Original article

Effect of the essential oil addition on the oxidative stability of fried–salted peanuts

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Summary The objective of this study was to evaluate the antioxidant effect of essential oils on the oxidative stability of fried–salted peanuts. Fried–salted peanut (FP), fried–salted peanuts with butyl hydroxytoluene (FP-BHT), and fried–salted peanuts with rosemary (FP-R), oregano (FP-O) and laurel (FP-L) essential oils were prepared. Peroxide value (PV), *p*-anisidine value (AV) and conjugated diene (CD) measurements, and descriptive analysis were carried out during 112 days of storage to determine the antioxidant effect of essential oils on product stability. FP with essential oils showed protection against the lipid oxidation process. PV and AV were higher during storage when compared with the other samples with essential oils. The oxidised and cardboard flavour intensities increased and the roasted peanutty flavour decreased much more in FP during storage than the other products studied. Laurel, oregano and BHT showed similar antioxidant activity and increased shelf-life of FP. These essential oils could be used as natural antioxidants in foods with high lipid contents.

Keywords Antioxidant, essential oils, lipid oxidation, peanuts, sensory, stability.

Introduction

Peanuts contain approximately 50–55% oil. About 80% of the peanut oil is composed of unsaturated fatty acids: 30–35% linoleic and 45–50% oleic acids (Grosso & Guzman, 1995). This composition makes peanuts and derived products susceptible to the development of rancid and off-flavours through lipid oxidation (Braddock *et al*., 1995; St. Angelo, 1996; Frankel, 2005).

Fried foods are highly palatable because of their fat content and the development of unique flavours and aromas. Fried–salted peanut (FP) is one of the most consumed peanut products around the world. This product has higher overall acceptance than dry-roasted peanuts (Grosso & Resurreccion, 2002; Nepote *et al*., 2004). Fried–salted peanuts may be prepared with different kinds of vegetable oils. The chemical composition of the oil used for the oil-roasting process influences the shelf-life and the acceptability of FP (Ryan *et al*., 2008). The oxidation process, which occurs in this product during storage, increases the chemical and sensory indicators of lipid oxidation (Nepote *et al*., 2006c).

Oxidation products and rancid flavours decrease the sensory quality of peanut products (Gills & Resurreccion, 2000; Grosso & Resurreccion, 2002), making them unacceptable to consumers. These undesirable products have harmful effects on health, such as heart diseases, emphysemas, mutagenesis and carcinogenesis (Barlow, 1990; Benzie, 1996). 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 is questioned (Barlow, 1990; Pokorny, 1991). For these reasons, there is renewed interest in the increased use of naturally occurring antioxidants. Natural antioxidants are presumed to be safe because they occur in nature and in many cases are derived from plant sources. Many researchers have studied the potential antioxidant activity of compounds from natural sources (St. Angelo, 1996). Besides, natural antioxidants are accepted by consumers because they could contribute not only to preventing lipid oxidation but also to improving sensory properties (Pokorny, 1991; Sacchetti *et al*., 2005).

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Different authors reported the antioxidant properties of essential oils of aromatic species such as oregano, rosemary and laurel (Madsen & Bertelsen, 1995; Zygadlo *et al*., 1995; Maestri *et al*., 1996; Kulisic *et al*., 2004; Sacchetti *et al*., 2005; Tomaino *et al*., 2005). However, the antioxidant effect of essential oils on food was not studied in depth. The objective of this study was to evaluate the antioxidant effect of essential oils on the oxidative stability of fried-salted peanuts analysing chemical and sensory changes on this product during storage.

Materials and methods

Materials

Sound and mature seeds of blanched peanuts (*Arachis hypogaea* L.) type Runner, size 38/42 kernels per oz (2005 crop) were provided by the company, Lorenzati, Ruescht y Cia (Ticino, Córdoba, Argentina). Before processing, peanuts were inspected; damaged and bruised kernels were manually removed.

In this study, three aromatic species were used: oregano (*Origanum vulgare*), rosemary (*Rosmarinus officinalis*) and laurel (*Laurus nobilis*). Leaves of each species (crop 2005) were provided by the Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Córdoba, Argentina. The essential oils were obtained by hydrodistillation according to Zygadlo *et al*. (1995) and kept in dark glass flasks in a freezer at −18°C until they were used.

Product elaboration

Fried-salted peanuts

Peanuts were roasted at 170°C in refined sunflower oil (Natura, Aceitera General Dehesa, General Deheza, Córdoba, Argentina) for 5 min in an oil-roaster (model Dupralys, Moulinex, Shanghai, China) until a medium point measured as an average Hunter colour, lightness (L) value of 50 ± 1.0 (Johnsen *et al*., 1988). To these fried peanuts, 2% (w/w) fine granulated salt (sodium chloride; Laboratorios Cicarelli, Santa Fe, Argentina) was added. Two percent (w/w) refined sunflower oil (Natura, Aceitera General Dehesa, General Cabrera, Córdoba, Argentina) was also added for glossing and helping the salt stick to the peanut kernels.

FP with essential oils

Fried-salted peanuts with oregano (FP-O), rosemary (FP-R) and laurel (FP-L) essential oils as natural antioxidants were prepared following the same procedure described for FP; 0.01% (w/w) of essential oil was added to the FP. A sample of FP with butyl hydroxytoluene (FP-BHT) was prepared by adding 0.01% (w/w) of BHT to the FP. The antioxidants were added to the glossy sunflower oil. The synthetic antioxidant, BHT, was used as a positive comparative reference of antioxidant activity.

Storage conditions and samplings

After preparation of FP, FP-O, FP-R, FP-L and FP-BHT, samples were packaged into 27 × 28 cm plastic bags (Ziploc; Johnson & Son, Buenos Aires, Argentina). The samples were stored at 23°C (room temperature). Samples of each product were removed from storage for evaluation analysing chemical and sensory indicators of lipid oxidation to detect changes in the stored samples (Frankel, 2005). Sampling was done on 28, 56, 84 and 112 days. Samples were also evaluated on day 'zero'.

