Sensory and Chemical Stabilities of High-Oleic and Normal-Oleic Peanuts in Shell During Long-Term Storage

María Paula Martín, Antonella Luciana Grosso, Valeria Nepote, and Nelson Rubén Grosso

Abstract: Oxidative rancidity is one of the major causes of peanut quality deterioration. The in-shell nut industry's greatest concern is to preserve high quality and extended the shelf life of these products. This research determined the sensory and chemical stabilities of raw in-shell high-oleic and normal-oleic peanuts during long-term storage. In-shell peanuts samples of normal- and high-oleic types were stored at room temperature (23 °C) for 675 days. The quality parameters, like the fatty acid composition, moisture content, free fatty acids (FFA), peroxide value (PV), conjugated dienes (CD), and *p*-anisidine value (pAV), as well as sensory attributes, were analyzed every 45 days. High-oleic samples showed a 4.36-fold higher oleic acid/linolenic acid (O/L) ratio (O/L = 10.65) than normal-oleic peanuts (O/L = 2.44). FFA, PV, CD, pAV, and oxidized and cardboard flavors increased in all stored samples but especially in normal-oleic peanuts. Conversely, roasted peanutty flavor decreased in all samples during storage but in lower proportion in high oleic peanut samples. The sensory and chemical changes that occurred in unshelled normal- or high-oleic peanut samples were not remarkable, suggesting that the shell may protect peanut kernels against deterioration. However, in-shell high-oleic samples show greater stability and shelf life than normal-oleic peanuts under the studied storage condition.

Keywords: groundnut, oxidation, quality, stability, unshelled

Practical Application: Quality preservation of peanuts is important for the food industry using peanuts as an ingredient. Peanut processors are concerned as to the best ways to preserve peanut quality for long-term storage. Raw high oleic peanuts kept in the shells show better preservation of their sensory and quality properties during storage. In-shell peanuts constitute an appropriate alternative to preserve chemical and sensory properties of this product.

Introduction

World peanut production totals approximately 40.5 million metric tons per year, with China as the world's largest producer, followed by India and the United States (USDA, 2017). Harvested in-shell, peanuts are moved in bulk from the field to the industrial plants, using trucks. Then, several manufacturing steps occur: precleaning to eliminate ground and foreign materials, drying to decrease the moisture and avoid mold growth, and storage. At this point, manufacturers have the option of storing in-shell peanuts or removing the hulls to give raw shelled peanuts (Cowart, Powell, Locke, Starling, & Takash, 2016). In Argentina, which is an important world peanut producer, the harvested peanuts without processing (unshelled peanuts) are kept in grain storage warehouses at room temperature for more than 1 year because it is the most economical way to store peanuts for a long term.

Peanuts contain approximately 45% to 55% oil. Their high lipid content along with their high percentage of unsaturated fatty acids make peanut seeds prone to lipid oxidation (Shahidi & John, 2013). Oxidative rancidity is one of the major causes of quality deterioration owing to the formation of free radicals and numerous aliphatic aldehydes, ketones, and alcohols responsible for the development of undesirable flavors in peanut products (Wang, Adhikari, & Hung, 2017b). Oxidative changes also lead to the destruction of some nutritive molecules, such as tocopherols (Silva, Martinez, Casini, & Grosso, 2010). Also, free radicals are produced that can have an impact on human health, increasing the risk of cardiovascular diseases and cancer (Hashempour-Baltork, Torbati, Azadmard-Damirchi, & Savage, 2016).

Owing to their unique flavor and nutritional composition, peanuts are frequently used in the preparation of new and improved food products. Whether used as whole food or a primary ingredient, peanut seeds must be preserved throughout the marketing chain. Many factors influence the shelf life of peanut and peanut by-products, such as type, breeding lines, kernel ripeness at harvest, seed size, and processing and storage conditions like temperature, time, light, and oxygen (Talbot, 2016).

Nowadays, 2 Runner type peanuts are mainly produced in the world: high-oleic and normal-oleic cultivars. In comparison to normal-oleic peanuts, high-oleic peanuts have more oxidative stability after the roasting process (Nepote, Olmedo, Mestrallet, & Grosso, 2009). Consequently high-oleic peanuts are more suited to the preparation of various kinds of peanut products, like dry roasted peanuts, oil-roasted peanuts, peanut paste/butter, among others (Nepote, Mestrallet, Accietto, Galizzi, & Grosso, 2006a; Nepote, Mestrallet, & Grosso, 2006b; Riveros et al., 2010).

JFDS-2018-0573 Submitted 4/25/2018, Accepted 6/27/2018. *Authors Martín, AL Grosso and NR Grosso are with Facultad de Ciencias Agropecuarias, Univ. Nacional de Córdoba (UNC), Instit. Multidisciplinario de Biología Vegetal (IMBIV), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Ing, Agr. Félix Aldo Marrone 746, CC 509, X5016GCA, Córdoba, Argentina. Author Nepote is with Facultad de Ciencias Exactas, Físicas y Naturales (UNC), IMBIV-CONICET, Córdoba, Argentina. Direct inquiries to author Nelson R. Grosso (E-mail: nrgrosso@agro.unc.edu.ar).*

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However, to date, no literature is available on the stability of raw high-oleic peanuts in comparison to raw normal-oleic peanuts.

