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ORIGINAL PAPER

Aguaribay and Cedron Essential Oils as Natural Antioxidants in Oil-Roasted and Salted Peanuts

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Abstract The study objective was to evaluate the antioxidant effect of aguaribay and cedron essential oils on oil-roasted and salted peanuts. Fried-salted peanuts (FP), fried-salted peanuts with addition of BHT (FP-BHT) aguaribay (FP-A) and cedron (FP-C) essential oils were prepared. Peroxide (PV) and *p*-anisidine (AV) values, conjugated dienes (CD) and sensory descriptive attributes were analyzed on the products during storage. The major compounds detected were 25.6 % spathulenol and 24.4 % geranial and 27.3 % neral in cedron essential oils and 12.7 % elemol, 11.7 % α-pinene, 9.3 % β-pinene, 8.3 % limonene and 8.2 % α-phellandrene in aguaribay essential oil. PV, AV and CD were lower in FP-BHT during storage. At storage day 112, PVs were 94.86, 82.74, 76.29, and 63.89 mequiv O_2 kg^{-1} in FP, FP-A, FP-C and FP-BHT, respectively. FP-C and FP-A had lipid oxidation values between FP and FP-BHT. The intensity ratings of oxidized and cardboard flavors increased more in the control sample (FP) than the other samples. At storage day 112, FP-A, FP-BHT and FP-C exhibited oxidized intensity ratings of 24.13, 24.9 and 26.1, respectively, lower than FP (35.83). Aguaribay and cedron essential oils showed protective effect against lipid oxidation in fried-salted peanuts. However, these essential oils could affect the sensory profile and consumer acceptance of this product.

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Introduction

Peanuts contain approximately 50–55 % oil. About 80 % of the peanut oil is composed of unsaturated fatty acids: 45–50 % oleic acid (18:1) and 30–35 % linoleic acid (18:2) [1]. This chemical composition makes peanuts and derived products susceptible to the development of rancid and off-flavors through lipid oxidation [2]. Oxidation and rancid flavors decrease the sensory quality of peanut products making them unacceptable to consumers [3]. In addition, lipid oxidation products have harmful effects on health, may cause heart diseases, anginas, mutagenesis, and others [4].

Synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and propyl gallate (PG) are used in many foods to prevent rancidity. However, their health safety has been questioned [5]. Natural antioxidants are presumed to be safe because they occur in nature and in many cases are derived from plant sources. Natural antioxidants have many advantages: they are accepted by consumers, considered safe and have less regulator requirements [6]. The antioxidant properties can be due to many substances including some vitamins, flavonoids, terpenoids, carotenoids and phytoestrogens [7].

Essential oils present in spice extracts are responsible for the characteristic aroma and these compounds can be removed by steam distillation at normal atmospheric pressure, but their antioxidant activity may be partially lost during heating. The obtained extracts may be further concentrated or separated into fractions by molecular distillation [8].

A variety of tests expressing antioxidant potency of food components have been suggested. These can be categorized into two groups: assays for radical scavenging ability and assays that test the ability to inhibit lipid oxidation under accelerated conditions [8, 9]. The features of an oxidation system are a substrate, an oxidant and an initiator, intermediates and final products. Measurement of any one of these can be used to assess antioxidant activity [8, 10].

A recent study reported antioxidant activities from essential oils of four oregano species that grow up in Argentina [11]. Different authors reported the antioxidant properties of essential oils of aromatic species such as oregano, rosemary and laurel, among others [6, 12–14]. However, antioxidant properties of aguaribay and cedron have not been reported on peanut products.

Aguaribay and cedron essential oils essential oils have shown antimicrobial properties [15, 16]. The chemical composition in these essential oils exhibits molecules such as α and β pinene and α and β phellandrene in aguaribay [17–19] and limonene and geranial in cedron [20, 21]. Many essential oils rich in terpenes in their composition have evidenced antioxidant activity. Essential oils from *Citrus sinensis* rich in limonene, and from *Eucalyptus camaldulensis* rich in *p*-cymene, 1,8-cineole, β-phellandrene and spathulenol, and from *Myrtus communis* L. rich in 1.8-cineole and methyl eugenol were reported with moderate antioxidant activity [22]. In addition, there are studies performed on aguaribay [15, 23] and cedron [24] that reported antioxidant activity in extracts of these plants.

The objective of this study was to evaluate the antioxidant effect of aguaribay and cedron essential oils on the oxidative stability of fried-salted peanuts.

Experiment Procedures

Peanuts

Sound and mature seeds of blanched peanuts (*Arachis hypogaea* L.) type Runner, size 38/42 kernels per oz (crop 2010) were provided by Lorenzati, Ruescht and Cia (Ticino, Córdoba, Argentina). Before processing, peanuts were inspected; damaged and bruised kernels were manually removed.

Essential Oils Extraction

Two aromatic species were used: leaves of aguaribay (*Schinus molle*) and cedron (*Aloysia triphyla*) were provided by the Facultad de Ciencias Agropecuarias—Universidad Nacional de Cordoba (Cordoba, Argentina). Plant material was collected in December, 2010. The essential oils were obtained by hydrodistillation according to Zygadlo et al. [13] and kept in dark glass flasks at −18 °C until they were used.

