A Study of the Relationships among Consumer Acceptance, Oxidation Chemical Indicators, and Sensory Attributes in High-Oleic and Normal Peanuts

V. NEPOTE, R.H. OLMEDO, M.G. MESTRALLET, AND N.R. GROSSO

ABSTRACT: The purpose of this study was to determine the relationships between overall acceptance, chemical indicators, and sensory attributes in roasted peanuts harvested from high-oleic peanut genotypes produced in Argentina. Oleic/linoleic ratio (O/L), peroxide value, p-anisidine value, conjugated dienes, consumer acceptance, and descriptive analysis were performed on roasted peanuts prepared using 16 genotypes of normal and high-oleic peanuts. Principal component and cluster analysis were performed on the chemical and sensory data from peanut genotypes. Acceptance was positively associated with O/L, crunchiness, sweetness, roasted peanutty flavor, and hardness. Acceptability was negatively associated with cardboard, oxidized, and sour flavors. The high-oleic genotypes, 4896-11-C, and 9399-10 showed high consumer acceptance with 7 or "like moderately" in a hedonic scale of 9 points. Some high-oleic peanut lines, such as 9399-10, could be used to replace normal peanuts without affecting consumer acceptance of peanut products processed from them and more stability due to the high-oleic condition.

Keywords: high oleic, oxidation, peanut, sensory, stability

Introduction

A large proportion of peanut production in the world is used as domestic food. The end products obtained are peanut butter, salted peanut products, confections, and roasting stock. These peanut-containing foods enjoy widespread popularity because of their unique roasted peanut flavor (Ahmed and Young 1982) conditioned of a complex blend of heterocyclic compounds such as alkylpyrazines (St. Angelo 1996).

Peanuts contain approximately 50% to 55% oil. Normal peanut oil is composed of about 80% unsaturated fatty acids containing 45% oleic (18:1) and 35% linoleic (18:2) acids (Grosso and Guzman 1995). Because they contain high levels of polyunsaturated fatty acids, peanuts are susceptible to lipid oxidation, leading indirectly to the formation of numerous aliphatic aldehydes, ketones, and alcohols responsible for rancid and off-flavors in peanut products (Bett and Boylston 1992; St. Angelo 1996).

Simultaneously, sensory attributes such as oxidized, cardboard, and painty sensory attributes increase in such peanut products (Gills and Resurreccion 2000; Grosso and Resurreccion 2002). Using regression analysis, Grosso and Resurreccion (2002) demonstrated hexanal content and descriptive attributes such as oxidized and painty flavors be strong determinants ($R^2 = 0.70$) of overall consumer acceptance of stored roasted or cracker-coated runner peanuts.

Modification of the composition in vegetable oils to improve stability has been the focus of several studies (Liu and White 1992; Warner and others 1997). For example, high-oleic peanut genotypes developed in the United States containing approximately 80% oleic and 2% to 3% linoleic acid were resistant to the oxidation process, showing improved chemical and sensory stability throughout storage when compared with normal peanuts (Mugendi and others 1998; Pattee and others 2002; Nepote and others 2006a, 2006b).

In addition, high-oleic oils have shown a beneficial effect in human health. Monounsaturated fatty acids (MUFA) as oleic acid offers protection against cardiovascular disease by lowering low-density lipoprotein—cholesterol (LDL) ("bad" cholesterol) levels while raising high-density lipoprotein—cholesterol (HDL) (the "good" cholesterol) levels. Polyunsaturate fatty acids (PUFA) tend to lower both. MUFAs also decrease the susceptibility of LDL to oxidation, which in turn reduces the atherogenicity of the LDL (Ruiz-Gutierrez and others 1999).

Obviously, consumer perception is an important aspect defining food product quality (Muñoz and others 1992), and attributes resulting from lipid oxidation reactions make food unacceptable to consumers (St. Angelo 1996). Chemical analyses coupled with the intensity of off-flavors associated with rancidity as measured through descriptive panels could be useful variables for predicting consumer response to stored peanut products. In addition, consumer acceptance may be influenced by the intensities of sensory attributes associated with different peanut genotypes used to prepare a peanut product. A study of the effect on consumer acceptance of different high-oleic peanut genotypes in Argentina and its relationship with other variables as sensory attributes and lipid oxidation indicators (peroxide value, p-anisidine, and so on) has not been performed yet. Therefore, the objective of this study was to determine the relationships among overall acceptance, chemical indicators of lipid oxidation, and sensory attributes in roasted peanuts prepared with high-oleic peanut genotypes and normal peanuts produced in Argentina. The chemical indicators of lipid oxidation

MS 20080095 Submitted 2/6/2008, Accepted 9/15/2008. *Authors Olmedo, Mestrallet, and Grosso are with Química Biológica, Facultad de Ciencias Agropecuarias (UNC), IMBIV-CONICET, CC 509, 5000 Córdoba, Argentina. Author Nepote is with ICTA, Facultad de Ciencias Exactas, Físicas y Naturales (UNC), IMBIV-CONICET, Córdoba, Argentina. Direct inquiries to author Grosso (E-mail: nrgrosso@agro.uncor.edu).*

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analyzed in this study were peroxide value, p-anisidine, and conjugated dienes. The sensory analysis included consumer test for overall acceptance and descriptive analysis for identifying and quantifying sensory attributes of roasted peanuts.