Chemical analyses

Oil extraction

The oil was obtained by cold pressing of 100 g product using a 20-ton press (HE-DU; Hermes I. Dupraz SRL, Córdoba, Argentina). For this procedure, 20 g of peanut oil was extracted and used for chemical analyses: peroxide, *p*-anisidine and conjugate diene determinations.

Peroxide value

Peroxide value (PV) was evaluated following the Association of Official Analytical Chemists method 28.022 (AOAC, 1980) using 5 g oil of each sample. The iodine formed was titrated with 0.1 N $Na_2S_2O_3$. The PV was expressed as milliequivalents of active oxygen per kilogram of oil ($meqO_2/kg$) and calculated with the formula: PV ($meqO_2/kg$) = (volume in mL of $Na_2S_2O_3$) × (0.1 N) × (1000)/(g oil).

p-Anisidine value

p-Anisidine value (AV) was evaluated following the IUPAC method (IUPAC, 1987a). The *p*-anisidine reagent was prepared with 0.25 g *p*-anisidine hydrochloride (BDH Laboratory Reagents, Poole, UK), each 100 mL solution in glacial acetic acid. The absorbencies of samples were measured at 350 nm in a spectrophotometer (UV-V Diode Array Spectrophotometer Hewlett Packard HP 8452 A, Palo Alto, CA, USA). The AV was given by the formula: $AV = 25 \times (1.2As - Ab) \times (m^{-1})$, where As is the absorbance of the fat solution after reaction with the *p*-anisidine reagent, Ab the absorbance of the fat solution and m is the mass of the peanut oil in grams.

Conjugated dienes

Weighed oil samples were dissolved in 6 mL of n-hexane. The conjugated diene (CD) absorbance was measured at 232 nm, in a spectrophotometer (UV-V Diode Array Spectrophotometer Hewlett Packard HP 8452 A, USA). The results were reported as the sample extinction coefficient E (1%, 1 cm) (IUPAC, 1987b; COI, 2001).

Sensory analysis

Descriptive analysis

A total of twelve trained panelists (nine female and three male) participated for descriptive analysis of fried-salted peanut storage study. All panelists had 4 years of experience evaluating peanut products (roasted peanuts, honey-roasted peanuts and fried-salted peanuts) and were selected on the following criteria: (a) people with natural dentition; (b) people without food allergies; (c) non-smokers; (d) people between the ages of 18 and 64 years; (e) people who consume roasted peanuts and/or peanut products at least once a month; (f) people available for all sessions; (g) people interested in participating; and (h) people capable of verbally communicating the observations regarding the product (Plemmons & Resurreccion, 1998). Before being qualified, all panelists showed a perfect score in a taste sensitivity test and the ability to identify five of seven commonly found food flavours (Meilgaard *et al*., 1991; Mestrallet *et al*., 2004; Nepote *et al*., 2004).

All twelve panelists were trained and calibrated in four training sessions during 4 days. Each training session lasted 2 h. Descriptive analysis procedures as described by Meilgaard *et al*. (1991), Grosso & Resurreccion (2002) and Nepote *et al*. (2004) were used during the training and evaluation sections. Panelists evaluated samples using a 'hybrid' descriptive analysis method including the Quantitative Descriptive Analysis (Tragon Corp., Redwood City, CA, USA) and the Spectrum™ Analysis Methods (Sensory Spectrum, Inc., Chatham, NJ, USA). A 150-mm unstructured line scale was used (Plemmons & Resurreccion, 1998). A list of attribute definitions (Table 1) and a sheet with warm-up and reference intensity ratings for each attribute (Table 2) were developed during the training sections (Grosso & Resurreccion, 2002; Nepote *et al*., 2004). The attribute definitions were based on the peanut lexicon (Johnsen *et al*., 1988).

Sample evaluation

All samples were evaluated in partitioned booths under fluorescent light at room temperature. Ten grams of the product sample was placed in plastic cups with lids coded with three-digit random numbers. Panelists evaluated fifteen samples per day plus a warm-up sample: eight samples in the morning and eight samples in the afternoon. 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 complete randomised block design. The data were registered on paper ballots.

Statistical analysis

The experiment was performed in three repetitions. The data were analysed using the InfoStat software (version 1.1; Facultad de Ciencias Agropecuarias, Universidad Nacional de Cordoba). Mean and standard deviation values were calculated. Analysis of variance and Duncan tests were used to detect significant differences ($\alpha = 0.05$) between mean values. Pearson's coefficient was used to calculate the correlation between dependent variables from chemical and sensory analyses. Regression equations were used to determine if the independent variables (time) had an effect on the sensory attributes, PV, AV and CD (Sokal & Rohlf, 1994).

Table 1 Definitions of attributes used in the descriptive analysis of fried-salted peanuts with and without essential oils

Attribute[a]	Definition
Appearance	
1. Brown Colour	The intensity or the strength of brown colour from light to dark brown
2. Roughness	The appearance associated with uneven surface
3. Glossy	The appearance associated with the amount of light reflected by the product surface
Aromatics	
4. Essential oil aroma	The aromatic associated with essential oil of rosemary, oregano or laurel
5. Roasted peanutty	The aromatic associated with medium-roasted peanuts
6. Oxidised	The aromatic associated with rancid fats and oils
7. Cardboard	The aromatic associated with wet cardboard
Tastes	
8. Sweetness	Taste on the tongue associated with sucrose solutions
9. Salty	Taste on the tongue associated with sodium chloride solutions
10. Sour	Taste on the tongue associated with acid agents such as citric acid solutions
11. Bitterness	Taste on the tongue associated with bitter solutions such as caffeine
Feeling factors	
12. Astringent	
Texture	
13. Hardness	Force needed to compress a food between molar teeth
14. Crunchiness	Force needed and amount of sound generated from chewing a sample with molar teeth

[a]Attributes listed in order as perceived by panelists.

