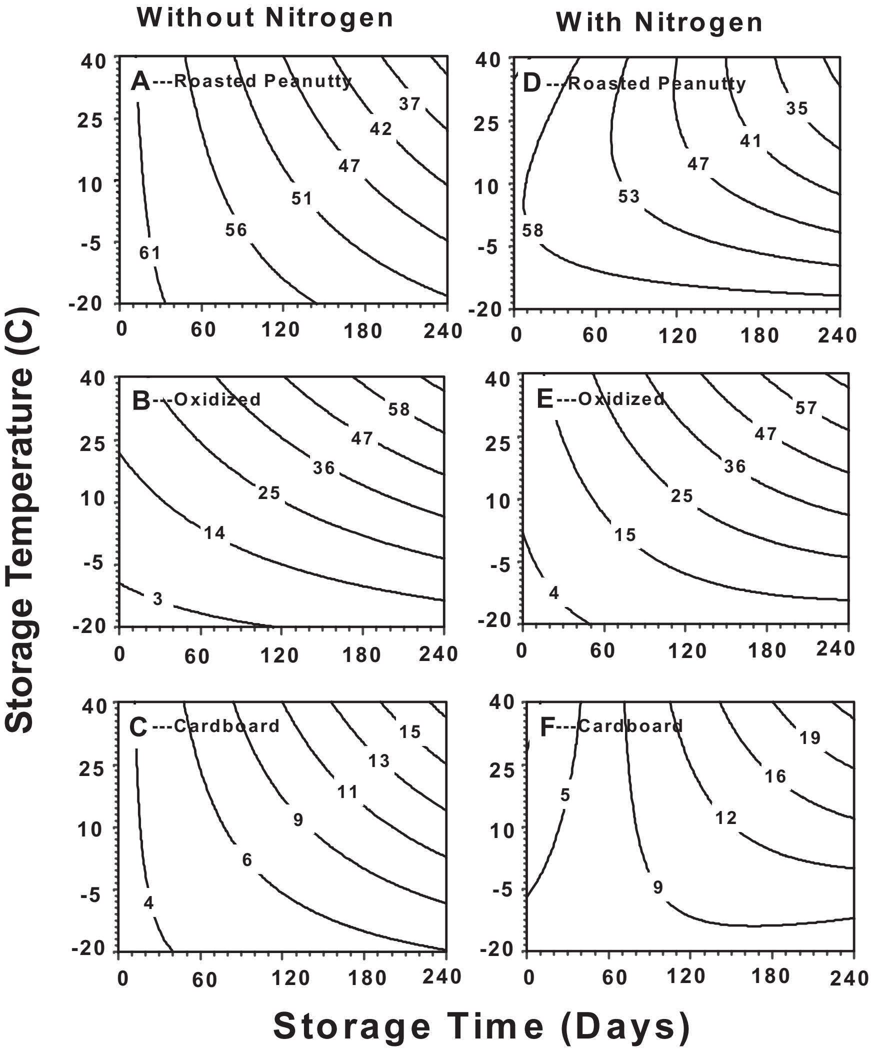

FIG. 4. CONTOUR PLOTS FROM PREDICTION MODELS FOR DESCRIPTIVE ANALYSIS ATTRIBUTES IN CRACKER-COATED PEANUTS

The contour lines indicate a constant intensity rating. Samples packaged without nitrogen: (A) roasted peanutty; (B) oxidized; (C) cardboard. Samples packaged with nitrogen: (D) roasted peanutty; (E) oxidized; (F) cardboard.

