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Preserving sensory attributes of roasted peanuts using edible coatings

Cecilia G. Riveros,[1] Marta G. Mestrallet,[1] Patricia R. Quiroga,[1] Valeria Nepote[2] & Nelson R Grosso[1]*

1 Química Biológica, Facultad de Ciencias Agropecuarias (UNC), IMBIV-CONICET, CC 509, 5016 Córdoba, Argentina
2 ICTA, Facultad de Ciencias Exactas, Físicas y Naturales, IMBIV-CONICET, Córdoba, Argentina

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Summary Peanut products are susceptible to develop rancid and off-flavours through lipid oxidation. Preservation of these products is one of the problems in the peanut industry. The purpose of this work was to determine the sensory and chemical stability of roasted peanuts (RP) coated with different edible coatings: carboxymethyl cellulose (RP-CMC), methyl cellulose (RP-MC) or whey protein (RP-WPI) during storage. Sensory attributes and chemical indicators (peroxide and *p*-anisidine values, and conjugated dienes) of lipid oxidation were measured during storage. Chemical indicator values and intensity ratings of oxidised and cardboard flavours had lower increase in RP-CMC, RP-MC and RP-WPI during storage than in RP, whereas roasted peanutty flavour showed a lower decrease. The stability of RP-CMC is about a double longer with respect to RP. These results indicate that edible coatings preserve the sensory properties of roasted peanuts. Carboxymethyl cellulose exhibited the best protecting effect on this product.

Keywords Descriptive analysis, edible film, oxidation, peanuts, preserving, rancidity, sensory, stability.

Introduction

The peanut-containing foods enjoy widespread popularity because of their pleasant aroma, unique nutty flavour and smooth crisp texture (Ahmed & Young, 1982). Peanuts contain high levels of oil (45–54%) with elevated concentration of unsaturated fatty acids (30–35% linoleic acid and 45–50% oleic acid). Owing to their high oil content and elevated unsaturated fatty acid concentration, peanuts are susceptible to developing rancidity and off-flavours through lipid oxidation (Boskou & Elmadfa, 2011). The oxidation reactions lead indirectly to the formation of numerous aliphatic aldehydes, ketones and alcohols (Bett & Boylston, 1992). Simultaneously, off-flavours like oxidised, cardboard and painty increase in peanuts products (Nepote *et al.*, 2006a,b; Ryan *et al.*, 2008; Olmedo *et al.*, 2009; Riveros *et al.*, 2010).

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. Natural antioxidants are presumed to be safe because they occur in nature and have functional and sensory properties (Boskou & Elmadfa, 2011). Essential oils and tocopherols can act as natural antioxidant (Silva *et al.*, 2010; Quiroga *et al.*, 2011), and their activity has been evaluated in peanut product with the goal to decrease deterioration process and to increase their shelf life (Olmedo *et al.*, 2008; Silva *et al.*, 2010). The antioxidant effect of these compounds is not enough in many cases. Then, edible coatings could be an alternative to replace them or to complement the preserving effect on the product.

Edible films and coatings play an important role in the quality, safety, transportation, storage and display of a wide range of fresh and processed foods. These food coatings are an innovation within biodegradable active packaging concept, which interacts with food to extend shelf life and improve safety and/or functional or sensory properties while maintaining the quality of food packaging. Edible films and coatings based on biopolymers have taken as a major boom in the food industry owing to many factors such as biodegradability characteristics that contribute to reducing environmental pollution, and their potential to prevent the alteration in food mainly preserving physical, chemical and sensory properties (Embuscado & Huber, 2009). Particularly in peanut products, the function of edible coatings for preserving their quality could be related to some

*Correspondent: Fax: +54 351 4334116;
e-mail: nrgrosso@agro.unc.edu.ar

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properties of these coatings such as to reduce water loss, gas diffusion, movement of oils and fats and loss of volatile flavours and aromas, and to improve ending product appearance

Edible coatings in peanut products may prevent moisture loss and oxygen diffusion, be used as a vehicle for additives such as antioxidants and flavouring agents and improve the consumer acceptance for applying flavouring. Therefore, edible coatings could be used as a method for increasing shelf life of food products improving the stability of lipids especially in lipid-containing foods, thus preventing loss of sensory and nutritional quality (Boskou & Elmadfa, 2011). Edible coatings are an alternative of coating for food that can be produced from materials with film-forming ability. Components used for the preparation of edible coatings can be classified into three categories: hydrocolloids, lipids and composites (Bourtoom, 2008). In addition, edible coatings prepared with hydrocolloid compounds can decrease the oil absorption in fried food products. High oil content in fried products as banana chips or oil-roasted peanuts shortens the shelf life of the product. Edible coating prepared with guar or xanthan gums‘ solutions has a remarkable effect of reducing the amount of oil absorption making that this kind of fried product, healthier snacks for consumers (Sothornvit, 2011).