Materials and Methods

Materials

Sound and mature seeds of different peanut genotypes (*Arachis hypogaea* L.), type Runner, size 38/42 kernels per oz (2004 crop) were provided by "Criadero El Carmen" company from General Cabrera, Cordoba, Argentina. Before roasting, peanuts were inspected, and damaged and bruised kernels were manually removed.

Peanut genotypes were classified and numbered as follows: (a) normal peanut cultivars (controls): Tegua (1), and 4495-1-B (15); (b) high-oleic acid cultivars: Granoleico (2), and FMR-458 (14); (c) high-oleic breeding lines: Tegua 87.5% (3), 4896-1 (4), 4896-4 (5), 4896-11-C (6), 4896-11-D (7), 4896-13-A (8), 4896-13-BD (9), 4896-13-C (16), 4896-13-F (10), 7698-2-E (12), 7698-5-C (11), and 9399-10 (13).

Preparation of samples

Peanuts were roasted at 170 °C in an oven (Memert, modell 600, Schwabach, Germany) for 30 min. Peanuts were heated to a medium roast or to an average Hunter color Lightness (L) value of 50 ± 1.0 [14]. The color was measured using a photocolorimeter HunterLab (ColorFlex, Reston, Va., U.S.A.).

After preparation of roasted peanuts, samples were packaged in 27×28 cm plastic bags (Ziploc, Johnson and Son, Buenos Aires, Argentina) and stored in them at −18 °C in freezer for a week until analysis.

For the chemical analysis, approximately 20 g peanut oil was obtained by cold pressing from 100 g roasted peanuts using a 20-ton press (HE-DU, Hermes I. Dupraz SRL, Cordoba, Argentina).

Chemical analysis

The Oleic/Linoleic (O/L) ratio was calculated using the percentages of oleic and linoleic acids. Oleic and linoleic fatty acids percentages of roasted peanut samples were determined by gas-liquid chromatography. Fatty acid methyl esters were prepared on the peanut oils by transmethylation with a 3% solution of sulphuric acid (Cicarelli Laboratorios, San Lorenzo, Argentina) in methanol (Cicarelli Laboratorios). The fatty acid methyl esters of total lipids were analyzed on a Hewlett Packard HP-6890 gas-liquid chromatograph (Calif., U.S.A.) equipped with a flame ionization detector (FID HP-3398). An HP-INNO-Wax capillary column (30 m × 0.32 mm × 0.5 nm, with polar polyethylene glycol; Agilent Technologies, Santa Clara, Calif., U.S.A.) was used. Separation, identification, and quantification of the fatty acid methyl esters were performed according to the method of Grosso and others (2000).

Peroxide value (PV) was evaluated following the AOAC method (AOAC 1980) using 5 g oil from each roasted peanut sample. The PV was expressed as miliequivalents of active oxygen per kilogram of oil ($meqO_2/kg$).

p-Anisidine value (AV) was evaluated following the IUPAC method (IUPAC 1987). The *p*-anisidine reagent (BDH Laboratory Reagents, Poole, U.K.) was prepared at 0.25% (w/v) in glacial acetic acid (Cicarelli Laboratorios). The absorbancies of samples were measured at 350 nm in a spectrophotometer (UV-V Diode Array Spectrophotometer Hewlett Packard HP 8452 A, Calif., U.S.A.). The *p*-anisidine value was given by the formula: $AV = 25 \times (1.2\ As - Ab) \times (m^{-1})$, where "As" is absorbance of the fat solution after reaction with the *p*-anisidine reagent, "Ab" is the absorbance of the fat solution, and "m" is the mass of the peanut oil in grams.

Conjugated dienes (CD) were determined from weighed oil samples that were dissolved in 6 mL n-hexane. The conjugated diene absorbencies were measured at 232 nm in a spectrophotometer (UV-V Diode Array Spectrophotometer, Hewlett Packard HP 8452 A). The results were reported as the sample extinction coefficient E (1%, 1 cm) and calculated by the formula: $CD = (A \times 6) \times (m \times 100)^{-1}$, where "A" is the absorbance of the fat solution at 232 nm and m is the mass of the peanut oil in grams. (COI 2001).

Sensory methods

Consumer tests. The panelists ($n = 100$) were from Cordoba (Argentina) and were recruited according to the following criteria: (1) ages between 18 and 65 y, (2) nonsmokers, (3) people without food allergies, and (4) people who consumed roasted peanuts and/or peanut products at least twice a week. For sample evaluation, 5 g of the peanut samples were placed into plastic cups with lids coded with 3-digit random numbers. Samples consisting of roasted peanuts of different genotypes (3 replications) were prepared for the panelists. Six samples were presented to the panelists in random order during the test day. Samples were presented with water and paper ballots on a plastic tray. The panelists were instructed to consume the whole sample and then rinse their mouths with water between samples to minimize any residual effect. A 9-point hedonic scale ranging from 1 = dislike extremely to 9 = like extremely was used to evaluate overall acceptance from the samples (Peryam and Pilgrim 1957).