Results and discussion

Chemical and sensory analyses in FP from storage

Chemical analysis

Changes in chemical indicators of lipid oxidation (PV, AV and CD) during storage of the peanut samples are presented in Fig. 1. All chemical indicators increased with storage time in all peanut products. A similar

Table 2 Standard reference and warm up intensity ratings used in descriptive analysis for fried. salted peanuts with and without essential oils

Attribute	Reference	Reference intensity[a]	Warm up intensity[a,b]
Appearance			
1. Brown colour	Cardboard (lightness value, $L = 47 \pm 1.0$)	65	44
2. Roughness	Corn flakes (Granix, Buenos Aires Argentina)	89	33
3. Glossy	Peanuts coated with chocolate (ARCOR, Colonia Caroya, Cordoba, Argentina)	58	21
Aromatics			
4. Essential oil aroma	0.1% rosemary essential oil in refined sunflower oil (Natura, AGD, General. Cabrera, Argentina)	42	0
	0.1% oregano essential oil in refined sunflower oil (Natura, AGD, General. Cabrera, Argentina)	64	0
	0.1% laurel essential oil in refined sunflower oil (Natura, AGD, General. Cabrera, Argentina)	53	0
5. Roasted peanutty	Dry roasted peanuts (JL SA, Ticino, Córdoba, Argentina)	76	76
6. Oxidised	Rancid peanuts	76	5
7. Cardboard	Moist cardboard	41	12
Tastes			
8. Sweetness	2.0% sucrose solution	20	19
	5.0% sucrose solution	50	
	10% sucrose solution	100	
	15% sucrose solution	150	
9. Salty	0.2% NaCl solution	25	9
	0.35% NaCl solution	50	
	0.5% NaCl solution	85	
10. Bitterness	0.05% caffeine solution	20	7
	0.08% caffeine solution	50	
	0.15% caffeine solution	100	
11. Sour	0.05% citric acid solution	20	5
	0.08% citric acid solution	50	
	0.15% citric acid solution	100	
Feeling factors			
12. Astringent	Four tea bags (La Virginia, Córdoba, Argentina) in 1 L of water soaked 1 h	45	9
Texture			
13. Hardness	Almonds (Grandiet, Cordoba, Argentina)	74	48
14. Crunchiness	Corn flakes (Granix, Buenos Aires, Argentina)	90	41

[a]Intensity ratings are based on 150 mm unstructured line scales.
[b]Medium (lightness value, $L = 50 \pm 1.0$) roasted peanuts (Blanched Runner, Ticino, Córdoba, Argentina).

tendency was observed in a previous study analysing FP prepared with regular Runner peanuts (Nepote *et al.*, 2006c).

The PVs of peanut samples were from 4.17 (day 0) to 131.7 (day 112) in FP, from 8.67 to 121.6 in FP-L, from 7.07 to 119.8 in FP-R, from 4.41 to 109.6 in FP-O, and from 3.87 to 79.0 in FP-BHT. Significant differences were observed among the peanut products. From day 56, FP had higher PV (106.3 ± 0.7 meqO_2/kg) than the other samples. The PV increase was lower in FP-O, FP-L and FP-R than in FP. Among FP with essential oils, FP-O had lower PV increase. The lowest increase among all samples was observed in FP-BHT. Therefore, FP with essential oils exhibited antioxidant activity. Other researchers (Kulisic *et al.*, 2004; Kosar *et al.*, 2005; Tomaino *et al.*, 2005; Rocha-Guzman *et al.*, 2007) observed antioxidant activity of oregano, laurel and rosemary essence oils measured by DPPH (2,2-Diphenyl-1-picrylhydrazyl) and TBAR (thiobarbituric acid reactants) methods. Bera *et al.* (2006) found that a natural antioxidant extracted from *Carum copticum* decreased the PVs in flax oil that is rich in linolenic acid and very susceptible to oxidation. Rosemary extract was effective against lipid oxidation in bread sprayed with different vegetable oils (Frutos & Hernandez-Herrero, 2005).

The AV of peanut samples during storage varied from 1.15 (day 0) to 14.86 (day 112) in FP, from 1.28 to 10.84 in FP-R, from 1.35 to 9.95 in FP-L, from 1.62 to 7.9 in FP-O, and from 1.35 to 5.27 in FP-BHT. Significant differences were detected between the samples. FP and FP-BHT exhibited the highest and the lowest AV increase, respectively. FP-O showed a lower AV increase than the other FPs with essence oils. No significant differences were found between FP-L and FP-O in AV.

The CD values of peanut samples during storage varied from 5.11 (day 0) to 18.10 (day 112) in FP, from 4.58 to 17.77 in FP-L, from 4.42 to 17.07 in FP-O, from 5.04 to 16.80 in FP-R, and from 2.62 to 13.08 in