Previous studies have demonstrated that the quality of different types of foods and their raw materials could be preserved by applying an edible coating layer (Maftoonazad & Ramaswamy, 2005; Bravin *et al.*, 2006; Gayol *et al.*, 2009). Researchers have shown that peanuts treated with coatings become more stable and increased their shelf life (Min & Krochta, 2007; Wambura *et al.*, 2008; Mestrallet *et al.*, 2009). Roasted peanuts coated with edible film may preserve the intensity ratings of their sensory attributes for longer because of edible coatings act as oxygen barrier decreasing deterioration process (Han *et al.*, 2008; Wambura *et al.*, 2010). However, the effect on sensory attributes of roasted peanuts treated with different edible coatings has not been studied.

The purpose of this work was to evaluate the sensory and chemical stability of roasted peanuts coated with different edible coatings like carboxymethyl cellulose, methyl cellulose or whey protein during storage.

Materials and methods

Materials

Sound and mature seeds of peanuts (*Arachis hypogaea* L.) type Runner (cv. Tegua), size 38/42 kernels per ounce (2010 crop), were provided by the company ‘Criadero del Carmen’, General Cabrera, Cordoba, Argentina. Before processing, peanuts were inspected; damaged and bruised kernels were manually removed.

Edible coatings

The components used in the preparation of edible coatings were carboxymethyl cellulose (CMC), methyl cellulose (MC) and whey protein (WPI) and were provided by the company ‘Todo Droga’ (Cordoba, Argentina).

CMC coating preparation

To prepare a 0.5% (w/v) solution of CMC, 0.5 g of CMC powder was dispersed into 100 mL of sterile deionised water followed by stirring until the powder was wetted and a consistent dispersion was obtained. The solution was then allowed to equilibrate to room temperature. Then, glycerol was added as a plasticiser (1.9%), and the solution was stirred for another 10 min and cooled (Wambura *et al.*, 2008).

MC coating preparation

To prepare a 2% (w/v) solution of MC, 2 g of MC powder was dispersed into 100 mL of sterile deionised water followed by stirring until the powder was wetted and a consistent dispersion was obtained. The solution was then allowed to equilibrate to room temperature. Then, glycerol was added as a plasticiser (1.9%), and the solution was stirred for another 10 min and cooled (Maftoonazad & Ramaswamy, 2005).

WPI coating preparation

Whey protein solution was prepared at 11% (w/w) in sterile deionised water. The same weight of glycerol as that of WPI was added to the solution. Then, it was maintained at 90 °C for 30 min in a water bath and cooled on ice (Min & Krochta, 2007; Wambura *et al.*, 2008).

Product preparation

Blanched peanuts were roasted at 140 °C in an oven (Memert, model 600, Schwabach, Germany) for 30 min. Peanuts were heated to a medium roast measured as an average Hunter colour lightness (L) value of 50 ± 1.0 (Johnsen *et al.*, 1988). The roasted peanuts were placed into a stainless steel coating pan rotating at 28 rpm. The different coating solutions (CMC, MC and WPI) were applied on the roasted peanuts. The coating percentage of CMC, CM or WPI was 4% of the product. This percentage was chosen because this proportion of coating allowed an even coating layer around the peanuts kernels. For the coating procedure, the coating pan was kept rotating for 5 min until the coating layer was distributed evenly on the product. After that, the coated kernels were removed from the coating pan and placed into a oven (Memert, model

600) and heated at 130 °C at 20 min to dry off the excess of moisture.

Sample treatments for the experiment were as follows: uncoated roasted peanuts (RP) as the control sample, roasted peanuts coated with CMC (RP-CMC), roasted peanuts coated with MC (RP-MC) and roasted peanuts coated with WPI (RP-WPI).

The drying off process after coating was performed with the objective to leave the product with its characteristic moisture (between 1.2 and 2.0%). This process was used in CMC-RP, CM-RP and WPI-RP treatments. The final moistures in the treatments were 1.96% in CMC-RP, 1.92% in CM-RP, 1.67% in WIP-RP and 1.58% in RP.

The coating efficacy (CE) was determined using the following formula, CE = [g coated peanut kernels/(g peanut kernels + g coating solution)] x 100. The coating efficacies during the coating process of roasted peanuts were 91.02 for CMC, 90.04% for CM and 74.79% WPI.