According to earlier authors (Chang, Sreedharan, & Schneider, 2013; Mozingo, O´Keefe, Sanders, & Hendrix, 2004), the in-shell nut industry´s greatest concern is to preserve the high quality of these products over an extended shelf life, avoiding rancidity reactions until consumption. Chang et al. (2013) indicated that to maintain a moisture content appropriate for avoiding spoilage by microorganisms, raw unshelled peanuts are more effective and can be stored for a longer duration relative to raw shelled peanuts. Nevertheless, a study of the sensory and chemical quality of raw unshelled peanuts stored over a prolonged period has not yet been performed. The objective of this study was to determine the sensory and chemical stabilities of raw in-shell high-oleic and normal-oleic peanuts during long-term storage.

Materials and Methods

Materials

In-shell peanut samples (type Runner, crop 2013) were provided by seven Argentinean companies that process peanuts: Lorenzati (1), Agrotransporte (2), Dichiara (3), Empresa NN (4), Manisel (5), Grupo Ckoops (6), and Prodeman (7). Peanut samples were classified in normal peanuts: N1, N2, N3, N4, N5, N6, and N7, and high oleic peanuts: HO1, HO2, HO3, HO4, HO5, and HO6. Normal and high oleic Runner peanuts belonged to the variety (cultivar) 'and N7 and 'Granoleico', respectively. They were harvested using agricultural industrial machinery (digging and threshing) and transported in bulk using trucks to the processing factories. Likewise, peanut samples used in this research were cultivated and harvested in the same area (around General Cabrera, Cordoba).

Storage conditions and sampling

The samples (seven of normal peanuts and six of high oleic peanuts) were separately packed in jute bags (three repetitions of each sample) and stored at room temperature (23 ± 3 °C) and 64 ± 10% relative humidity to simulate industrial storage conditions for 675 days. Samples were removed from storage every 45 days to analyze chemical and sensory quality parameters. These storage conditions were chosen because they are the regular conditions used to store peanuts in shell.

Chemical analysis

The peanut moisture content was determined by the AOAC method 27.500 (AOAC, 2010). Peanut oil was obtained by cold pressing using a 20-ton press (HE-DU, Hermes I. Dupraz S.R.L., Córdoba, Argentina).

Fatty acid profile was determined on peanut oil samples at the beginning of the study (day 0). Fatty acid methyl esters (FAMEs) were prepared by transmethylation using a 30 g/L solution of sulphuric acid in methanol. The fatty acid methyl esters were analyzed using a Perkin Elmer Clarus 600 gas liquid chromatograph (Waltham, MA, U.S.A.). A SAC^{TM}-5 capillary column (30 m × 0.25 mm i.d., 0.25 mm film thickness; C#24156, Supelco) was used. The separated fatty acid methyl esters were identified by comparing their retention times with those of authentic samples purchased from Sigma Chemical Co. (St Louis, MO, U.S.A.). Quantitative fatty acid analysis was performed using heptadecanoic acid methyl ester (Sigma Chemical Co.) as internal standard. Iodine value (IV) was calculated from the fatty acid composition using the formula:

$$IV = (\%\,C18{:}1 \times 0{,}8601) + (\%\,C18{:}2 \times 1{,}7321) + (\%\,C20{:}1 \times 0{,}7854)$$ (Asensio, Grosso, & Juliani, 2015).

Chemical indicators of lipid oxidation were determined on peanut oil samples. Peroxide value (PV) was reported as milliequivalents of oxygen per kilogram of oil ($meqO_2/kg$) (AOAC, 2010). Conjugate dienes (CD) were measured at 232 nm in a spectrophotometer UV-V Diode Array (Hewlett Packard^{TM} HP 8452 A, Palo Alto, CA, U.S.A.) and expressed as extinction coefficient (E 1%, 1 cm) (COI, 2001). *p*-anisidine value (p-AV) was determined according to IUPAC (1987). Free fatty acids (FFA) were reported as oleic acid/100 g peanut oil (AOAC, 2010).