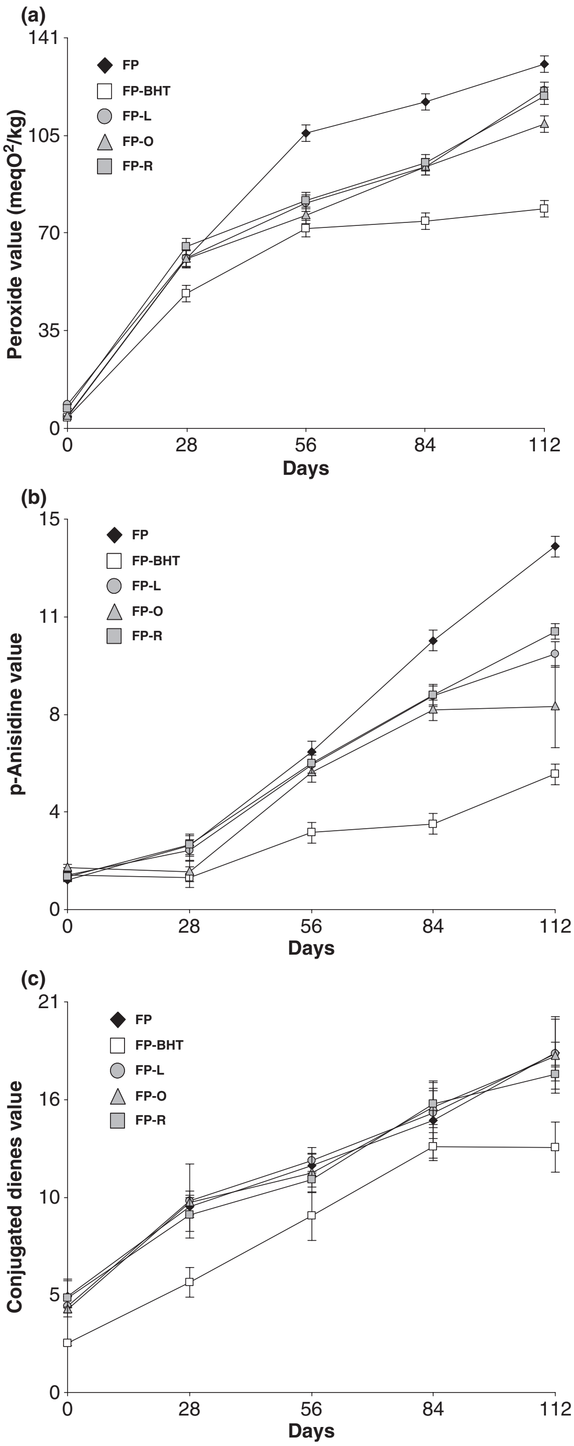

Figure 1 (a) Peroxide value (PV), (b) *p*-anisidine value (AV), and (c) conjugated dienes (CD) in fried-salted peanuts (FP), fried-salted peanuts with BHT (FP-BHT), fried-salted peanuts with oregano essential oil (FP-O), fried-salted peanuts with rosemary essential oil (FP-R) and fried-salted peanuts with laurel essential oil (FP-L) during storage.

FP-BHT. The FP with essence oils (FP-O, FP-L and FP-O) and FP did not show significant differences among them during storage. FP-BHT had the lowest CD.

In other studies, it was found that temperature affects oxidative process in peanut products throughout storage (Nepote *et al.*, 2006a). In the present study, temperature was constant during storage, and the differences in chemical changes among the samples were due to the effect of natural and synthetic antioxidant addition.

In vitro studies demonstrated that oregano, rosemary and laurel essential oils have antioxidant properties (Demo *et al.*, 1998; Kulisic *et al.*, 2004; Frutos & Hernandez-Herrero, 2005). This property is due to the presence of phenolic compounds with high radical-scavenging activity. Compounds like tymol, eugenol and camphor were found in oregano, laurel and rosemary, respectively. These compounds have shown a high antioxidant activity in the essential oil. Because of those compounds, the FP products supplemented with natural essential oils (oregano, laurel and rosemary) showed higher stability in relation to lipid oxidation than the product without essential oil addition.

Descriptive analysis

The following attributes were described for FP products: brown colour, roughness, glossiness, sweetness, salty, sour, bitterness, essential oil aroma, roasted peanutty, oxidised, cardboard, astringent, crunchiness and hardness. The intensity ratings of these attributes for each sample at day 0 of storage are presented in Table 3. Significant differences between samples were only found in essential oil aroma and roasted peanutty attribute.

The intensity ratings of the following attributes: brown colour, roughness, glossiness, sweetness, salty, sour, bitterness, astringent, crunchiness and hardness did not change during storage. The intensity ratings of essential oil aroma and roasted peanutty attribute decreased during storage. On the contrary, the intensity ratings of oxidised and cardboard flavours increased during storage (Fig. 2). Nepote *et al.* (2006c) also observed that the intensities of cardboard and oxidised flavours increased during storage in fried-salted peanuts prepared with regular and high oleic Runner peanuts.

Fried-salted peanuts with oregano essence had the lowest initial intensity of essential oil aroma (36.68) in comparison with FP-L (43.79) and FP-R (44.32). The highest decrease of the intensity ratings in this attribute with the storage time was showed in FP-R (Fig. 2a). The intensity ratings of this attribute after 112 days of storage were 11.57 in FP-R, 14.65 in FP-O and 26.28 in FP-L. These results indicate that the intensities of the oregano and laurel essences remain higher in the product than rosemary essence during storage. The panelists clearly detected the essential oil aroma in the samples during storage. They were trained to identify and

Table 3 Mean ± standard deviation of sensory variables for fried-salted peanuts with and without essential oils at day 0 of storage

	Fried-salted peanuts[a]				
Attributes	**FP**	**FP-BHT**	**FP-O**	**FP-L**	**FP-R**
Brown colour	47.04 ± 0.59	45.89 ± 0.63	46.21 ± 1.51	46.85 ± 0.59	46.71 ± 1.88
Roughness	30.63 ± 1.08	29.86 ± 1.96	30.63 ± 0.54	30.71 ± 0.64	30.32 ± 1.20
Glossy	21.40 ± 0.93	21.93 ± 0.28	22.19 ± 1.68	21.86 ± 0.75	22.82 ± 0.93
Essential oil aroma[b]	0.00[a]	0.00[a]	36.68 ± 3.94[b]	43.79 ± 2.94[c]	44.32 ± 0.46[c]
Oxidised	4.28 ± 0.49	5.36 ± 0.88	5.05 ± 0.62	6.27 ± 1.52	5.38 ± 0.63
Cardboard	9.32 ± 0.31	10.36 ± 1.38	9.68 ± 1.12	11.33 ± 1.13	9.32 ± 0.43
Roasted peanutty[b]	55.57 ± 1.56[b]	56.39 ± 0.88[b]	51.38 ± 1.63[a]	49.49 ± 0.70[a]	50.79 ± 1.32[a]
Sweetness	17.57 ± 0.69	17.99 ± 1.09	17.33 ± 1.05	17.40 ± 0.42	16.11 ± 1.30
Salty	80.47 ± 3.12	79.51 ± 2.93	80.33 ± 0.76	80.89 ± 2.66	80.18 ± 1.46
Bitterness	7.18 ± 1.33	7.29 ± 0.38	7.81 ± 0.33	8.54 ± 0.52	8.46 ± 0.34
Sour	5.82 ± 1.15	6.24 ± 0.47	6.68 ± 0.90	7.58 ± 1.18	7.00 ± 0.88
Astringent	8.54 ± 1.16	8.61 ± 1.42	9.76 ± 1.10	9.85 ± 0.24	9.88 ± 1.11
Crunchiness	42.57 ± 0.96	43.21 ± 0.62	41.56 ± 0.92	42.29 ± 0.81	41.84 ± 1.44
Hardness	47.82 ± 0.98	47.94 ± 0.50	47.25 ± 0.90	47.79 ± 0.59	47.29 ± 1.43