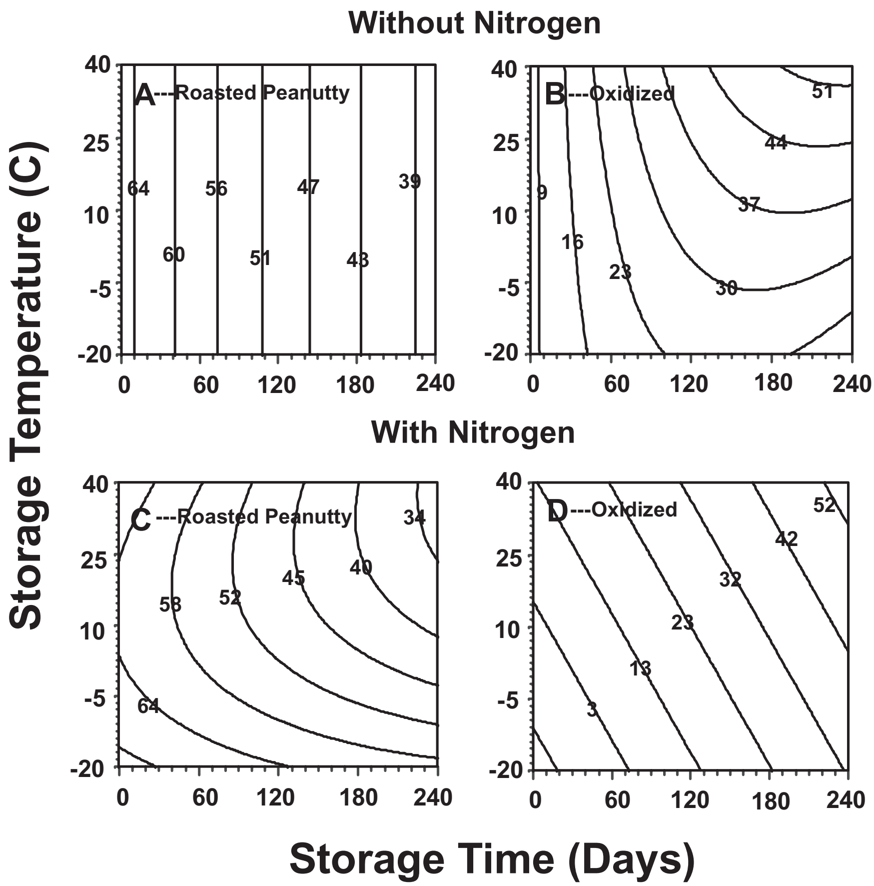

FIG. 5. CONTOUR PLOTS FROM PREDICTION MODELS FOR DESCRIPTIVE ANALYSIS ATTRIBUTES IN ROASTED PEANUTS

The contour lines indicate a constant intensity rating. Samples packaged without nitrogen: (A) roasted peanutty and (B) oxidized. Samples packaged with nitrogen: (C) roasted peanutty and (D) oxidized.

nitrogen, the predicted oxidized flavor intensities after storage for 90 days are 29 and 40 at temperatures of 23 and 40C, respectively. With nitrogen, predicted oxidized flavor intensities after storage for 90 days are 27 and 36 at 23 and 40C, respectively.

Predicted intensities for cardboard flavor are shown without (Fig. 4C) and with (Fig. 4F) nitrogen. Cardboard intensities are initially low (<19) but increase with increasing storage time and temperature. Predicted cardboard flavor intensities after storage without nitrogen for 90 days are 8 and 9 at temperatures of 23 and 40C, respectively. With nitrogen, predicted cardboard flavor intensities are slightly higher at 10 and 11 after storage for 90 days at 23 and 40C, respectively.

Contour plots for the effect of storage time and temperature on RP for roasted peanutty and oxidized flavors are shown in Fig. 5. Temperature had no effect on predicted roasted peanutty flavor of RP when nitrogen was not used (Fig. 5A), but a linear effect ($R^2 = 0.87$, Table 2) was observed because of the increase in storage time wherein an increase in storage time decreased roasted peanutty intensity. The predicted roasted peanutty flavor of RP stored without nitrogen for 90 days at 23 is lower at 51 but did not change much at 40C (rating = 54). Increasing storage time and temperature decreased roasted peanutty intensity when nitrogen was used ($R^2 = 0.79$, Table 2). The predicted roasted peanutty ratings for RP with nitrogen after 90 days of storage at 23 and 40C are 51 and 54, respectively. At −19C, RP with nitrogen remained similar in roasted peanutty intensity to the control for 120 days, whereas when nitrogen was not used, storage for only 10 days resulted in a decrease in the roasted peanutty intensity, regardless of storage temperature.