Sensory descriptive analysis

For sensory analysis, peanut hulls were manually removed from samples. Peanut kernels were roasted at 155 °C for 20 min in an air circulation oven (Garmont, Alta Gracia, Argentina). After the roasting process, samples were cooled off at room temperature and manually blanched removing the peanut skins before to perform the sensory analysis (Martín, Nepote, & Grosso, 2016). Trained sensory panelists (seven women and two men) with 6 years of experience in evaluating peanut products participated in the descriptive analysis evaluation. After being qualified, all panelists demonstrated the ability to identify five of seven commonly found food flavors in a taste sensitivity test according to Meilgaard, Civille, and Carr (2006). After selection, the judges were trained and calibrated in 4 sessions for 4 days according to Nepote et al. (2009). During these training sessions a list of definitions and reference intensity ratings were developed. After reviewing definitions, descriptors and references, panelists were calibrated by obtaining a mean rating with a standard deviation within 10 points. After re-evaluated samples and reaching a consensus within these parameter, medium roasted peanuts were presented (warm-up) and were used as the initial sample during training and tasting sessions. This warm up sample improves judges response reliability according to Plemmons and Resurreccion (1998). A 'hybrid' descriptive analysis method combining the quantitative descriptive analysis (Tragon Corp., Redwood City, CA, U.S.A.) and Spectrum TM analysis (Sensory Spectrum, Inc., Chatham, NJ, U.S.A.) was used for evaluating samples (Grosso & Resurreccion, 2002; Meilgaard et al., 2006). Attribute intensity ratings were measured in a 150 mm unstructured linear scale. Peanut samples were evaluated by panelists in individual booths under fluorescent light at room temperature. Ten grams of the peanut samples were placed into plastic cups with lids coded with 3-digit random numbers. Data were registered on paper ballots. Samples were tested in a completely randomized block design so that all judges evaluated all treatment combinations (Martín et al., 2016).

Statistical analysis

Data were analyzed using INFOSTAT software Version 2015p (Facultad de Ciencias Agropecuarias, Univ. Nacional de Córdoba, Córdoba, Argentina). Means and standard deviations were calculated. ANOVA and LSD Fisher's multiple range test were developed to find significant differences among means in data from chemical and sensory analysis of peanut samples during storage ($\alpha = 0.05$). Simple linear equations were used for regression between storage time and dependent variables evaluated on peanut samples (Nepote et al., 2009; Olmedo et al., 2009). Diagnosis tests were conducted to probe the regression assumptions (statistical

Table 1–Fatty acid composition (relative percentage %) of in-shell raw peanuts.

Fatty acids	Normal peanuts[a]	High Oleic peanuts[a]
Palmitic acid (C16:0)	7.10 ± 1.06 B	5.48 ± 0.35 A
Stearic acid (C18:0)	2.59 ± 0.09	2.51 ± 0.12
Oleic acid (C18:1)	57.89 ± 6.18 A	76.33 ± 1.94 B
Linoleic acid (C18:2)	25.16 ± 5.51 B	7.65 ± 1.90 A
Linolenic acid (C18:3)	0.20 ± 0.03	0.18 ± 0.04
Arachidic acid (C20:0)	1.03 ± 0.05	1.03 ± 0.07
Eicosenoic acid (C20:1)	2.02 ± 0.21 A	2.49 ± 0.09 B
Behenic acid (C22:0)	3.29 ± 0.18	3.42 ± 0.14
Erucic Acid (C22:1)	0.24 ± 0.04 A	0.34 ± 0.04 B
Lignoceric acid (C24:0)	1.40 ± 0.12	1.42 ± 0.11
Oleic/linoleic ratio	2.44 ± 0.77 A	10.65 ± 3.28 B
Saturated/unsaturated ratio	0.18 ± 0.02 B	0.16 ± 0.01 B
Iodine value	94.93 ± 4.09 B	80.86 ± 1.79 A

[a]Means ± standard deviations followed by different letters in each row indicate significant differences between peanut cultivars (n = 39, ANOVA and test LSD, $\alpha = 0.05$).

independence of the errors, normal distribution with mean = 0 and homoscedasticity). Principal component analysis (PCA) was performed to explore associations between treatments, chemical, and sensory variables. Pearson coefficients were calculated to determine correlations between dependent variables of peanut storage study.

Results and Discussion

Fatty acid composition

The peanut samples from different companies were grouped into normal-oleic and high-oleic peanuts, due to their similarities in fatty acid composition. The relative percentage of each fatty acid in normal- and high-oleic peanuts revealed significant differences in their fatty acid composition (Table 1). Normal-oleic peanuts tended to have lower oleic (C18:1), eicosenoic (C20:1), and erucic (C22:1) acids, O/L ratio, and higher palmitic (C16:0), linoleic (C18:2), and linolenic (C18:3) acids, S/U ratio, and iodine value than high-oleic peanuts. The O/L ratios were about 4.36-fold higher in high-oleic samples (O/L = 10.65) compared to normal-oleic peanuts (O/L = 2.44). A similar composition was found in previous works on Argentinean peanuts (Martín et al., 2016; Nepote et al., 2006a). This difference in composition suggests that in-shell high-oleic peanuts would be more stable against oxidation of their lipids when compared with normal-oleic peanuts. Despite no past investigations involving storage of raw in-shell peanuts, information is available comparing roasted shelled normal- and high-oleic peanuts during storage (Nepote et al., 2006a, 2006b; Wilkin, Ashton, Fielding, & Tatham, 2014). Those investigations highlight the longer shelf life associated with the high-oleic trait relative to the normal-oleic trait.