[a]FP: fried-salted peanuts, FP-BHT: fried-salted peanuts with BHT, FP-O: fried-salted peanuts with oregano essential oil, FP-L fried-salted peanuts with laurel essential oil, FP-R: fried-salted peanuts with rosemary essential oil.
[b]Mean values followed with the same letters in the raw are not significantly different at $\alpha = 0.05$.

quantify this attribute. The comments and opinion of the panelists regarding the essential oils and fried-salted peanuts as a food product were very positive. Fried-salted peanuts are a kind of snack. Oregano, laurel and rosemary flavors match with snack products. Food products with essential oils as preservative could be focalised for consumer with preference to functional foods. Consumer acceptance tests determine overall preference or linking of a product, or of a product's sensory properties such as appearance, including colour, flavour and texture (Meilgaard *et al.*, 1991). For that reason, an acceptance test in FP with essential oils should be conducted to measure liking or preference for the product sensory properties and to quantify consumer responses by relating these to descriptive analysis or chemical results.

Volatile compounds that cause oxidised odour and flavour are produced when lipid oxidation process is at an advanced stage. These off-flavours are related to the oxidised attribute (Frankel, 2005). The oxidised intensity changes in FP samples studied in this work are presented in Fig. 2b. All products exhibited an increase in oxidised intensity ratings during storage. The initial intensities of this attribute in the peanut samples were between 4.28 (FP) and 6.27 (FP-L). Significant differences between samples in the oxidised intensity were detected after day 28. At the end of the storage (112 days), the FP had the highest oxidised intensity rating (35.76) and FP-BHT had the lowest intensity rating (17.14). At this storage time, the FP samples with essential oils showed oxidised intensity ratings between FP and FP-BHT (FP-O = 26.43, FP-L = 28.89 and FP-R = 32.00). In a previous study (Nepote *et al.*, 2006c), FP prepared with regular Runner kernels showed similar oxidised intensity ratings from 7 (day 0) to 31 (day 142) during storage at room temperature.

The cardboard flavour is also related to lipid oxidation (St. Angelo, 1996). This attribute had a similar behaviour to the oxidised flavour (Fig. 2c). Significant differences between FP samples were observed after day 28. At day 112 of storage, the intensity ratings of cardboard attribute were 21.00 in FP, 18.9 in FP-R, 18.00 in FP-O, 17.5 in FP-L and 14.43 in FP-BHT. The intensity ratings of cardboard flavour in FP-R, FP-O and FP-L were between the intensities of FP and FP-BHT. The FP with essential oils did not show significant differences between them but they had significant differences with respect to FP and FP-BHT.

Roasted peanutty flavour is considered a positive sensory attribute in peanut products (Johnsen *et al.*, 1988). This flavour is related to a group of compounds named alquilpyrazines that are produced in the roasting process as a consequence of the reactions between the amine group of proteins and sugars. A decrease in this sensory attribute is correlated with a decrease in the alquilpyrazine content (Bett & Boylston, 1992). In roasted peanut products, the intensity ratings of roasted peanutty flavour decreased during storage (Brannan *et al.*, 1999; Grosso & Resurreccion, 2002; Nepote *et al.*, 2004, 2006a,b,c). In this study, the intensity rating of roasted peanutty flavour decreased in all FP samples throughout storage (Fig. 2d). All samples showed the highest intensity in this attribute at the beginning of the storage (day 0). The intensity ratings were between 56.39 (FP-BHT) and 49.49 (FP-L). FP had the highest decrease in the intensity rating of roasted peanutty attribute