Essential Oil Chemical Analysis

A Perkin-Elmer® Clarus 600 GC–MS (Shelton, CT, USA) coupled with an ion trap mass detector equipped with a capillary column DB-5 (30 m, 0.25 mm i.d. and 0.25 mm coating thickness) was used for the separation of the essential oil components. Helium was the carrier gas with a flow rate of 0.9 mL/min. The temperature program was 60 °C for 5 min, rate of 5 °C/min and final temperature of 250 °C. The detector and injector temperatures were 280 and 260 °C, respectively. Ionization was performed by electron impact at 70 eV. Mass spectral data were acquired in the scan mode in the *m/z* range 35–450. The compounds were identified by comparing their retention times and mass spectra with NIST libraries. The main components were further identified by coinjection of authentic standards (SIGMA® St. Louis, MO, USA). The components were quantified by normalization of peak area and the response factor was considered to be 1 for all compounds.

Product Elaboration

Oil-Roasted (Fried) and Salted Peanuts (FP)

Peanuts were oil-roasted at 170 °C in refined sunflower oil (Natura, Aceitera General Deheza, General Deheza, Cordoba, Argentina) for 5 min in an oil-roaster (model Dupralys, Molinex, Shanghai, China). The degree of roasting was until a medium point that corresponded to a Hunter color, lightness (*L*) value of 50 ± 1.0 [25]. Two percent (w/w) of fine granulated salt (sodium chloride; Laboratorios Cicarelli, Santa Fe, Argentina) and 2 % (w/w) refined sunflower oil (Natura, Aceitera General Deheza, General Deheza, Córdoba, Argentina) were added onto the oil-roasted peanut kernels. After frying, peanut kernels were placed in a stainless steel coating pan rotating at 28 rpm. Then, refined sunflower oil was applied to the peanut kernels. The coating pan was kept rotating for 5 min to homogenize the distribution of sunflower oil on the product. Finally, the fine granulate salt was poured into the coating pan to coat the kernels. The objective to add refined sunflower oil was to gloss the finished product and to ensure that the salt stuck to the kernels.

Fried-Salted Peanut with Oregano Essential Oil (FP-O)

Fried-salted peanuts with the addition of "aguaribay" and "cedron" essential oils were prepared following the same procedure described for FP. The essential oil (0.02 % w/w of final product) was added to the fried peanut kernels. The "aguaribay" and "cedron" essential oils were included in the refined sunflower oil added after the frying process. Then, the refined sunflower oil was applied to the fried peanuts as described for FP preparation.

Storage Conditions and Samplings

After preparation of FP, FP-A and FP-C, samples were packaged into 27 × 28 cm plastic bags (Ziploc; Johnson & Son, Buenos Aires, Argentina). The weight of each sample was 150 g per bag. The product was packaged in a normal atmosphere with 21 % oxygen. The samples were stored at 23 °C (room temperature) in darkness, with 60–70 % relative humidity. Samples of each product were removed from storage for evaluation of changes in chemical and sensory indicators of lipid oxidation [26]. Samples were removed from storage at 28, 56, 84 and 112 days. Samples were also evaluated on day 'zero'.

Chemical Analyses

Determination of Free-Radical Scavenging Activity (test DPPH-FRSA) and Total Phenolic Content

The test DPPH (2,2-diphenyl-1-picrylhydrazyl) was measured according to Choi et al. [27]. The activity and was calculated according to the equation:

$$\text{Percentage of inhibition} = [(A_c - A_a)/A_c] \times 100$$

where A_c and A_a are values of absorbance taken after 30 min for the control and essential oil samples, respectively [28].

The phenol content assay was performed according to Dambolena et al. [29] using Folin-Cicolteau reagent.

Determination of Lipid Oxidation Indicators from Peanut Samples

The oil was obtained by a cold pressing process of 100 g fried-salted peanuts using a 20-ton press (HE-DU, Hermes I. Dupraz SRL, Córdoba, Argentina). For this procedure, 20 g oil was extracted and used for chemical analyses: peroxide [30], *p*-anisidine [31], and conjugate diene [32] measurements.

Sensory Descriptive Analysis

A total of 12 trained panelists (nine female and three male) participated in the descriptive analysis of fried-salted peanuts. Eight panelists had 9 years of experience evaluating peanut products. All panelists were trained and calibrated in four training sessions over 6 days. Each training session lasted 2 h. A hybrid descriptive analysis method consisting of the quantitative descriptive analysis (Tragon Corp., Redwood City, CA, USA) and the Spectrum TM analysis (Sensory Spectrum, Inc., Chatham, NJ, USA) methods were used for training and evaluation sessions [33, 34]. A 150-mm unstructured line scale was used for sample evaluation. A list of definitions and a sheet with warm-up and reference intensity ratings (Table 1) were developed during the training sessions [3, 35]. The attribute definitions were based on peanut lexicon [25].