Chemical indicators

The chemical indicators of the peanut samples (moisture, FFA, lipid oxidation indicators) during storage are demonstrated in Figures 1 and 2. Moisture (Figure 1a) remained approximately constant for all peanut samples during the entire 675 days of storage. The mean moisture value of all samples was 5.57 g/100 g, with a minimum of 3.87 g/100 g and a maximum of 8.27 g/100 g. Significant differences between samples and days were not found. Martín et al. (2016) reported a decreasing trend in moisture content that was greater in raw peanuts stored at 40 °C in ventilated bags than in high-barrier bags.

The FFA (Figure 1b) accumulated during storage for all peanut samples. However, significant differences between peanut cultivars

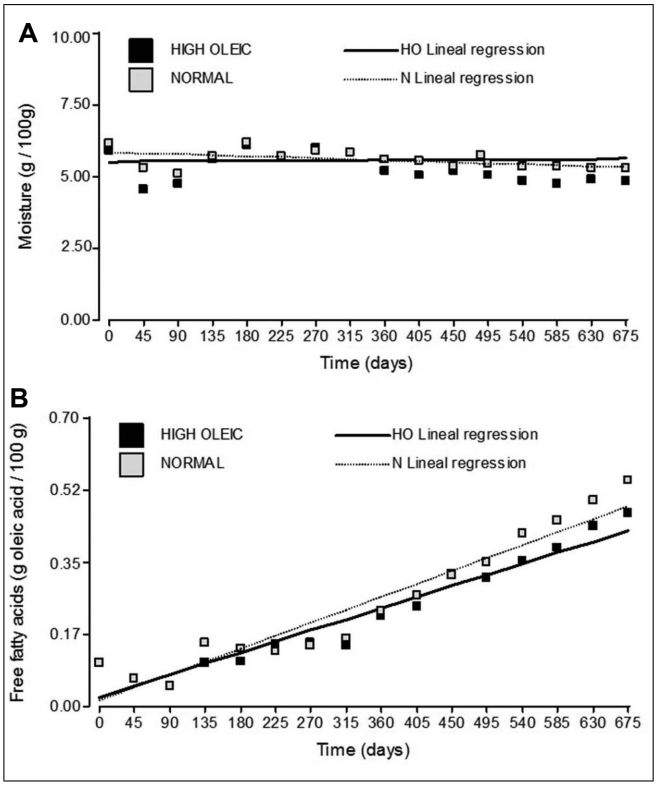

Figure 1–Mean values and linear regression curves of chemical variables: (A) moisture content and (B) free fatty acids evaluated in in-shell raw peanut samples: normal (N) and high oleic (HO) during storage at 23 °C and 64 ± 10% relative humidity.

were not observed. All samples had FFA averages of 0.10 g oleic acid/100 g at the beginning of the study (0 days of storage) and reached 0.47 to 0.55 g oleic acid/100 g at the end of storage (675 days). Thus, the FFA values in this work were kept within the acceptable limits (<1.00 g oleic acid/100 g) (Codex-Stan 200, 1995). Talbot (2016) indicated that FFA are released by the hydrolytic breakdown of the triglyceride molecule. Besides the presence of an active lipase, these types of reactions rely on the presence of water. The lack of significant differences for FFA between samples in the present investigation could be due to the absence of significant differences in their moisture contents. Nevertheless, the amount of existing water allows for the occurrence of these types of deterioration reactions.

Lipid oxidation indicators, PV (Figure 2a), CD (Figure 2b), and pAV (Figure 2c), intensified in all samples throughout the storage. Initially, both groups presented low values of these indicators (PV = 0.38 to 0.50 meqO_2/kg, CD = 0.66 to 0.76 E 1%, 1 cm, pAV = 0.07 to 0.10), without significant differences between each other. Overall, however, the high-oleic samples showed lower increment tendencies in all these indicators than normal-oleic peanuts, during storage.

Both groups showed significant differences in PV and pAV after 270 days of storage, and in CD after 180 days. Normal- and high-oleic samples reached the following values after 675 days of storage: PV: 2.04 and 1.66 meqO_2/kg, CD: 4.97 and 3.70 E 1%, 1 cm, and pAV: 2.89 and 1.49, respectively. Increasing trends in these chemical indicators for raw peanuts were also established in previous works (Chun, Lee, & Eitenmiller, 2005; Martín et al., 2016). The maximum PV expected in raw peanuts is 2 meq O_2/kg oil (Sanders, Adelsberg, Hendrix, & McMichael, 1999). In the