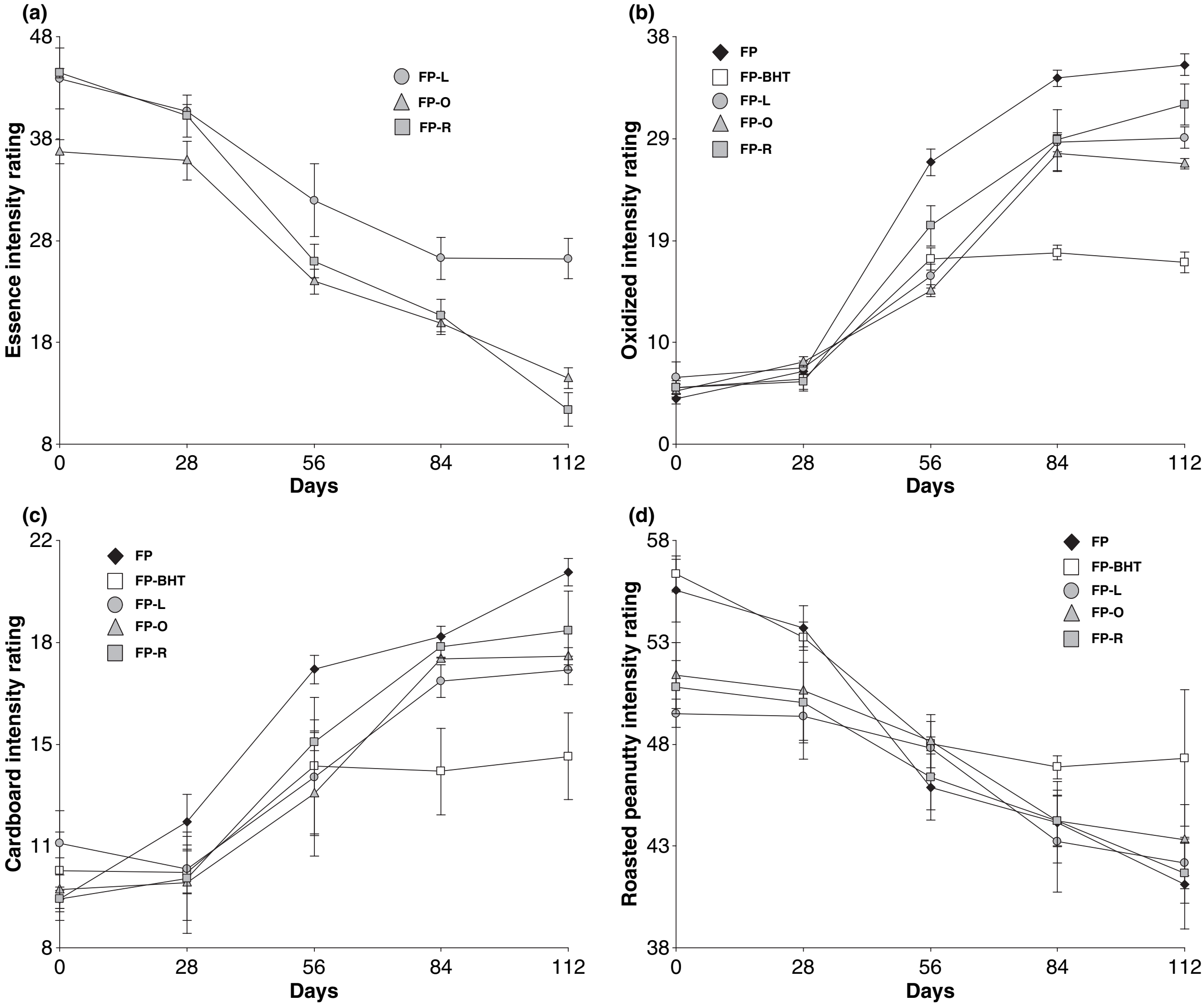

Figure 2 Intensity ratings of sensory attributes: (a) essential oil aroma, (b) oxidised, (c) cardboard, and (d) roasted peanutty in fried-salted peanuts (FP), fried-salted peanuts with BHT (FP-BHT), and fried-salted peanuts with oregano (FP-O), rosemary essential oil (FP-R) and laurel (FP-L) essential oils during storage time.

during storage. FP-BHT was the most stable sample during storage as regards the intensity changes in roasted peanutty flavour. At day 112 of storage, the intensities of roasted peanutty flavour were 40.89 in FP, 41.62 in FP-R, 42.10 in FP-L, 43.24 in FP-O and 47.29 in FP-BHT. In a previous study (Nepote *et al.*, 2006c), the roasted peanutty intensity ratings in FP prepared with regular Runner and high oleic peanut kernels also decreased during storage; this effect was more remarkable in the product prepared with regular Runner peanuts.

Correlation and regression analysis

Only variables of the samples that changed during storage were analysed by correlations and regression analyses. These variables are the following: chemical indicators of lipid oxidation (PV, AV and CD), and the sensory variables as essential oil aroma, roasted peanutty, oxidised, and cardboard flavours.

Pearson correlation coefficients between the analysed variables for all FP samples were analysed. PV, AV, CD, and oxidised and cardboard flavours showed a positive correlation higher than 0.7. These values indicate that these variables increased their content or intensity rating during storage. These variables (PV, AV, CD, oxidised and cardboard) showed negative correlation with the essential oil aroma and roasted peanutty flavour. These correlations were more negative than −0.7. It indicates that essential oil aroma and roasted peanutty flavour decreased when the chemical and sensory variables related to lipid oxidation as PV, AV, CD, and oxidised and cardboard flavours increased. Positive correlation higher than 0.7 was also observed between essential aroma and roasted peanut flavour in the FP with essential oil (FP-O, FP-L and FP-R).

Relationships among chemical and sensory variables were reported in other studies. Bett & Boylston (1992) detected in roasted peanuts that cardboard flavour intensity had a linear increase across storage time while roasted peanutty flavour intensity decreased as storage time increased. Muego-Gnanasekharan & Resurrección (1992) also detected that oxidised and cardboard flavour intensities exhibited a linear increase during storage in peanut paste. Nepote *et al.* (2006a,b) reported that chemical variables (PV, AV, CD) and descriptive attributes (oxidised, cardboard and roasted peanutty flavours) were correlated in roasted and FP during storage.

Lineal regression equations of chemical and sensory variables (dependent variables) and storage time (independent variable) in FP products are presented in Table 4. In general, the regression models for these variables showed the adjusted R^2 higher than 0.6 (except oxidised flavour in FP-BHT and cardboard flavour in FP-BHT). Therefore, these variables can be considered a good predictor for lipid oxidation changes in FP with and without essential and these equations can be used to predict the chemical and sensory changes in these peanut products during storage.

Significant differences in the regression equation slopes (β_1) were found between samples for the dependent variables (PV, AV, and essential oil aroma, roasted peanutty, oxidised and cardboard sensory attributes) except for the conjugated dienes (Table 4).

Grosso & Resurreccion (2002) reported that roasted peanut samples with a value of 5 (neither like nor dislike) for overall acceptance on the nine-point hedonic scale can be considered as a level to decide if a peanut product is unacceptable for the consumer. Besides, those authors found that roasted peanuts reached the five point in overall acceptance rating on the nine-point hedonic scale when the oxidised flavour rating is 36.2 in an unstructured lineal scale of 150 mm. Using the regression equation obtained in this study and considering the value of 36.2 as a reference of shelf-life in consumer acceptance for peanut products, this value should be reached after 101 days in FP, 121 days in FP-R, 136 days in FP-L, 146 days in FP-O and 253 days in FP-BHT. These predictions of the shelf-life in FP with and without essential oils confirm that rosemary, laurel and oregano essential oils have a protective effect against lipid oxidation in this peanut product but these essential oils are less effective than the synthetic antioxidant, BHT.