Descriptive analysis. A total of 12 trained panelists (9 female and 3 male) participated in the descriptive analysis of roasted peanuts. All panelists had 4 y of experience evaluating peanut products and were selected according to the following criteria: (1) people with natural dentition, (2) people without food allergies, (3)nonsmokers, (4) people between the ages of 18 and 64, (5) people who consume roasted peanuts and/or peanut products at least once a month, (6) people available for all sessions, (7) people interested in participating, and (8) people able to verbally communicate the observations regarding the product (Plemmons and Resurreccion 1998). For panelist selection, a screening test was performed for descriptive analysis. Before being qualified, all panelists showed a perfect score in a taste sensitivity test and the ability to identify 5 of 7 commonly found food flavors (Meilgaard and others 1991).

All 12 panelists were trained and calibrated in 4 training sessions during 4 d. Each training session lasted for 2 h. A hybrid descriptive analysis method 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 were used for training and evaluation sessions as reported by Grosso and Resurreccion (2002). A 150-mm unstructured line scale was used for sample evaluation (Stone and Sidel 1985). A list of definitions and a sheet with warm-up and reference intensity ratings (Table 1) were developed during the training sections (Grosso and Resurreccion 2002; Nepote and others 2004). The attributes definitions were based on peanut lexicon (Johnsen and others 1988).

All samples were evaluated in partitioned booths under fluorescent light at room temperature. Ten grams of the product sample were placed into plastic cups with lids coded with 3-digit random numbers. Panelists evaluated 12 samples and the warm-up sample per day. Every evaluation day was divided in 2 sessions of 2 h (2 h during the morning and 2 h during the noon). Before beginning the evaluation of the samples, the panelists retested all references and the warm-up sample. The final lists of warm-up and reference

intensity ratings and definitions were posted in the booths for all test sessions. Samples were tested using a randomized complete block design. The data were registered on paper ballots.

Statistical analysis

The experiment was replicated 3 times. The data were analyzed using the InfoStat software, version 2006 (Facultad de Ciencias Agropecuarias, Univ. Nac de Cordoba). Means and standard deviations were calculated. Analysis of variance (ANOVA, $\alpha = 0.05$) and the Duncan's multiple range test were performed to find significant differences among means from the chemical and sensory variables in peanut genotypes. Principal component analysis (PCA) (Johnson and Wichern 1998) was performed on the correlation matrix of the standardized data from the chemical and sensory variables of all samples. The purpose of the PCA was to explore associations between chemical and sensory variables, and peanut genotypes. Cluster analysis (CA) was performed to obtain groups of peanut genotypes with similar characteristics. Sample similarities were calculated on the basis of the Euclidean distance, and the groups of peanut genotypes with similar characteristics were obtained using the average linkage or the unweighted pair-group method using an arithmetic average (UPGMA). Means, standard deviations, ANOVA, and Duncan's multiple range test were also performed in the variables of the peanut genotype groups obtained from the cluster analysis (Sokal and Michener 1958).

Means and standard deviations of variables from peanut genotype groups obtained in the cluster analysis were calculated. ANOVA ($\alpha = 0.05$) and the Duncan's multiple range test were performed to find significant differences between means from the chemical and sensory variables in groups of peanut genotypes and their means separation (Sokal and Michener 1958).

Results and Discussion

Chemical analysis of roasted peanuts

The results of chemical analysis: O/L ratio, peroxide value (PV), *p*-anisidine value (AV), and conjugated dienes (CD) of each peanut genotype are presented in Table 2. These variables showed significant differences between peanut genotypes ($\alpha = 0.05$). The normal cultivars had O/L ratios from 1.13 (Tegua) to 1.32 (4495-1-B), the high-oleic cultivars from 13.54 (FMR-458) to 17.7 (Granoleico), and the high-oleic breeding lines from 11.49 (7698-5-C) to 18.95 (4896-11-C). The O/L ratio variability observed in high-oleic breeding lines could be explained by locality (Bansal and others 1993; Grosso and others 1994) or genetic effects (Branch and others 1990). In this study, the genetic effects could be the cause due to all peanut lines used in this study were cultivated and harvested in the same locality and at the same time. In this case, some peanut lines as in 7698-5-C with low O/L ratio could not be stabilized at all their high-oleic character. High-oleic peanuts contain high concentrations of

Table 1—Definitions of attributes, standard references, and warm-up intensity ratings used in descriptive analysis of roasted peanuts.

Attribute[a]	Definition[b]	Reference	Reference intensity[c]	Warm-up intensity[c,d]
Appearance				
1. Brown color	The intensity or the strength of brown color from light to dark brown.	Cardboard	40	38
Aromatics				
2. Roasted peanutty	The aromatic associated with medium roasted peanuts.	Dry roasted peanuts[e]	69	56
3. Oxidized	The aromatic associated with rancid fats and oils.	Rancid peanuts	53	15
4. Cardboard	The aromatic associated with wet cardboard.	Moist cardboard: 1 mL distilled water absorbed by 0.5 g cardboard	52	13
5. Burnt	The aromatic associated with over roasted peanuts	Dark roasted peanuts[f]	60	20
6. Raw/Beany	The aromatic associated with uncooked or raw peanuts.	Raw peanuts	69	10
Tastes				
7. Sweetness	Taste on the tongue associated with sucrose solutions.	20 g/kg sucrose solution	20	17
		50 g/kg sucrose solution	50	
		100 g/kg sucrose solution	100	
		150 g/kg sucrose solution	150	
8. Salty	Taste on the tongue associated with sodium chloride solutions.	2 g/kg NaCl solution	25	12
		3.5 g/kg NaCl solution	50	
		5 g/kg NaCl solution	85	
9. Sour	Taste on the tongue associated with acid agents such as citric acid solutions.	0.5 g/kg citric acid solution	20	7
		0.8 g/kg citric acid solution	50	
		1.5 g/kg citric acid solution	100	
10. Bitter	Taste on the tongue associated with bitter solutions such as caffeine.	0.5 g/kg caffeine solution	20	9
		0.8 g/kg caffeine solution	50	
		1.5 g/kg caffeine solution	100	
Texture				
11. Crunchiness	Force needed and amount of sound generated from chewing a sample with molar teeth.	Corn flakes[g]	102	40
12. Hardness	Force needed to compress a food between molar teeth.	Almonds[h]	56	45