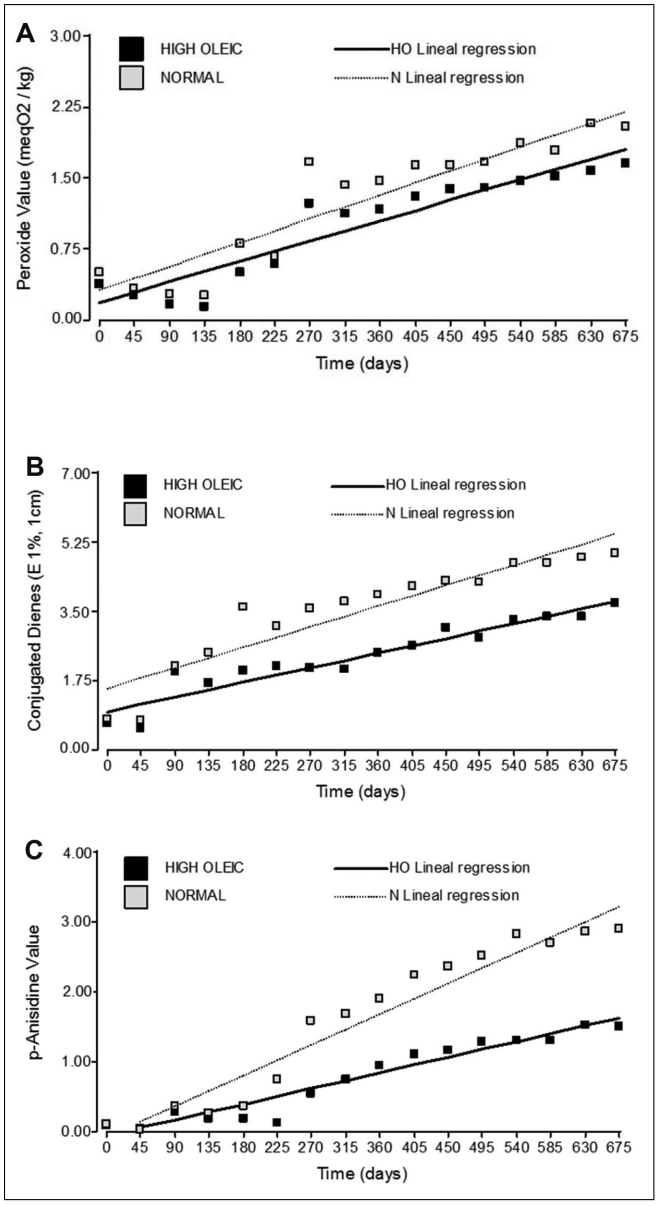

Figure 2–Mean values and linear regression curves of oxidation indicators: (A) peroxide value, (B) conjugated dienes, and (C) *p*-anisidine value evaluated in in-shell raw peanut samples: normal (N) and high oleic (HO) during storage at 23 °C and 64 ± 10% relative humidity.

present investigation, only normal-oleic peanuts reached this tolerance level at the end of storage. Wilkin et al. (2014) compared the rates of lipid oxidation between roasted shelled high-oleic and conventional peanuts at 30 °C. Accordingly, a PV of approximately 20 meq O_2/kg for conventional peanut cultivars was recorded after 6 to 7 weeks of storage while high-oleic peanuts reached a PV of 15 meq O_2/kg oil after storage for 20 weeks. Furthermore, Chun et al. (2005) investigated the stability of raw and roasted shelled peanuts stored at 21 °C under air and vacuum. They found that raw peanuts had higher stability (PV < 2 meq O_2/kg after 38 weeks under air), whereas, under the same conditions, the PV of roasted peanuts rapidly increased, reaching 47 meq O_2/kg at 12 weeks. Considering the present and previous results, the shells could act as a protective system, avoiding oxygen permeability and thus, maintaining oxidative indicators below those values reached by shelled products. Raw peanuts, either high-oleic or normal-oleic cultivars, present good oxidative stability when retained in the shell, extending their shelf life.

Table 2–Intensity ratings (0-150 mm linear unstructured scale) of sensory attributes evaluated on in-shell raw peanut samples (0 storage days).

Sensory attribute	Normal peanuts[a]	High Oleic peanuts[a]
Brown color	39.10 ± 4.62	39.29 ± 3.63
Glossiness	18.20 ± 2.96	17.94 ± 3.01
Roughness	19.53 ± 3.86	20.17 ± 3.40
Oxidized	2.28 ± 2.48 B	0.89 ± 2.32 A
Cardboard	3.90 ± 3.46	3.89 ± 2.64
Roasted peanutty	79.50 ± 11.33	81.66 ± 8.64
Sweetness	21.65 ± 2.54 A	22.60 ± 2.75 B
Saltiness	5.45 ± 0.88	5.31 ± 0.76
Sourness	3.80 ± 3.09	3.34 ± 2.71
Bitterness	5.43 ± 2.01	5.31 ± 1.47
Astringency	10.13 ± 2.64	9.91 ± 3.03
Crunchiness	46.48 ± 3.80	47.03 ± 3.43
Hardness	51.85 ± 2.41	51.31 ± 3.04

[a]Means ± standard deviations followed by different letters in each row indicate significant differences between peanut cultivars (n = 39, ANOVA and test LSD, $\alpha = 0.05$).