All samples were evaluated in partitioned booths at room temperature under white light produced by 2 Lumilux Plus Eco fluorescent lamps of 58 W/840 cool white (OSRAM Argentina Compania de Lamparas Electricas SA, Buenos Aires, Argentina) with a light intensity of 5200 lumen per lamp. Ten grams of sample were placed into plastic cups with lids coded with three-digit random numbers. Panelists evaluated six samples and a warm-up sample per session. Before beginning the evaluation of the samples, the panelists re-tested 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 reported results were mean values obtained from all intensity measurements performed by the panelists for each attribute of each sample.

Statistical Analysis

The experiment was carried out with three repetitions. Three different lots of peanuts were used and each lot of peanuts was considered a repetition. The data were analyzed using InfoStat software, version 2007.p (Facultad de Ciencias Agropecuarias, Universidad Nacional de Cordoba). Means and standard deviations were calculated. Analysis of variance and the Fisher LSD test were used to determine significant differences between mean values ($\alpha = 0.05$). The Pearson coefficient was used to calculate correlation between dependent variables from chemical and sensory analyses. Regression equations were used to determine if the independent variable (time) had an effect on the chemical and on sensory variables.

Results and Discussion

Essential Oil Analysis

'The compounds and relative percentages (% area) of cedron and aguaribay essential oil separated by CG-MS analysis are presented in Table 2. The major compounds of cedron essential oil were 25.6 % spathulenol and two geometric isomers derived from citral: 24.4 % Geranial (*E*-isomer or citral A) and 27.3 % neral (*Z*-isomer or citral B). The citral isomers are terpenoids with functional carbonyl groups that have a strong odor and spathulenol is a sesquiterpene with hydroxyl functional groups. Rabbani et al. [36] determined that citral had antioxidant activity. The major compounds in aguaribay essential oil were

Table 1 Definitions of attributes, standard references and warm-up intensity ratings used in descriptive analysis of fried-salted peanuts with addition of aguaribay and cedron essential oils

Attribute[a]	Definition[b]	Reference	Reference intensity[c]	Warm-up intensity[c,d]	Samples intensity[c,e]
Appearance					
1-Brown color	The intensity or the strength of brown color from light to dark brown	Cardboard (lightness value, $L = 47 \pm 1.0$)	65	46	44.1 ± 0.2
2-Roughness	The appearance associated with uneven surface	Corn flakes[f]	85	35	37.3 ± 0.8
3-Glossiness	The appearance associated with the amount of light reflected by the product surface	Peanuts coated with chocolate[g]	58	53	45.7 ± 0.7
Aromatics					
4-Aguaribay essential oil aroma	The aromatic associated with essential oil of "aguaribay"	0.1 % "aguaribay" essential oil in sunflower oil[h]	45	0	35.4 ± 2.7
5-Cedron essential oil aroma	The aromatic associated with essential oil of "cedron"	0.1 % "cedron" essential oil in sunflower oil[h]	42	0	29.7 ± 0.9
6-Roasted peanutty	The aromatic associated with medium roasted peanuts	Dry roasted peanuts[i]	76	58	53.2 ± 0.5
7-Oxidized	The aromatic associated with rancid fats and oils	Rancid peanuts[j]	112; 30	5	6.5 ± 0.8
8-Cardboard	The aromatic associated with wet cardboard	Moist cardboard[k]	74	3	4.7 ± 0.7
Tastes					
9-Sweetness	Taste on the tongue associated with sucrose solutions	2.0 % sucrose solution	20	19	18.6 ± 0.5
		5.0 % sucrose solution	50		
		10.0 % sucrose solution	100		
10-Saltiness	Taste on the tongue associated with sodium chloride solutions	0.2 % NaCl solution	25	80	76.0 ± 1.3
		0.35 % NaCl solution	50		
		0.5 % NaCl solution	85		
11-Sourness	Taste on the tongue associated with acid agents such as citric acid solutions	0.05 % citric acid solution	20	7	9.9 ± 0.5
		0.08 % citric acid solution	50		
		0.15 % citric acid solution	100		
12-Bitterness	Taste on the tongue associated with bitter solutions such as caffeine	0.05 % caffeine solution	20	8	8.6 ± 1.1
		0.08 % caffeine solution	50		
		0.15 % caffeine solution	100		
Feeling Factors					
13-Astringency	The shrinking or puckering of the tongue surface	Tea infusion[l]	80	20	25.8 ± 1.1
Texture					
14-Hardness	Force needed to compress a food between molar teeth	Almonds[m]	80	45	44.7 ± 0.5
15-Crunchiness	Force needed and amount of sound generated from chewing a sample with molar teeth	Corn flakes[e]	95	47	46.7 ± 0.5

[a] Attributes listed in order as perceived by panelists

[b] The attributes definitions were based on a lexicon for peanut samples [25, 34]

[c] Intensity ratings are based on 150 mm unstructured line scales

[d] Medium roasted peanuts (lightness value, $L = 50 \pm 1$), Type Runner, Blanched, Cordoba, Argentina

[e] Intensity rating mean of sensory attributes from peanuts products measured on day "0" of storage