[a] Attributes listed in order as perceived by panelists.
[b] The attribute definitions were based on a lexicon for peanut samples (Muñoz and others 1992).
[c] Intensity ratings are based on 150-mm unstructured line scales.
[d] Medium (lightness value, $L = 50 \pm 1$) roasted peanuts (type Runner, Blanched).
[e] Dry roasted peanuts, type Runner, JL SA, Ticino, Cordoba, Argentina.
[f] Dark roasted peanuts, type Runner, lightness value $L = 36 \pm 1$.
[g] Corn flakes, Granix, Buenos Aires, Argentina.
[h] Almonds, Grandiet, Cordoba, Argentina.

monounsaturated fatty acids (especially oleic acid) around 80% and very low percentage of polyunsaturated fatty acids around 4%. On the contrary, normal peanuts have higher percentage of polyunsaturated fatty acids (around 37%) and lower monounsaturated fatty acids (47%) with respect to high-oleic peanuts. For that reason, normal peanuts are more susceptible to lipid oxidation (O'Keefe and others 1993; Nepote and others 2006b). O/L ratios in Tegua and Granoleico cultivars reported by Nepote and others (2006a) were similar to the values observed in this study. Other researchers (O'Keefe and others 1993; Andersen and others 1998) found O/L ratios between 16 and 28 in high-oleic peanuts and 1 and 3 in normal peanut genotypes from the United States.

In general, the most of high-oleic genotypes showed lower values in the chemical indicators of lipid oxidation (PV, AV, and CD) than in the normal cultivars. The highest PV and CD were found in the normal cultivar, Tegua (5.19 and 4.16, respectively). In this study, the PV, AV, and CD in roasted peanuts were higher in Tegua than in Granoleico. Nepote and others (2006a) reported that these chemical indicators of lipid oxidation increased with storage time in both peanut cultivars but the increase was higher in Tegua.

Sensory analysis of roasted peanuts

The results of consumer acceptance and descriptive analysis sensory tests are presented in Table 3. The sensory variables that showed significant differences between peanut genotypes (α = 0.05) were overall acceptance and descriptive attributes, roasted peanutty flavor, and sweetness.

Consumer test. The overall acceptance means of the samples were from 5.7 ("6: like slightly") to 7.1 ("7: like moderately"). Significant differences were found between peanut genotypes. The HO breeding lines 13 and 6 showed values around 7 ("like moderately") on a 9-point hedonic scale. The HO breeding line 13 had higher overall acceptance than the normal cultivars, Tegua and 4495-1-B. Tegua and Granoleico were not significantly different in consumer acceptance showing values around 6 ("like slightly"). In a previous study, roasted peanuts also showed overall acceptances of about "6 = like slightly" in a hedonic scale of 9 points (Grosso and Resurreccion 2002; Nepote and others 2004).

Descriptive analysis. Roasted peanutty flavor and sweetness were the only 2 attributes that showed significant differences among peanut genotypes. The intensities of the roasted peanutty attribute were from 50.9 (HO breeding line 16) to 56.5 (HO breeding lines 6 and 13). Roasted peanutty flavor did not differ between Tegua (1) and Granoleic (2) cultivars. In a previous work (Nepote and others 2006b), a trained panel did not detect differences in the intensities of roasted peanutty flavor between Granoleico and Tegua in fried-salted peanuts, either. Roasted peanutty flavor may be attributed to the presence of pyrazines (Buckholz and Daun 1981; Crippen and others 1992). Difference in roasted peanutty flavor intensities among peanut genotypes could be related to variation in pyrazines concentration. The intensities of the sweetness attribute were from 14.5 (normal cultivar 15) to 18.5 (HO cultivar 14).

The other attributes—brown color, oxidized, cardboard, burnt, raw, salty, sour, and bitter flavors, crunchiness, and hardness—did not exhibit significant differences among peanut genotypes. However, some of these attributes such as oxidized, cardboard, sour, and bitter attributes were more variable showing trend to be higher in normal cultivars than in HO cultivars and breeding lines.

Principal component analysis (PCA)

Figure 1 is the biplot obtained from the first 2 principal components (PC) of PCA. The biplot was separated in 2 graphics that show more clearly the variability of the relations among dependent variables from chemical and sensory results (Figure 1A) and peanut genotypes (Figure 1B). The first 2 PC of the PCA explains 60% of total variability in the peanut samples. This percentage of total variability is relatively low. However, the authors of this study considered this percentage acceptable to draw correlation among the variables. Correlations between chemical and sensory variables were explored (Figure 1A). Acceptance was positively associated mainly with O/L, crunchiness, and sweetness, and also with salty, roasted peanutty flavors, and with hardness. This variable was negatively associated mainly with cardboard, oxidized, and sour flavors. Chemical indicators of lipid oxidation (PV, AV, and CD) were positively related among them and with the descriptive attributes:

Table 2—Means (n = 3) of chemical variables analyzed in roasted peanuts prepared with kernels of different high-oleic and normal genotypes.