Sensory analysis

The intensity ratings of sensory attributes evaluated on peanut samples at day 0 (Table 2) corroborated those examined previously in various peanut products. Such products include roasted peanuts (Martín et al., 2016; Mestrallet, Nepote, Quiroga, & Grosso, 2009; Nepote et al., 2006a), fried-salted peanuts (Nepote et al., 2006b; Olmedo, Asensio, Nepote, Mestrallet, & Grosso, 2009; Olmedo, Nepote, & Grosso, 2012a), peanut paste (Riveros et al., 2010), and peanuts with edible coatings (Mestrallet et al., 2009; Olmedo, Nepote, & Grosso, 2012b; Riveros, Mestrallet, Quiroga, Nepote, & Grosso, 2013). In this study, all peanut samples had a similar initial sensory profile. Isleib et al. (2015) indicated that a critical point for processors is the identification of flavor differences between high-oleic and conventional peanuts cultivars. In that study, a few significant differences in the sensory profile between high-oleic and normal-oleic peanuts occurred. These findings correlate with the results of this study, where the oxidized flavor and sweetness were the only attributes with significant differences between peanut cultivars, and high-oleic peanuts had more intense sweetness and less oxidized flavor intensities than normal-oleic peanuts.

Roasted peanutty flavor, hardness, crunchiness, and brown appearance were the sensory attributes with the highest intensity ratings in all samples, and without significant differences between cultivars. Oxidized and cardboard attributes are related to lipid oxidation processes, and in the present evaluation, their intensities were lower than 4 (scale 0 to 150 mm) in all samples, indicating fresh products. Wang, Adhikari, and Hung (2017a) studied the acceptability and preference drivers of normal- and high-oleic, shelled and in-shell roasted peanuts and informed no significant differences in the roasted peanutty attribute among the samples. These conclusions could indicate that the roasted peanutty flavor is a pleasant aroma that is not altered by the presence of the peanut shell.

On the whole, most sample attributes changed little during storage. However, oxidized, cardboard, and roasted peanutty flavors had significant differences throughout storage and between cultivars (Figure 3). Peanut cultivars showed significant differences in oxidized flavor at 90 days, in cardboard flavor at 225 days, and in roasted peanutty flavor at 540 days of storage. At the end of the study, high-oleic samples had a higher roasted

peanutty flavor, and lower oxidized and cardboard flavors than normal-oleic peanuts. These findings were consistent with those found by Reed, Sims, Gorbet, and O'Keefe (2002). Moreover, Nepote et al. (2009) studied the relationships among consumer acceptance, chemical oxidation indicators, and sensory attributes in high-oleic and normal-oleic peanuts. The authors highlighted that high-oleic cultivars were better associated with the sensory attributes, sweetness and roasted peanutty flavors than normal-oleic peanuts. Conversely, Isleib, Pattee, Sanders, Hendrix, and Dean (2006) found slightly greater intensities of roasted peanut, astringent, over-roast, and nutty attributes, and minor decreases in the intensities of the cardboard and painty sensory attributes in the high-oleic compared to normal-oleic peanut lines. Those authors concluded that on average, the high-oleic trait does not appear to have a major impact on sensory quality, although there were individual instances in which the trait was associated with differences in sensory attribute intensities that may be perceptible to consumers.

A review published by Derbyshire (2014) indicated that when compared with normal-oleic peanuts, a higher O/L ratio and lower values for oxidation indicators in high-oleic peanuts enhanced their sensory profile and acceptability, and reduced the oxidized flavors. Such conclusions support the findings in this work.

Regression analysis

Regression equations of FFA, PV, CD, pAV, and sensory attributes (oxidized, cardboard, and roasted peanutty flavors) in roasted peanut samples throughout storage, as shown in Table 3, are also represented in scatter plots (Figure 1 to 3). All models were significant ($P < 0.01$, analysis of variance from the regression), and most of them had $R^2 > 0.60$. Differences in tendencies (β_1, the slope from the linear regression) between samples during storage were observed in pAV and cardboard flavor. High-oleic peanuts displayed lower increasing trends of these variables during storage than normal-oleic peanuts.

The linear equations could be used to predict the shelf life of unshelled raw peanuts. Considering the maximum PV expected in raw peanuts (2 meq O_2/kg oil), high-oleic cultivars had a shelf life of 756 days and normal-oleic varieties of 602 days, respectively, when stored unshelled at room temperature. Although unshelled raw peanuts had a long shelf life, high-oleic peanuts displayed 1.25-fold the shelf life with respect to normal-oleic peanuts.

Storage assays and shelf life analyses have already been investigated in several peanut products (Martín et al., 2016; Nepote et al., 2006a, 2006b; Nepote, Mestrallet, & Grosso, 2004; Olmedo et al., 2009; Riveros et al., 2010) but previous storage studies of unshelled raw peanuts are not found. For roasted peanuts, 10 meq O_2/kg is considered a limiting PV. Nepote et al. (2006b) found shelf lives of 8 and 202 days for roasted shelled normal-oleic peanuts (Tegua) and roasted shelled high-oleic peanuts (Granoleico), respectively, stored at room temperature (23 °C). Shelf lives between 19 and 34 days were established in honey roasted peanuts, also stored at room temperature (23 °C) (Nepote et al., 2004). It is known that roasted peanuts exhibit a significantly shorter shelf life than raw peanuts (Chun et al., 2005) as consequence of roasting process that trigger the autooxidation reaction. The findings of the current research indicate that the shell acts to extend the sensory and chemical qualities for a longer duration in comparison to the shelled product, especially if raw peanuts are stored in-shell.