[f] Corn flakes, Granix, Buenos Aires, Argentina

[g] Peanuts coated with chocolate, ARCOR, Colonia Caroya, Córdoba, Argentina

[h] Refined sunflower oil (Natura, AGD, General Cabrera, Argentina)

[i] Dry roasted peanuts, type Runner, JL SA, Ticino, Córdoba, Argentina

[j] Dry roasted peanuts (type Runner, blanched, Córdoba, Argentina) stored at 40 °C during 120 days (intensity rating = 30) and 6 months (intensity rating = 112)

[k] Moist cardboard: 1 mL distilled water absorbed by 0.5 g cardboard

[l] Tea infusion: four tea bags (La Virginia, Córdoba, Argentina) soaked in 1 L of distilled water at 80 °C during 10 min

[m] Almonds, Grandiet, Córdoba, Argentina

Table 2 Chemical composition and relative percentage of terpenoids from cedron and aguaribay essentials oils analyzed by GC analysis

Cedron (*Aloysia triphylla*)			Aguaribay (*Schinus molle*)		
Compounds	%	SD	Compounds	%	SD
Alpha pinene	1.4	0.1	Tricyclene	1.0	0.1
6-Methyl-5-hepten-2-one	0.6	0.1	**Alpha pinene**	**11.7**	**0.2**
p-Cymene	1.1	0.1	**Beta pinene**	**9.3**	**0.2**
Myrcene	6.6	0.2	**Limonene**	**8.3**	**0.1**
Geranial	**24.4**	**0.2**	Thujene	1.1	0.1
Neral	**27.3**	**0.2**	Terpinen-4-ol	2.1	0.1
Spathulenol	**25.6**	**0.2**	Sabinene	4.7	0.1
Ar-curcumene	0.7	0.1	Pinocarvyl acetate trans	0.2	0.1
Dihydrocarvone cis	0.9	0.1	Pinocarveol cis	2.1	0.1
Dihydrocarvone trans	0.5	0.1	**Alpha phellandrene**	**8.2**	**0.2**
Limonene oxide cis	0.5	0.1	*p*-Cymene	4.3	0.1
Trans sabinol	0.4	0.1	Myrcene	3.6	0.2
Pinocarvyl acetate	0.4	0.1	Gamma muurolene	7.1	0.2
Farnesyl acetate EE	1.6	0.2	Isobornyl formate	1.5	0.1
Farnesyl acetate ZE	2.1	0.1	Gamma himachelene	0.7	0.1
Beta bisabolene	0.5	0.1	Germacrene D	1.5	0.1
Beta caryophyllene	1.6	0.1	Germacrene D-4-ol	1.7	0.1
Germacrene D	0.2	0.1	Fenchene alpha	5.1	0.2
Epi-alpha-cadino	0.2	0.1	Eudesmol gamma	2.8	0.1
Gamma muurolene	2.6	0.1	**Elemol**	**12.7**	**0.2**
			Camphene	5.1	0.2
			Delta cadinene	1.6	0.1
			Alpha cadine	0.4	0.1
Total	**99.2**		**Total**	**96.8**	

% percentage media, *SD* standard deviation

Bold letter denotes major compounds in the essential oil composition

elemol, α-pinene, β-pinene, limonene and α-phellandrene for 12.7, 11.7, 9.3, 8.3 and 8.2 %, respectively. α-phellandrene and limonene are rich in cyclic terpene. Elemol, and α and β-terpene have cyclic sesquiterpene and aliphatic terpene in their chemical structure, respectively. Selim [37] and Malhotra et al. [38] reported the antioxidant activity of elemol, α and β-pinene, and limonene. Terpenoids in plants are antioxidant by three different ways: quenching of singlet oxygen, hydrogen transfer, or electron transfer [39]. The chemical composition found in cedron and aguaribay essential oil indicates that these essential oils could act as natural antioxidant.

Free-Radical Scavenging Activities (Test DPPH-FRSA) and Total Phenolic Content

The total phenolic contents and free-radical-scavening activities (FRSA) are presented in Table 3. Cedron and aguribay showed significant differences in these chemical parameters. Cedron essential oil exhibited higher value in FRSA and phenolic content than aguaribay essential oil. Dambolena et al. [29] reported a 70 % FRSA and 18 mg/g phenolic content in oregano essential oil. These values observed in oregano essential oil were higher than in cedron and aguaribay essential oils. The high content of phenolic compounds like thymol, carvacrol and terpinen-4-ol in oregano essential oil could explain the observed differences with respect to the essential oils analyzed in this study.

Chemical Changes in Fried-Salted Peanuts During Storage

Changes in chemical indicators of lipid oxidation (peroxide value, *p*-anisidine value and conjugated dienes) during storage of the peanut samples are presented in Fig. 1. These chemical indicators increased with storage time in all peanut products (FP, FP-A, FP-C and FP-BHT). Similar tendencies were observed in previous researches on fried-salted peanuts prepared with Runner peanuts [40–42].