Peanut genotypes	O/L ratio[c]	Peroxide value[a,c]	*p*-Anisidine value[c]	Conjugated dienes[b,c]
Normal cultivars				
Tegua (1)	1.13 a	5.19 c	1.09 b	4.16 g
4495-1-B (15)	1.32 a	3.55 b	1.08 b	2.53 e
High-oleic cultivars				
Granoleico (2)	17.7 ef	1.01 ab	0.42 a	1.65 cde
FMR-458 (14)	13.54 bc	0.93 ab	0.34 a	1.11 ab
High-oleic breeding lines				
Tegua 87.5% (3)	16.33 cdef	1.05 b	0.43 a	1.53 cde
4896-1 (4)	15.19 cde	0.93 ab	0.47 a	1.42 bc
4896-4 (5)	15.57cde	0.77 ab	0.41 a	0.98 a
4896-11-C (6)	18.95 f	0.99 ab	0.60 ab	1.67 cde
4896-11-D (7)	17.28 def	0.80 ab	0.64 ab	1.48 cd
4896-13-A (8)	15.04 cde	0.84 ab	0.58 ab	2.24 f
4896-13-BD (9)	16.86 def	0.78 ab	0.14 a	1.43 bc
4896-13-F (10)	11.49 b	0.81 ab	0.19 a	1.05 a
7698-5-C (11)	14.89 cde	0.86 ab	0.66 ab	1.04 a
7698-2-E (12)	15.82 cde	0.43 a	0.49 a	1.81 de
9399-10 (13)	14.53 cd	0.96 ab	0.44 a	1.32 abc
4896-13-C (16)	13.96 bc	1.00 ab	0.29 a	2.40 f

[a]Expressed as meqO_2/kg.
[b]Expressed as extinction coefficient E (1%, 1 cm).
[c]Means followed by the same letters in each column showed no significant differences among peanut genotypes (ANOVA and Duncan test, α = 0.05).

Table 3—Means of sensory analysis results in roasted peanuts prepared with kernels of different high-oleic and normal genotypes.

	Consumer analysis	Descriptive analysis[b]											
		Appearance	Aromatics					Tastes				Texture	
Peanut genotypes	Acceptance[a,c]	Brown color	Roasted peanutty[c]	Oxidized	Cardboard	Burnt	Raw	Sweet ness[c]	Salty	Sour	Bitter	Crunchiness	Hardness
Normal cultivars													
Tegua (1)	6.4 bcd	32.5	52.4 abc	12.3	11.5	12.3	10.9	17.0 bc	10.9	7.7	8.8	39.0	40.7
4495-1-B (15)	5.8 ab	34.0	52.7 abcd	12.4	12.5	14.6	9.0	14.5 a	10.6	8.3	11.4	39.0	41.2
High-oleic cultivars													
Granoleico (2)	6.0 abc	33.3	54.7 bcde	9.6	10.5	13.8	11.0	16.6 b	10.7	7.5	8.5	39.8	41.5
FMR-458 (14)	6.5 cde	32.9	55.3 cde	8.7	11.0	13.8	10.1	18.5 c	11.2	6.7	7.7	39.8	42.5
High-oleic breeding lines													
Tegua 87.5% (3)	5.9 abc	32.3	52.8 abcd	10.6	11.7	14.6	10.2	16.1 ab	10.4	7.5	9.2	40.0	42.2
4896-1 (4)	6.6 cde	32.9	54.1 bcde	9.9	10.9	14.1	10.8	16.3 ab	10.6	7.4	8.9	38.4	40.8
4896-4 (5)	6.1 abc	32.6	52.4 abc	10.4	11.5	13.8	13.0	16.3 ab	10.9	7.6	9.1	39.0	41.5
4896-11-C (6)	6.9 de	34.4	56.5 e	9.3	10.9	14.1	9.7	16.8 b	10.9	7.4	8.1	39.9	42.2
4896-11-D (7)	5.7 a	35.4	55.5 de	10.1	11.1	18.4	9.1	16.1 ab	11.1	7.0	9.7	39.6	41.8
4896-13-A (8)	5.8 ab	33.9	53.1 abcd	10.1	11.1	13.3	11.9	16.3 ab	10.3	7.5	9.0	39.2	41.4
4896-13-BD (9)	6.5 cde	32.5	53.0 abcd	10.7	11.0	13.3	12.5	16.9 bc	11.0	7.4	8.6	37.9	40.9
4896-13-F (10)	5.9 abc	33.4	52.2 ab	9.9	11.5	13.4	11.4	16.1 ab	11.0	7.6	8.6	39.1	41.5
7698-5-C (11)	6.3 abcd	35.3	54.5 bcde	9.8	11.8	16.4	10.0	16.1 ab	10.6	7.9	10.3	38.1	41.8
7698-2-E (12)	5.8 ab	33.0	51.9 ab	10.3	11.9	12.0	13.0	15.5 ab	10.4	7.8	9.2	39.0	41.3
9399-10 (13)	7.1 e	33.4	56.5 e	8.9	10.3	14.0	9.8	16.6 b	10.6	6.8	8.5	39.7	41.4
4896-13-C (16)	5.8 ab	32.8	50.9 a	10.5	11.4	13.4	13.7	15.5 ab	10.5	7.5	9.2	39.3	40.8