PCA and correlation analysis

PCA was conducted to establish associations between the dependent variables (chemical and sensory) and the stored in-shell peanut samples, and a biplot of the first two principal components (PC) obtained by PCA was constructed (Figure 4). The first two PCs explained 69% variability in the samples during 675 days of storage. The variables, cardboard and oxidized flavors, pAV, and

Table 3–Coefficients and R^2 values from regression equations of free fatty acids (FFA), peroxide value (PV), conjugated dienes (CD), p-anisidine value (pAV) and sensory attributes (oxidized, cardboard, roasted peanutty flavors) in peanut samples during storage time.

	Normal peanuts			High oleic peanuts		
Dependent variable	β_0[a]	β_1[ab]	R^2	β_0[a]	β_1[ab]	R^2
Free fatty acids	0.0137	0.0007	0.8096	0.0224	0.0006	0.7874
Peroxide value	0.3142	0.0028	0.6904	0.1868	0.0024	0.7891
Conjugated dienes	1.5429	0.0058	0.5044	0.9552	0.0041	0.7567
p-Anisidine value	−0.0836	0.0049	0.7441	−0.0603	0.0025 A	0.7486
Oxidized	1.8613	0.0072	0.5847	0.9731	0.0061	0.7651
Cardboard	4.9720	0.0093	0.6829	4.4268	0.0066 A	0.7360
Roasted peanutty	80.1821	−0.0246	0.7507	80.3102	−0.0224	0.7245

[a]Regression coefficients for the general regression equation $Y = \beta_0 + \beta_1 X$. where Y is the dependent variable (FFA, PV, CD, pAV, oxidized, cardboard, roasted peanutty flavors) and X is the independent variable (days of storage).
[b]Slope coefficients (β_1) followed by different letter indicate significant differences between peanut cultivars (ANOVA and test LSD, $\alpha = 0.05$).

Table 4–Significant correlation coefficients ($P < 0.05$) between dependent variables evaluated on peanut samples: O/L ratio, free fatty acids (FFA), peroxide value (PV), conjugates dienes (CD), *p*-anisidine value (pAV), and oxidized, cardboard and roasted peanutty flavors.

	O/L	FFA	PV	CD	pAV	Oxidized	Cardboard
PV	−0.40	0.76					
CD	−0.53	0.59	0.62				
pAV		0.67	0.75	0.53			
Oxidized		0.67	0.67	0.77	0.71		
Cardboard		0.71	0.75	0.75	0.76	0.89	
Roasted peanutty	0.37	−0.75	−0.76	−0.66	−0.71	−0.80	−0.81

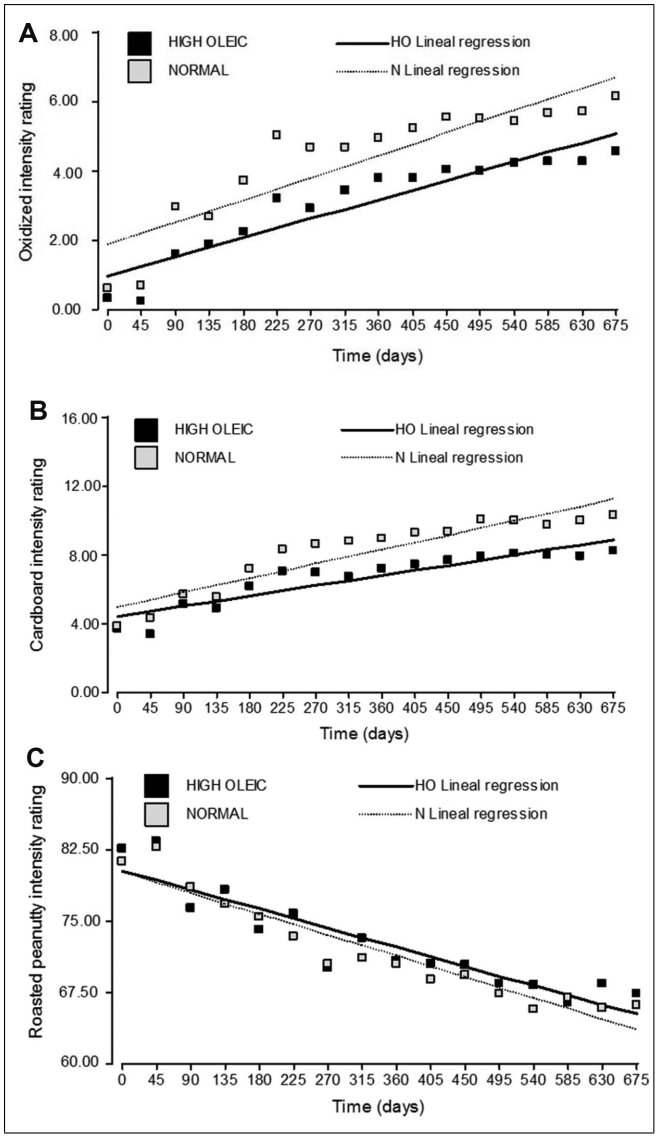

Figure 3–Average intensity ratings and linear regression curves of sensory attributes: (A) oxidized, (B) cardboard, and (C) roasted peanutty flavors evaluated in-shell raw peanut samples: normal (N) and high oleic (HO) during storage at 23 °C and 64 ± 10% relative humidity.