The PV, AV and CD were not significantly different ($\alpha = 0.05$) before day 28 (Fig. 1). From day 28 to day 112, all chemical indicators became significantly different. FP

Table 3 Total phenolic content (expressed as mg Gallic acid/g of dry weight) and free-radical scavenging activity (%) (FRSA) from cedron and aguaribay

Essential oil	Phenol content (mg/g of dry weight)[a]	FRSA (%)[a]
Cedron	14.06 ± 0.06[b]	48.18 ± 1.69[b]
Aguaribay	8.32 ± 0.09[a]	18.03 ± 2.13[a]

[a] Values with different letters in the same column are significantly different from each other according to Fisher's multiple range test at $P \leq 0.05$ ($n = 3$)

had the highest PV, AV and CD and FP-BHT had the lowest values of these chemical indicators during storage. FP-A and FP-C showed PV, AV and CD between FP and FP-BHT. In PV and AV, FP-C had lower values than FP-A. Conjugated dienes in FP-A and FP-C were not significantly different during storage. At day 112 of storage, CD values were 19.94 in FP, 16.66 in FP-A, 16.11 in FP-C and 12.65 in FP-BHT. These results indicate that fried-salted peanuts prepared with the addition of aguaribay and cedron essential oils prevented the lipid oxidation process in this food product decreased lipid oxidation process. Different researchers have reported on the antioxidant activity of essential oil. In in-vitro studies, it was shown that oregano and others essential oils had antioxidant activity [14]. This activity was associated with the chemical composition of essential oils that have phenolics components. Thus, phenolic compounds may be responsible for the antioxidant activity because they act as free radical terminators. The oxidation chain can be retarded via scavenging the chain-carrying radical by donating hydrogen. The essential feature of functioning of phenols as an antioxidant (AH) is that AH· species derived from phenoxy radicals produced from monophenolics exist even in an aqueous medium as non-charged species. The ortho-substitution with electron donating alkyl or methoxy groups of phenols increases the stability of the free radical and hence its antioxidant potential. The position and degree of hydroxylation of phenolic compounds is of primary importance in determining their antioxidant activity. The ortho and para positions of hydroxyl groups contribute markedly to the antioxidant activity while the meta position has little or no effect on the antioxidant property [29, 43]. Aguaribay and cedron have different components such as α and β pinene, *p*-cymene and α and β phellandrene in aguaribay [17] and limonene, geranial, trans-geraniol, nerol, among others in cedron [20] that present antioxidant activity.

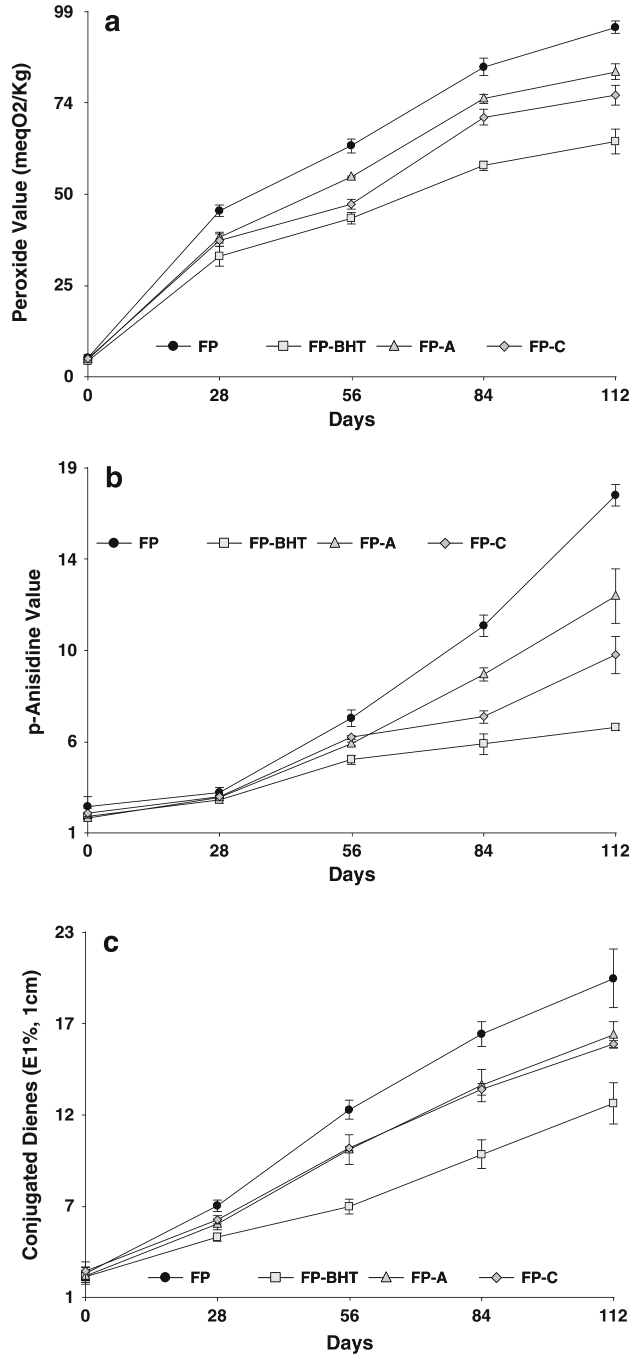

Fig. 1 **a** Peroxide value, **b** *p*-anisidine value and **c** conjugated dienes in fried-salted peanuts (FP) and fried-salted peanuts with addition of BHT(FP-BHT) aguaribay essential oil (FP-A) and cedron essential oil (FP-C) during storage time at 23 °C