[a]Overall acceptance measured in a hedonic scale of 9 points ($n = 100$).
[b]Attribute intensity rating measured in an unstructured line scale of 150 mm ($n = 12$).
[c]Means followed by the same letters in each column showed no significant differences among peanut genotypes (ANOVA and Duncan test, $\alpha = 0.05$).

oxidized, cardboard, sour, and bitter. These last attributes are also related to the oxidation process and produced dislike in consumer acceptability. The biplot suggests a poor association between acceptance and burnt, brown color, and raw attributes because the angle between the corresponding vectors is almost 90° (Gabriel 1971). This poor association between acceptance and burnt flavor was observed in HO line 7 that showed low acceptance score and high burnt intensity rating.

The dispersion of the points indicated high variability among samples. The variables: overall acceptance, O/L, sweetness, crunchiness, roasted peanutty flavor, hardness, and salty were placed to the left in the biplot (Figure 1A). The peanut genotypes that showed higher values in these variables were also placed to the left in the biplot (Figure 1B). The HO peanut genotypes 14, 13, 6, and Granoleico were placed more to the left in the biplot. On the contrary, the peanut genotypes with higher results in the variables related to lipid oxidation as PV, AV, and CD, and oxidized, cardboard, sour, and bitter sensory attributes are placed more to the right in the biplot. The normal peanut genotypes Tegua and 15 were placed more to the right in the biplot. There were some HO peanut genotypes like the breeding lines 3, 5, 7, 8, and 10 that were located close to the center of the biplot. This result was influenced for relatively low score in consumer acceptance and low value in chemical indicator of lipid oxidation (PV, AV, or CD) despite relatively high intensity ratings of roasted peanutty flavor and sweetness in some of these genotypes. In particular, the HO peanut genotypes 7 and 8 showed low acceptance (5.7 and 5.8, respectively) and low PV, CD, and AV (Table 2 and 3). But their intensity ratings of roasted peanutty flavor (55.5 and 53.1) and sweetness (16.1 and 16.3) were not low.

In other studies, relations among chemical and sensory variables were also found. Bett and Boylston (1992), Warner and others (1996), and Brannan and others (1999) reported that roasted peanutty flavor intensity and alkylpyrazines decreased in stored roasted peanuts. Bett and Boylston (1992) detected in roasted peanuts that cardboard flavor intensity had a linear increase across storage time in roasted peanuts while roasted peanutty flavor intensity decreased with storage time. Muego-Gnanasekharan and Resurreccion (1992) also detected that oxidized and cardboard flavor intensities exhibited a linear increase during storage time in peanut paste. Nepote and others (2006a, 2006b) reported that chemical variables (PV, AV, and CD) and descriptive attributes (oxidized, cardboard, and roasted peanutty) were correlated in roasted and fried-salted peanuts during storage. In those researches, positive correlations were observed among PV, AV, CD, and oxidized and cardboard flavors. These variables increased during storage time. On the contrary, negative correlations were exhibited between roasted peanutty flavor and PV, AV, CD, and oxidized and cardboard flavors because roasted peanutty flavor decreased during storage. Grosso and Resurreccion (2002) have determined the