Table 4 Regression equations and R^2 for the dependent variables: peroxide (PV) and p-anisidine (AV) values, conjugated dienes (CD) and sensory attributes in fried-salted peanuts with and without essential oils

Dependent variable	Samples[a]	Regression coefficients[b] β_0	β_1	ANOVA[c]	R^2
Essential oil aroma	FP-L	43.527444	−0.175052	b	0.85
	FP-O	38.201111	−0.212942	b	0.60
	FP-R	45.535714	−0.303260	a	0.81
Roasted peanutty	FP	55.790476	−0.138053	a	0.81
	FP-BHT	55.267857	−0.087890	b	0.66
	FP-L	50.567063	−0.074865	b	0.60
	FP-O	52.050397	−0.081186	b	0.76
	FP-R	51.431746	−0.086332	b	0.86
Oxidised	FP	3.473810	0.323583	c	0.81
	FP-BHT	5.912698	0.119685	a	0.48
	FP-L	4.046032	0.237011	b	0.79
	FP-O	3.773651	0.221866	b	0.83
	FP-R	3.301984	0.271485	bc	0.86
Cardboard	FP	9.734444	0.107778	c	0.90
	FP-BHT	10.261508	0.041901	a	0.52
	FP-L	10.194444	0.068056	b	0.70
	FP-O	8.786111	0.087946	bc	0.79
	FP-R	8.827381	0.097980	c	0.79
AV	FP	0.028000	0.121274	d	0.94
	FP-BHT	0.859333	0.035429	a	0.86
	FP-L	1.046000	0.078679	bc	0.89
	FP-O	1.287333	0.065452	b	0.89
	FP-R	0.930000	0.085095	c	0.96
PV	FP	22.138091	1.076022	c	0.88
	FP-BHT	21.339182	0.605436	a	0.73
	FP-L	25.041576	0.824584	b	0.77
	FP-O	22.702171	0.833853	b	0.85
	FP-R	28.384795	0.772425	b	0.70
CD	FP	5.835333	0.109226	a	0.92
	FP-BHT	3.191333	0.100536	a	0.93
	FP-L	5.698000	0.113000	a	0.93
	FP-O	5.454667	0.114690	a	0.93
	FP-R	5.694667	0.106298	a	0.95

[a]FP, fried-salted peanuts; FP-BHT, fried-salted peanuts with BHT; FP-O, fried-salted peanuts with oregano essential oil; FP-R, fried-salted peanuts with rosemary essential oil; FP-L, fried-salted peanuts with laurel essential oil.

[b]Regression equations: $Y = \beta_0 + \beta_1 X$, where Y = dependent variable (PV, AV, CD and sensory attributes) and X = independent variable (days).

[c]ANOVA and Duncan test: slopes (β_1) of each sample follows with the same letters in the column are not significantly different at $\alpha = 0.05$.

Conclusions

The results of the present work indicate that the addition of essential oils of oregano, laurel and rosemary on FP improve the stability of the product preventing lipid oxidation and development of rancid flavours. Therefore, these essential oils can be added as natural antioxidants in FP. However, these natural antioxidants showed lower antioxidant effect on the stability of this product with respect to the synthetic antioxidant, BHT. Probably, higher concentration of these essential oils or refined fractions obtained from them could increase this antioxidant effect. Synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and propyl gallate (PG) are used in many foods to prevent rancidity but there is a growing concern for the potential health hazards because of their synthetic conditions. The present research renews interest in the use of naturally occurring antioxidants in food industry. For that, these natural antioxidants could be used as replacement of synthetic antioxidants on food products with high content of lipids.

This study also provides equations to estimate shelf-life of fried-salted peanuts with and without antioxidant from descriptive analysis, peroxide and p-anisidine values.

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References

AOAC (1980). *Official Methods of Analysis of the AOAC*, 13th Edn (edited by W. Horwitz). Washington, DC: Association of Official Analytical Chemists.

Barlow, S. N. (1990). Toxicological aspect of antioxidants used as food aditivies. In: *Food Antioxidants* (edited by B. J. F. Hudson). Pp. 253–307. Amsterdam: Elsevier.

Benzie, I. F. F. (1996). Lipid peroxidation: a review of causes, consequences, measurement and dietary influences. *International Journal of food Sciences and Nutrition*, **47**, 233–244.

Bera, D., Lahiri, D. & Nag, A. (2006). Studies on a natural antioxidant for stabilization of edible oil and comparison with synthetic antioxidants. *Journal of Food Engineering*, **74**, 542–545.

Bett, K. L. & Boylston, T. D. (1992). Effect of storage on roasted peanut quality. In: *Lipid Oxidation in Food* (edited by A. J. St. Angelo). Pp. 322–343. ACS Symposium Series 500; Washington, DC: American Chemical Society.

Braddock, J. C., Sims, C. A. & O'Keefe, S. F. (1995). Flavor and oxidative stability of roasted high oleic acid peanuts. *Journal of Food Science*, **60**, 489–493.

Brannan, G. L., Koehler, P. E. & Ware, G. O. (1999). Physicochemical and sensory characteristics of defatted roasted peanuts during storage. *Peanut Science*, **26**, 44–53.

COI. (2001). *Método de análisis, prueba espectrofotométrica en el ultravioleta*. Document COI/T, 20/ Doc nº 19/Rev. 1. Madrid: International Olive Oil Council (IOOC).

Demo, A., Petrakis, C., Kefalas, P. & Boskou, D. (1998). Nutrient antioxidants in some herbs and Mediterranean plant leaves. *Food Research International*, **31**, 351–354.

Frankel, E. N. (2005). *Lipid Oxidation*, 2nd edn. Bridgewater: The Oily Press.