Sensory Changes in Fried-Salted Peanuts During Storage

The mean intensity ratings of the fourteen sensory attributes from descriptive analysis for fried-salted peanut samples at day 0 of storage are presented in Table 1. Sensory attributes intensity ratings in fried-salted peanut samples (FP, FP-BHT, FP-A and FP-C) were not significantly different. Only, the intensity ratings of essential oil aroma between FP-A and FP-C showed significant differences ($\alpha = 0.05$). Therefore, the addition of aguaribay and cedron essential oils in fried-salted peanuts was detected by

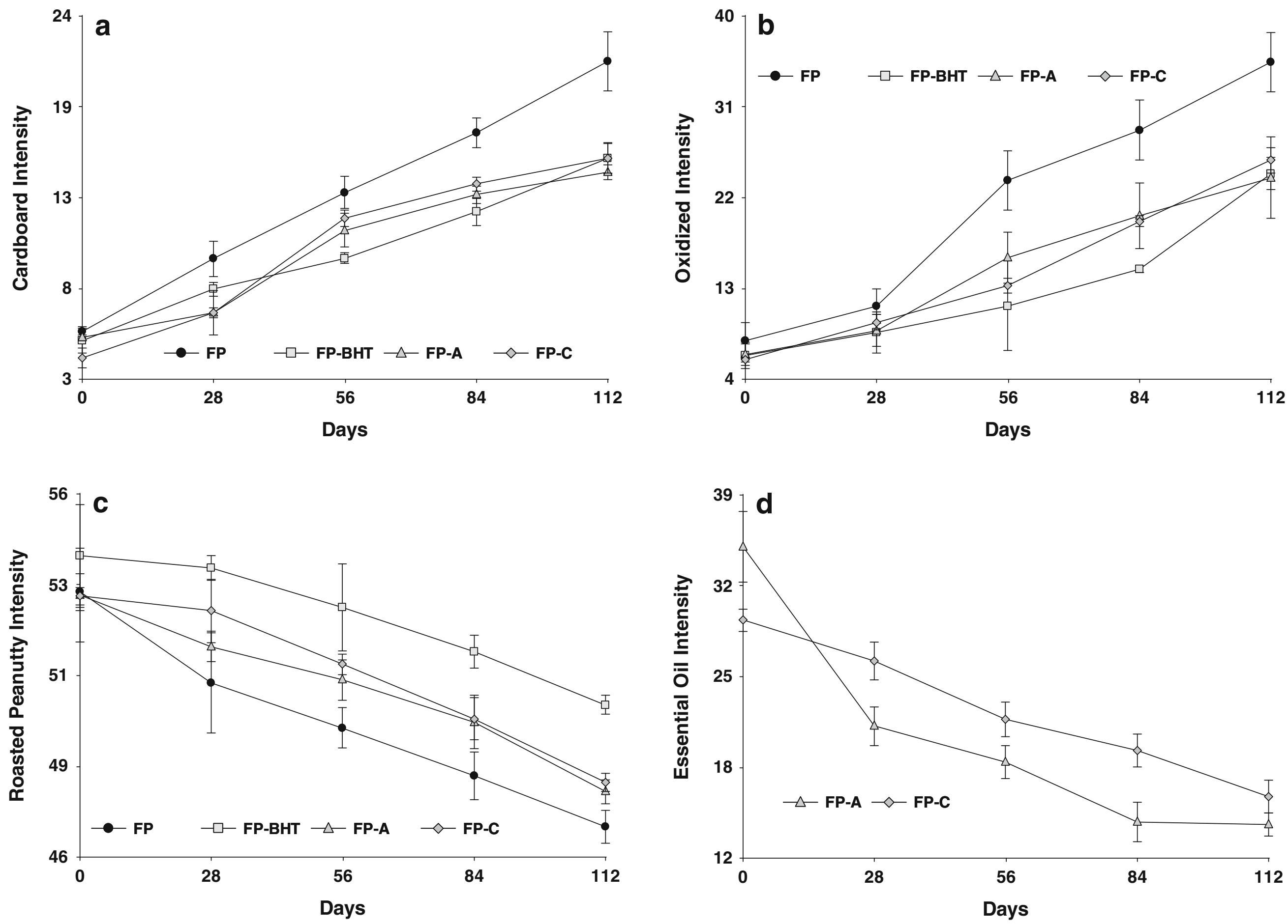

Fig. 2 Intensity ratings of sensory attributes: **a** cardboard, **b** oxidized, **c** roasted peanutty and **d** essential oil aroma in fried-salted peanuts (FP) and fried-salted peanuts with addition of BHT (FP-BHT), aguaribay essential oil (FP-A) and cedron essential oil (FP-A) during storage time at 23 °C

panelists meaning that the addition of essential oils in the product could affect its sensory properties. The intensity ratings of essential oil aroma were higher in FP-A than in FP-C. The sensory attributes of fried-salted peanuts described in this study showed similar intensity rating than those observed by other researchers [40, 41].