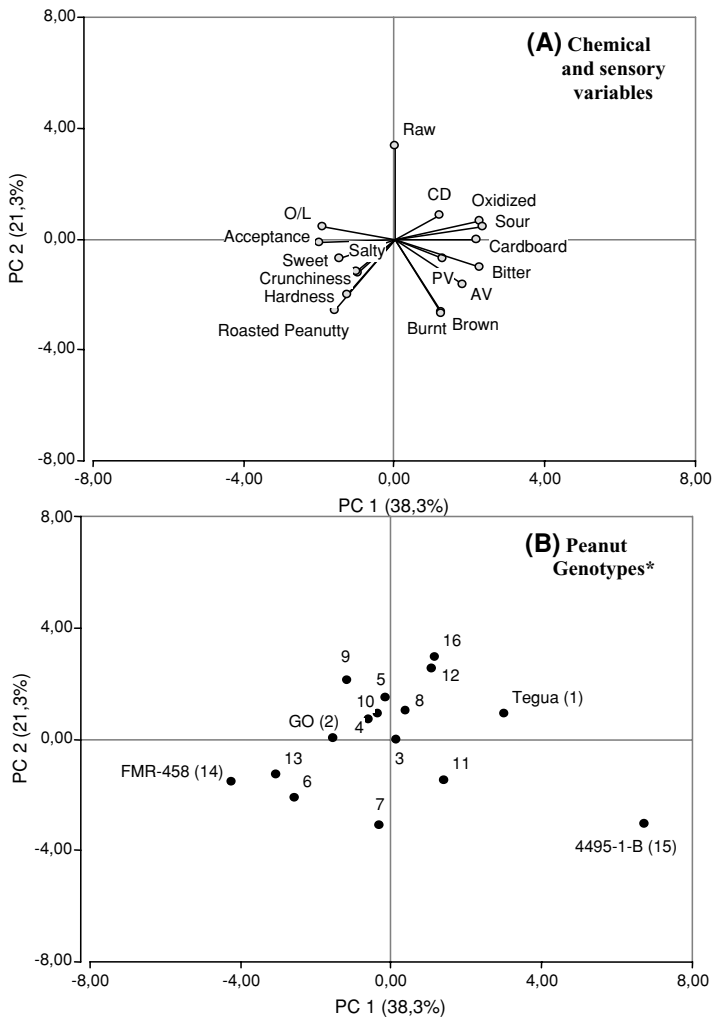

Figure 1 — Biplots from the 1st and 2nd principal components of PCA: (A) chemical and sensory variables, (B) variability of the high-oleic and normal peanut genotypes. Peanut genotypes: Normal cultivars: Tegua (1), 4495-1-B (15); High-oleic cultivars: Granoleico (2), FMR-458 (14); High-oleic breeding lines: Tegua 87.5% (3), 4896-1 (4), 4896-4 (5), 4896-11-C (6), 4896-11-D (7), 4896-13-A (8), 4896-13-BD (9), 4896-13-F (10), 7698-5-C (11), 7698-2-E (12), 9399-10 (13), 4896-13-C (16).

cutoff point for acceptability of stored roasted and cracker-coated peanuts. They found that oxidized, roasted peanutty, and painty flavors are good predictors of overall acceptance. However, in that study, other attributes like sweetness, salty, sour, bitter, cardboard, burnt, and raw/beany attributes, crunchiness, and hardness were not considered because they did not show significant changes during storage. In addition, other researchers (Pattee and others 2000) also studied chemical and sensory variables in different peanut genotypes. They reported that total sugar and carbohydrate contents showed positive correlation with sweet taste and roasted peanutty flavor and negative correlation with bitter taste and astringent feeling factor. Sensory attributes related to roasted peanut quality like sweetness and bitterness have been described as heritable traits (Pattee and Giesbrecht 1994; Pattee and others 1998).

In the present study, the storage effect was not analyzed but similar relations were found between chemical and sensory variables because of the variability in the peanut genotypes. On the one hand, descriptive sensory attributes like roasted peanutty flavor and sweetness, crunchiness, and hardness are positively related to the consumer overall acceptance, and simultaneously, oxidized, cardboard, bitter, and sour sensory attributes are negatively related to acceptability. On the other hand, some of the high-oleic peanut cultivars have higher overall acceptance. That is not directly related to their high O/L but is indirectly related to their lower intensities of oxidized, cardboard, bitter, and sour sensory attributes and their higher intensities of roasted peanutty, and sweetness flavors, mainly, due to the fact that intensity rating of these attributes could be affecting the degree of liking in the consumer test.

Cluster analysis

The results achieved by the cluster analysis (CA) of 16 peanut genotypes considering all the chemical and sensory variables are presented as a dendrogram in Figure 2. Four clusters of groups were observed: group A was formed by just one normal cultivar, Tegua; group B was also formed by just another normal cultivar, 15; group C was made up of high-oleic cultivars, Granoleico and 14 and high-oleic breeding lines 13 and 6; and group D was formed by the high-oleic breeding lines 3, 4, 5, 7, 8, 9, 10, 11, 12, and 16. These results disclosed that there were differences among groups of peanut genotypes. The chemical and sensory data may contain adequate information to attain peanut genotype differentiation according to the established classes.

In Table 4, mean values for the chemical and sensory variables are presented by group of peanut genotypes from cluster analysis. Significant differences were found between groups in most of the variables. Groups C and D (high-oleic genotypes) presented higher O/L ratio and lower PV, AV, and oxidized flavor than groups A and B (normal genotypes). The contrasting characteristics between the normal groups, groups A and B that could make them different in acceptance were lower sweetness and higher cardboard, burnt, and bitter flavors. The group C had higher acceptance and roasted peanutty flavor; however, the acceptance was not significantly different with respect to group A. However, the 2 groups showed

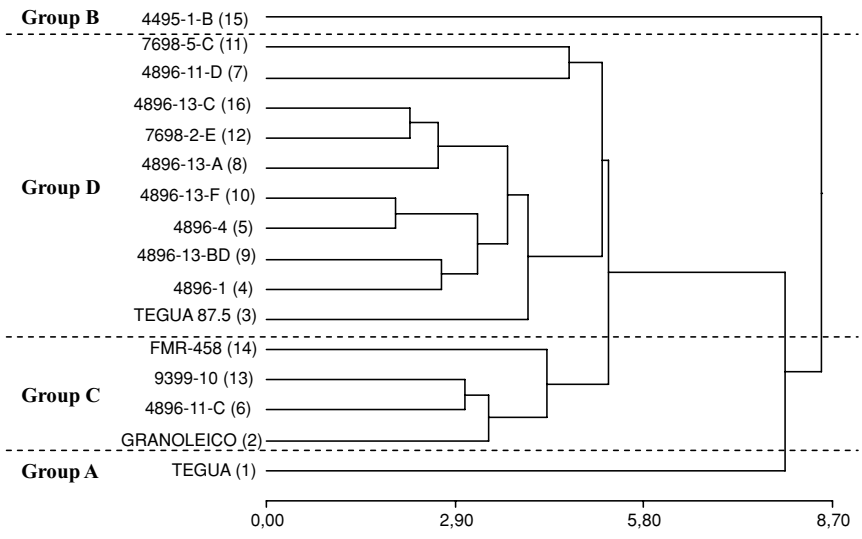

Figure 2—Dendrogram from cluster analysis of the high-oleic and normal peanut genotypes considering chemical and sensory variables.