Frutos, M. J. & Hernandez-Herrero, J. A. (2005). Effects of rosemary extract (*Rosmarinus officinalis*) on the stability of bread with an oil, garlic and parsley dressing. *Lebensmittel Wissenschaft und Technologie*, **38**, 651–655.

Gills, L. A. & Resurreccion, A.V.A. (2000). Sensory and physical properties of peanut butter treated with palm oil and hydrogenated vegetable oil to prevent oil separation. *Journal of Food Science*, **65**, 173–180.

Grosso, N. R. & Guzman, C. A. (1995). Chemical composition of aboriginal peanut (*A. hypogaea*) seeds from Peru. *Journal of Agricultural and Food Chemistry*, **43**, 102–105.

Grosso, N. R. & Resurreccion, A. V. A. (2002). Predicting consumer acceptance ratings of cracker-coated and roasted peanuts from descriptive analysis and hexanal measurements. *Journal of Food Science*, **67**, 1530–1537.

IUPAC (1987a). Method Number 2.504. Determination of the *p*-anisidine value. In: *Standard Methods for the Analysis of Oils, Fats and Derivatives*, 7th edn (edited by C. Paquot & A. Hautfenne). p. 210. Oxford: Blackwell Scientific Publications.

IUPAC (1987b). Method Number 2.505. Evidence of purity and deterioration from ultraviolet spectrometry. In: *Standard Methods for the Analysis of Oils, Fats and Derivatives*, 7th edn (edited by C. Paquot & A. Hautfenne). p. 211. Oxford: Blackwell Scientific Publications.

Johnsen, P. B., Civille, G. V., Vercellotti, J. R., Sanders, T. H. & Dus, C. A. (1988). Development of a lexicon for the description of peanut flavor. *Journal of Sensory Studies*, **3**, 9–17.

Kosar, M., Dorman, H. J. D. & Hiltunen, R. (2005). Effect of an acid treatment on the phytochemical and antioxidant characteristics of extracts from selected Lamiaceae species. *Food Chemistry*, **91**, 525–533.

Kulisic, T., Radonic, A., Katalinic, V. & Milos, M. (2004). Use of different methods for testing antioxidative activity of oregano essential oil. *Food Chemistry*, **85**, 633–640.

Madsen, H. & Bertelsen, G. (1995). Spices as antioxidans. *Trends in Food Science and Technology*, **6**, 271–277.

Maestri, D. M., Zygadlo, J. A., Lamarque, A. L., Labuckas, D. O. & Guzman, C. A. (1996). Effect of some oils on oxidative stability of peanut oil. *Grasas y Aceites*, **47**, 397–400.

Meilgaard, M., Civille, G. V. & Carr, B. T. (1991). *Sensory Evaluation Techniques*, 2nd edn. Boca Raton, FL: CRC Press Inc.

Mestrallet, M. G., Carnacini, L., Días, M. J. *et al.* (2004). Honey roasted peanuts and roasted peanuts from Argentina. Sensorial and chemical analyses. *Grasas y Aceites*, **55**, 401–408.

Muego-Gnanasekharan, K. F. & Resurrección, A. V. A. (1992). Physicochemical and sensory characteristic of peanut paste stored at different temperatures. *Journal of Food Science*, **57**, 1385–1389.

Nepote, V., Mestrallet, M. G. & Grosso, N. R. (2004). Natural antioxidant effect from peanut skins in honey roasted peanuts. *Journal of Food Science*, **69**, 295–300.

Nepote, V., Mestrallet, M. G., Ryan, L., Conci, S. & Grosso, N.R. (2006a). Sensorial and chemical changes in honey roasted peanuts and roasted peanuts stored under different temperatures. *Journal of The Science of Food and Agriculture*, **86**, 1057–1063.

Nepote, V., Mestrallet, M. G., Accietto, R., Galizzi, M. & Grosso, N. R. (2006b). Chemical and sensory stability of roasted high-oleic peanuts from Argentina. *Journal of the Science of Food and Agriculture*, **86**, 944–952.

Nepote, V., Mestrallet, M. G. & Grosso, N. R. (2006c). Oxidative stability in fried-salted peanuts elaborated with high-oleic and regular peanuts from Argentina. *International Journal of Food Science and Technology*, **41**, 900–909.

Plemmons, L. E. & Resurreccion, A.V.A. (1998). A warm-up sample improves reliability of responses in descriptive analysis. *Journal of Sensory Studies*, **13**, 359–376.

Pokorny, J. (1991). Natural antioxidant for food use. *Trends in Food Science and Technology*, **9**, 223–227.

Rocha-Guzman, N. E., Gallegos-Infante, J. A., Gonzales-Laredo, R. F. *et al.* (2007). Antioxidant effect of oregano (*Lippia berlandieri* v. Shauer) essential oil and mother liquors. *Food Chemistry*, **102**, 330–335.

Ryan, L. C., Mestrallet, M. G., Nepote, V., Conci, S. & Grosso, N. R. (2008). Composition, stability and acceptability of different vegetable oils used for frying peanuts. *International Journal of Food Science & Technology*, **43**, 193–199.

Sacchetti, G., Maietti, S., Muzzoli, M. *et al*. (2005). Comparative evaluation of 11 essential oils of different origin as functional antioxidants, antiradicals and antimicrobials in foods. *Food Chemistry*, **91**, 621–632.

Sokal, R.R. & Rohlf, F.J. (1994) *Biometry*, 3rd edn. San Francisco, CA: W.H. Freeman.

St. Angelo, A. J. (1996). Lipid oxidation in food. *Critical Reviews in Food Science and Nutrition*, **36**, 175–224.

Tomaino, A., Cimino, F., Zimbalatti, V. *et al*. (2005). Influence of heating on antioxidant activity and the chemical composition of some spice essential oils. *Food Chemistry*, **89**, 549–554.

Zygadlo, J. A., Lamarque, A. L., Grosso, N. R. & Maestri, D. M. (1995). Empleo de aceites esenciales como antioxidantes naturales. *Grasas y Aceites*, **46**, 285–288.