The intensity ratings of essential oil aroma, oxidized, cardboard and roasted peanutty flavors that changed during storage in the peanut products are presented in Fig 2. The intensity ratings of the other attributes (brown color, roughness, glossiness, sweetness, saltiness, sourness, bitterness, astringency, crunchiness, and hardness) did not change during storage. The intensity ratings of cardboard (Fig. 2a) and oxidized (Fig. 2b) flavors increased during storage in all samples. On the contrary, the intensity ratings of roasted peanutty flavor (Fig. 2c) and essential oil aroma (Fig. 2d) decreased during storage. Nepote et al. [40] also reported that the intensities of cardboard and oxidized flavors increased and roasted peanutty flavor decreased during storage in fried-salted peanuts prepared with regular and high-oleic peanuts.

Cardboard flavor is a sensory attribute related to lipid oxidation [3, 25]. The intensity ratings of cardboard flavor in fried-salted peanut samples are presented in Fig. 2a. All products exhibited an increase in cardboard intensity ratings during storage. Significant differences were observed between fried-salted peanut samples. From day 28 of storage, the intensity rating of cardboard flavor was higher in FP than the other products (FP-A, FP-C and FP-BHT). The highest cardboard intensity rating was found in FP (21.31 in a 150 mm line scale). FP, FP-A and FP-C did not differ significantly in cardboard intensity.

The oxidized flavor is also a sensory attribute related to lipid oxidation. Volatile compounds that cause rancid odor and flavor are produced during advanced stages of lipid oxidation [44]. The oxidized intensity ratings in fried-salted peanut samples are shown in Fig. 2b. This attribute had a similar behavior to the cardboard flavor. Significant

Table 4 Regression coefficients and adjusted R^2 for the dependent variables: peroxide (PV) and *p*-anisidine (AV) values, conjugated dienes (CD) and sensory attributes in fried-salted peanut samples during storage time

Dependent variable	Products	Regression[a]			
		β_0	β_1^b	ANOVA	R^2
Essential oil	FP-A	30.8944	−0.1790	A	0.7949
	FP-C	29.733	−0.1214	B	0.9511
Roasted peanutty	FP	52.6637	−0.0500	B	0.7111
	FP-BHT	54.3422	−0.0339	A	0.6545
	FP-A	53.2368	−0.0486	A	0.6982
	FP-C	53.4167	−0.0428	A	0.9219
Oxidized	FP	6.6902	0.2646	C	0.8358
	FP-BHT	4.4029	0.1542	A	0.8214
	FP-A	5.6178	0.1691	A	0.8812
	FP-C	4.7221	0.1805	B	0.9740
Cardboard	FP	5.5245	0.1405	C	0.9744
	FP-BHT	4.8522	0.0933	A	0.9715
	FP-A	4.9071	0.0945	A	0.9278
	FP-C	4.1738	0.1111	B	0.9419
CD	FP	2.7921	0.1586	C	0.9797
	FP-BHT	2.3032	0.0891	A	0.9634
	FP-A	2.4841	0.1292	B	0.9832
	FP-C	2.8723	0.1216	B	0.9921
AV	FP	0.7541	0.1345	D	0.9272
	FP-BHT	2.1315	0.0401	A	0.9536
	FP-A	1.0383	0.0967	C	0.9456
	FP-C	1.8253	0.0675	B	0.9493
PV	FP	14.7185	0.7795	D	0.9491
	FP-BHT	11.4884	0.5134	A	0.9308
	FP-A	12.1892	0.6921	C	0.9528
	FP-C	11.8431	0.6295	B	0.9435

FP fried-salted peanuts, *FP-BHT* fried-salted peanuts with BHT, *FP-A* fried-salted peanuts with "aguaribay" essential oil and FP-C fried-salted peanuts with "cedron" essential oil

[a] Regression equations: $Y = \beta_0 + \beta_1 X$; where Y = dependent variable (PV, AV, CD, essential oil aroma, cardboard, oxidized and roasted peanutty flavor)s); β_0 = a constant that it is equal the value of Y when the value of $X = 0$; β_1 = coefficients of X; X = independent variable (time); R^2: adjusted determination coefficient

[b] ANOVA and LSD Fisher test: the slope (β_1) of each variable and sample followed with the same letters in the column are not significantly different at $\alpha = 0.05$

differences in the oxidized intensity were detected between samples after day 28. At day 112, FP had the highest oxidized intensity rating (35.83 in a 150 mm line scale). FP-A, FP-BHT and FP-C exhibited the lowest intensity rating (24.13, 24.9 and 26.1 in a 150 mm line scale, respectively) and were not significantly different. The intensity ratings of cardboard and oxidized flavors indicate that aguaribay and cedron essential oils protected this food product against lipid oxidation by decreasing the formation of rancid flavors.