Table 4—Means of consumer acceptance, chemical variables, and descriptive analysis attributes in groups of high-oleic and normal peanut genotypes from cluster analysis.

		Chemical variables				Significant descriptive analysis attributes[c,e]					
Groups of peanut genotypes[a,b]	Consumer acceptance[e]	O/L	PV[e]	AV	CD[e]	Roasted peanutty	Oxidized	Cardboard	Burnt	Sweetness	Bitter
A ($n = 3 \times 1$)[d]	6.42 bc	1.13 a	5.19 c	1.09 b	4.16 c	52.42 a	12.30 b	11.46 b	12.33 a	17.03 b	8.81 a
B ($n = 3 \times 1$)[d]	5.79 a	1.32 a	3.55 b	1.08 b	2.53 b	52.70 a	12.44 b	12.51 c	14.60 b	14.54 a	11.38 b
C ($n = 3 \times 4$)[d]	6.64 c	16.18 b	0.97 a	0.44 a	1.44 a	55.80 b	9.14 a	10.65 a	13.96 a	16.98 b	8.25 a
D ($n = 3 \times 10$)[d]	6.05 ab	15.24 b	0.89 a	0.43 a	1.54 a	53.03 a	10.21 a	11.38 b	14.27 a	16.12 b	9.16 a

[a]Groups from CA: *Group A*: Tegua (1); *Group B*: 4495-1-B (15); *Group C*: Granoleico (2), FMR-458 (14), 4896-11-C (6), 9399-10 (13); and *Group D*: Tegua 87.5% (3), 4896-1 (4), 4896-4 (5), 4896-11-D (7), 4896-13-A (8), 4896-13-BD (9), 4896-13-F (10), 7698-5-C (11), 7698-2-E (12), 4896-13-C (16).
[b]Means followed by the same letters in each column showed no significant differences among peanut groups (ANOVA and Duncan test. $\alpha = 0.05$).
[c]Descriptive attributes that showed significant differences among peanut groups.
[d]The "*n*" value is calculated multiplying the 3 repetitions by the number of genotypes in the groups.
[e]The results were expressed as meqO_2/kg in PV and extinction coefficient E (1%, 1 cm) in CD. Overall acceptance was measured in a hedonic scale of 9 points. Attribute intensity rating of the descriptive analysis was measured in an unstructured line scale of 150 mm.

difference in sensory attributes as roasted peanutty, oxidized, and cardboard flavors that were related negatively with consumer acceptance. In these groups, the sensory attributes as burnt flavor, sweetness, and bitterness did not have significant difference. The HO peanut group, group C had higher consumer acceptance and roasted peanutty flavor and lower cardboard flavor than the HO peanut group, group D. However, both groups exhibited similar chemical values (PV, PA, and CD) and some sensory attributes as oxidized, burnt, sweetness, and bitter flavors. The higher consumer acceptance in group C with respect to group D could be influenced by higher roasted peanutty flavor and lower cardboard flavor. In cardboard flavor, group C showed the lowest intensity and group B, the highest intensity of this attribute. Cardboard attribute is related to lipid oxidation process and it is a negative sensory attribute in peanuts (St. Angelo 1996; Johnsen and others 1988). Group D showed significant lower PV, AV, CD, oxidized, cardboard, burnt, bitter, and significant higher sweetness than group B. However, group D did not have significant higher consumer acceptance score compared to group B. Sweetness and bitterness had inverse relation: group B had the lowest intensity of sweetness and the highest intensity of bitter attribute. These sensory results could direct the development of new HO peanut cultivar using HO peanut genotypes lines from the group C.

Conclusions

The results from the PCA indicated in general that roasted peanutty and sweetness were positive attributes and cardboard and oxidized flavors were negative attributes from the descriptive analysis in relation to the overall acceptance from the consumer test of roasted peanuts. The chemical indicators of lipid oxidation (PV, AV, and CD) were also negatively related to consumer acceptance; in addition, these lipid oxidation indicators were positively related to the negative descriptive attributes (oxidized and cardboard flavors). This relation between variables was observed in a group of HO peanut genotypes (group C) from the cluster analysis.

Some high-oleic peanut breeding lines did not show significant differences with respect to normal peanut cultivars (Tegua and 4495-1-B) and high-oleic peanut cultivars (Granoleico and FMR-458) in consumer acceptance. Besides, these some high-oleic peanut lines, high-oleic cultivars, and normal cultivars have similar intensities ratings in sensory attributes. Particularly, the high-oleic peanut line, 9399-10 (13) had higher overall acceptance and roasted peanutty flavor than normal peanut cultivars. For that, some of the high-oleic peanut lines produced in Argentina could be used to replace normal peanut cultivars without affecting consumer acceptance of peanut products. In addition, peanut products prepared with high-oleic peanuts will have the advantage of possessing high stability against lipid oxidation process.

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