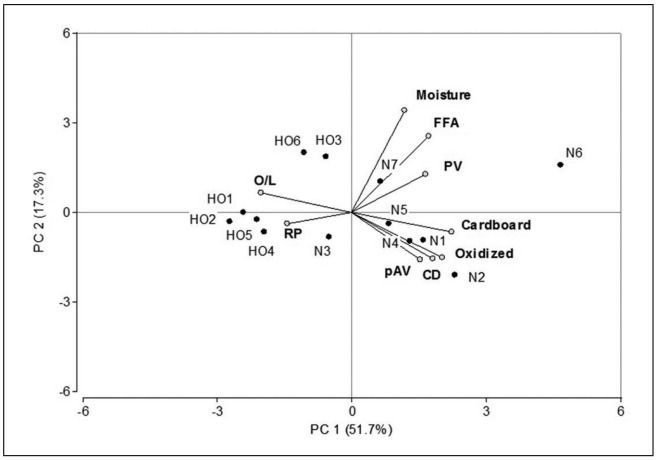

Figure 4–Biplot from the first and second components (PC) from principal component analysis. Variables: moisture content, oleic/linoleic ratio (O/L), free fatty acids (FFA), peroxide value (PV), conjugated dienes (CD), *p*-anisidine value (pAV), and oxidized, cardboard, and roasted peanutty (RP) flavors. Treatments: in-shell raw peanut samples from different companies and cultivars (normal = N and high oleic = HO) evaluated during 675 days of storage at 23 °C and 64 ± 10% relative humidity.

CD, were strongly and positively associated with each other and negatively associated with roasted peanutty flavor and the O/L ratio. Also, O/L ratio and roasted peanutty flavor were placed on the left-hand side of the biplot, clustered together with most of the high-oleic samples, except N3 peanuts. On the right-hand side of the biplot, normal-oleic peanut samples were linked with the other chemical and sensory variables, indicating a higher susceptibility of these samples to deterioration reactions relative to their high-oleic counterparts. Other association was observed between moisture content and FFA, which were not associated with other variables and samples.

Most of these associations were confirmed by correlation analysis (Pearson coefficients, *r*) (Table 4). Significant and positive correlation coefficients ($P < 0.05$) were observed among PV, CD, pAV, FFA, and oxidized and cardboard flavors, and between O/L and roasted peanutty flavor. Negative correlation coefficients ($P < 0.05$) were noted between O/L and PV and CD, and between roasted peanutty flavor and PV, CD, pAV, FFA, and oxidized and cardboard flavors. These results were due to the increase in PV, CD, pAV, FFA, and oxidized and cardboard flavors while roasted peanutty flavor decreased, as storage progressed. Previous researches reported relations between chemical and sensory variables for peanut products (Martín et al., 2016; Olmedo et al., 2009). Martín et al. (2016) assessed the impact of packaging materials on the chemical, microbiological, and sensory stability of stored raw peanuts. The authors noted positive associations among PV, CD, FFA, cardboard flavor, and O/L ratio, and negative correlation coefficients between moisture content, roasted peanutty flavor, and the variables mentioned above, for all samples. In that work, moisture and roasted peanutty flavor decreased while PV, CD, FFA, cardboard flavor, and O/L increased with storage.

Lin et al. (2016) examined the correlations between chemical components (proteins, lipids, oleic acid, linoleic acid) and volatile compounds in several different peanut cultivars. As a result, a positive correlation between oleic acid content and pyrazine compounds was revealed. Pyrazines are compounds associated with the characteristic flavor of roasted peanuts (Baker et al., 2003). These associations agreed with the present data (Figure 4 and Table 4), indicating that high-oleic cultivars had higher intensity ratings for roasted peanutty flavor than normal-oleic peanuts.

Conclusions

Some chemical changes in the different samples of in-shell raw peanuts were noticed throughout storage for 675 days. These chemical changes were reflected in sensory changes when peanut kernels were roasted, producing increases in oxidized and cardboard attributes, and decreases in the roasted peanutty flavor of stored peanuts. Overall, a comparison of the samples reveals that the differences in the fatty acid composition of the normal- and high-oleic cultivars produce differences in their chemical and sensory variables during storage. Both varieties were maintained in good condition for a prolonged time, suggesting the shell may protect peanut kernels, avoiding moisture changes, and lipid degradation by hydrolysis and oxidation. However, high-oleic samples have a longer shelf life than normal-oleic peanuts.

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Author Contributions

María Paula Martín and Antonella Luciana Grosso designed and interpreted the experimental essays. Valeria Nepote and Nelson Rubén Grosso contributed as co-advisor and advisor, respectively.

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