The contour plots for oxidized flavor intensity of RP are shown in Fig. 5B,D for RP stored without ($R^2 = 0.74$) and with ($R^2 = 0.67$) nitrogen, respectively. Oxidized flavor increased with increase in storage time and temperature. Predicted oxidized flavor intensity of RP packaged without nitrogen after 90 days of storage at 23 and 40C was 32 and 35, respectively. RP packaged with nitrogen at 23 and 40C for 90 days had lower predicted oxidized flavor intensities of 21 and 27, respectively.

Flushing plastic packages with nitrogen gas at the time of packaging minimizes oxygen and maximizes the product shelf life (Koski 1988). Modified atmosphere packaging involving nitrogen in high-gas barrier films has become important in the food preservation technology, to maintain food quality and extend shelf life in foods (Ellis *et al.* 1994). The ANOVA showed that samples packaged with nitrogen were significantly different from those packaged without nitrogen ($\alpha = 0.05$). In roasted peanuts, the predicted values (using equations from Table 2) for oxidized flavor intensity on day 150 at 40C were 46 in samples packaged without nitrogen and 37 in samples packaged with nitrogen. The observed mean values of oxidized flavor intensity on day 154 at 40C were 42.21 in roasted peanut samples packaged without nitrogen, and 35.25 in samples packaged with nitrogen. These results demonstrate the protective effect of nitrogen on oxidized flavor in RP samples but not in CCP samples.

Prediction of Shelf Life

The regression analysis indicated that at least 67–78% or more of the variation of oxidized flavor ratings could be explained by at least one model

(Table 2). Snacks such as RP and CCP would be stored at room temperature (23C) with or without nitrogen. Oxidized flavor attributes were used to predict the shelf life of RP and CCP (Grosso and Resurreccion 2002) and other peanut products such as peanut paste (Muego-Gnanasekharan and Resurreccion 1992). Oxidized flavor is the main attribute used in this work that is related to lipid oxidation and can be used as an indicator of storage deterioration. Therefore, the regression equation for oxidized flavor ratings could be used to predict the number of days for RP and CCP packaged without nitrogen, to attain a given oxidized flavor rating at any storage temperature between −19 and 40C. General terms of the equation are: Y is given oxidized flavor intensity; β_0 is the intercept when Y equals 0; β_1, β_2, β_{11}, β_{12} and β_{22} are parameters; X_1 and X_2 are the temperatures and the days, respectively; X_1^2 and X_2^2 are the squared terms; and X_1X_2 is the cross product term.

The predicted number of days in RP packaged without nitrogen can be calculated using Eq. (3) in Table 2, as follows:

$$X_1 = \frac{-G \pm \sqrt{(G^2 - 4\beta_{11}H)}}{2\beta_{11}}$$

Where $G = \beta_1 + \beta_{12}X_2$; $H = \beta_0 - Y - \beta_2X_2$.

According to Grosso and Resurreccion (2002), the product is considered unacceptable to consumers when samples of RP have an oxidized flavor rating of 36.2 or greater. This value corresponds to a predicted overall acceptance rating from consumer tests of <5 (neither like nor dislike) on a 9-point hedonic scale. By using the aforementioned prediction equations, RP samples packaged without nitrogen are expected to obtain an oxidized flavor rating of 36.2 after 116, 105 and 94 days at 23, 30 and 40C, respectively. The shelf life of RP stored without nitrogen, of almost 4 months at 23C is considerably longer than the 30-day shelf life (Clotfelter 1998) on which the sampling scheme was based.

The predicted number of days in CCP packaged without nitrogen can be calculated using Eq. (10) in Table 2, as follows:

$$X_1 = \frac{Y - \beta_0 - \beta_2X_2}{\beta_1 + \beta_{12}X_2}$$

Samples of CCP packaged without nitrogen that have an oxidized flavor rating of 27.4 or greater will have a predicted overall acceptance from consumer test of 5 or lower on a 9-point hedonic scale; under these conditions, the product is considered unacceptable (Grosso and Resurreccion 2002). By using the prediction equation, CCP samples are expected to obtain an oxidized flavor rating of 27.4 after 78, 56 and 32 days at 23, 30 and 40C, respectively.

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