Roasted peanutty flavor is considered a positive sensory attribute in peanut products [25]. This flavor is related to a group of compounds called alkyl-pyrazines that are produced in the roasting process as a consequence of the reactions between the amine group of proteins and sugars. It was shown that a reduction in this sensory attribute was correlated with a decrease in the alkyl-pyrazine content [45]. In the present study, the intensity rating of roasted peanutty flavor decreased in all fried-salted peanut samples through storage (Fig. 2c). The highest decrease in the roasted peanutty intensity ratings were observed in FP (from 53.08 to 47.23 on a 150-mm line scale) while the lowest decrease was exhibited in FP-BHT (from 53.98 to 50.27 on a 150-mm line scale). The intensity of this attribute in FP-C and FP-A fell in between those found for FP and FP-BHT. Other researchers reported similar decrease in the intensity ratings of this attribute during storage of fried salted peanuts [40–42]. A higher decrease in roasted peanutty flavor through storage is a negative effect to the sensory quality of the product. For this reason, it is very important to preserve this sensory attribute during the shelf-life of fried-salted peanuts.

Correlation and Regression Analysis

The chemical and sensory variables that changed significantly during storage were analyzed by correlations. These variables included PV, AV, CD, essential oil aroma, and roasted peanutty, oxidized, and cardboard flavors. Correlation coefficients higher than 0.6 were observed between chemical variables (PV, AV and CD) and sensory variables (oxidized and cardboard flavors) related to lipid oxidation process in all fried-salted peanut samples. The highest correlation (0.97) was detected between PV and CD in FP. Positive correlations between these variables were due to the fact that these measured increased during storage time. PV, AV, CD, and oxidized and cardboard flavors were negatively correlated with essential oil aroma and roasted peanutty flavor variables. These negative correlations were due to the fact that essential oil aroma and roasted peanutty flavor variables decreased when the chemical variables related to lipid oxidation increased during storage. These results indicates that the decrease of the intensity rating in essential oil aroma and roasted peanutty flavor is also affected by the deterioration process that the products suffered during storage. Positive correlation coefficient higher than 0.69 was observed between essential oil aroma and roasted peanut flavor in all fried-salted peanut products.

Bett and Boylston [45] reported that cardboard flavor intensity increased linearly increase across storage time while roasted peanutty flavor intensity decreased as storage time increased. Muego-Gnanasekharan and Resurreccion [46] observed that oxidized and cardboard flavor intensities exhibited a linear increase during storage time in peanut paste. Nepote et al. [26, 40] observed that chemical variables (PV, AV, CD) and sensory descriptive attributes (oxidized, cardboard and roasted peanutty flavors) were correlated in roasted and fried-salted peanuts during storage.

Linear regression coefficients between chemical and sensory variables (dependent variables) and storage time (independent variable) in fried-salted peanut samples are presented in the Table 4. The regression models for these variables showed the adjusted R^2 higher than 0.80 except for essential oil aroma in FP-A (0.79) and roasted peanutty in FP (0.71), FP-BHT (0.65) and FP-A (0.69). Therefore, the variables were well adjusted by a simple linear regression model and these regression equations can be used to predict the chemical and sensory changes in these peanut products during storage.

In addition, the difference in stability between samples could be analyzed through the oxidation tendencies. In Table 4, significant differences between the slopes (β_1) from regression equations were detected among samples except for roasted peanutty flavors. Higher slopes ($\beta 1$) indicate higher tendency to oxidation. β_1 values of CD, PV, IA, oxidized and cardboard flavors in FP were higher than the slopes in FP-BHT, FP-A and FP-C. On the other hand, more negative slopes ($\beta 1$) in roasted peanutty flavor indicate a higher tendency to lose its characteristic flavor. FP-A and FP-C showed less negative β_1 for roasted peanutty flavor than FP. The correlation and regression analyses also indicate that the addition of aguaribay and cedron essential oils to fried-salted peanuts provide protection against lipid oxidation.

Conclusions

According to the results observed in the present study on chemical and sensory changes in fried-salted peanuts during storage, the addition of aguaribay and cedron essential oils improve the stability of this peanut product by preventing lipid oxidation and development of rancid flavors. The aguaribay and cedron essential oil compositions corresponded to samples of aguaribay and cedron from Experiment Station, Facultad de Ciencias Agropecuarias, Universidad Nacional de Cordoba (crop 2010). Their chemical composition could change for multiple factors (crop year, localities, genotype, etc.). For that reason, the antioxidant effect of these essential oils on fried salted peanuts is only related to the essential oil composition reported in this study corresponding to plants harvested in 2010.

These essential oils could be considered as a natural antioxidant alternative for replacement of synthetic antioxidants used in foods. However, these essential oils could change the sensory profile of the food product affecting its consumer acceptance. Only descriptive analysis using a trained panel was carried out in this study. A consumer test should be performed to find out the impact produced by the inclusion of these essential oils on the product and how much this inclusion affects its acceptability.

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