Storage conditions and sampling

After preparation, 300 g of each of the RP, RP-CMC, RP-MC and RP-WPI samples was packed in 27 × 28 cm plastic bags with ethylene–vinyl alcohol as high barrier material (1–5 $cm^3\ m^{-2}$ per 24 h per bar oxygen permeability, DISE SA, Cordoba, Argentina) that were sealed using a sealing machine (Lipari® – CC400, Buenos Aires, Argentina) leaving 330-mL headspace with normal atmosphere (21% O_2) for assuring deterioration process in the product. Then, the packaged samples were stored at 40 °C (oven) to reproduce accelerated storage conditions. Samples were removed from storage after 0, 14, 28, 42 and 56 days for descriptive sensory analyses and measurement of chemical lipid oxidation indicators

Descriptive analysis

A total of ten trained panellists (six women and four men) with at least 6 years of experience in evaluating peanut products participated in the descriptive analysis of roasted peanut samples. All panellists were selected according to the following criteria: (i) people with natural dentition, (ii) people without food allergies, (iii) nonsmokers, (iv) people between the ages of eighteen and sixty-four, (v) people who consumed roasted peanuts and/or peanut products at least once a month, (vi) people available for all sessions, (vii) people interested in participating and (viii) people able to verbally communicate their observations regarding the product (Plemmons & Resurreccion, 1998). Before being qualified, all panellists showed a perfect score in a taste sensitivity test and the ability to identify five of seven commonly found food flavours.

The panellists were trained and calibrated in six training sessions for evaluating roasted peanuts. Each training session lasted 3 h. The descriptive analysis test procedures described by Nepote *et al.*, 2009; were used to train the panellists. A 'hybrid' descriptive analysis method combining the quantitative descriptive analysis (Tragon Corp., Redwood City, CA, USA) and Spectrum ™ analysis (Sensory Spectrum, Inc., Chatham, NJ, USA) methods was used by the panellists for evaluating sample (Meilgaard *et al.*, 2006). A 150-mm unstructured linear scale was used (Plemmons & Resurreccion, 1998). A list of definitions and a sheet with warm-up and reference intensity ratings (Table 1) were developed during the training sessions (Grosso & Resurreccion, 2002). The attribute definitions were based on the peanut lexicon (Johnsen *et al.*, 1988).

All samples were evaluated in partitioned booths under fluorescent light at room temperature. Product samples (10 g) were placed in plastic cups with lids coded with three-digit random numbers. The final lists of warm-up and reference intensity ratings and definitions (Table 1) were posted in the booths for all test sessions (Grosso & Resurreccion, 2002). The panellists were instructed to familiarise themselves with the reference standard intensities (Table 1) and then to evaluate the attribute intensity ratings of the roasted peanut samples. A completely randomised block design was used for testing samples. The data were registered on paper ballots.

Chemical analysis

Oil was obtained from the roasted peanuts by cold pressing using a 20-ton press (HE-DU, Hermes I. Dupraz SRL, Cordoba, Argentina). The peanut oil was used for chemical analyses: peroxide value, *p*-anisidine and conjugate dienes determinations.

Peroxide value (PV) was evaluated following AOAC method (AOAC, 1995). The PV was expressed as milliequivalents of active oxygen per kilogram of oil.

p-Anisidine value (AV) was evaluated following the IUPAC method (IUPAC, 1987). Absorbance of samples was measured at 350 nm in a spectrophotometer UV-V Diode Array Spectrophotometer Hewlett Packard HP 8452 A (Palo Alto, CA, USA).

Conjugated dienes (CD) were evaluated following the COI method (COI, 2001). Absorbance of conjugated dienes was measured in the same spectrophotometer used for *p*-anisidine at 232 nm. The results were reported as the sample extinction coefficient E (1%, 1 cm).

Statistical analysis

The experiment was carried out in three replications. The data were analysed using InfoStat Version 1.1

Table 1 Definitions of attributes, standard references and warm-up used for descriptive analysis, and mean intensity ratings of samples obtained at storage day zero

Attribute[a]	Definition	Reference	Reference intensity[b]	Warm-up intensity[b,c]	Sample intensity[b]
Appearance					
Brown colour	The intensity or the strength of brown colour from light to dark brown.	Cardboard (lightness value, $L = 47 \pm 1$)	65	41	42.46 ± 0.34
Roughness	The appearance associated with uneven surface.	Corn flakes[d]	85	23	22.36 ± 0.38
Glossiness[h]	The appearance associated with the amount of light reflected by the product surface.		45	16	16.17 ± 1.83^{a} (RP) 19.33 ± 1.02^{b} (RP-CMC) 23.50 ± 1.66^{c} (RP-MC) 23.75 ± 1.35^{c} (RP-WPI)
Aromatics					
Roasted peanutty	The aromatic associated with medium roasted peanuts.	Dry roasted peanuts[e]	81	78	77.22 ± 0.67
Oxidised	The aromatic associated with rancid fats and oils.	Rancid peanuts	112	2	2.43 ± 0.35
Cardboard	The aromatic associated with wet cardboard.	Moist cardboard	74	3	3.28 ± 0.25
Tastes					
Sweetness	Taste on the tongue associated with sucrose solutions	20 g kg^{-1} sucrose solution	20	21	21.39 ± 1.27
		50 g kg^{-1} sucrose solution	50		
		100 g kg^{-1} sucrose solution	100		
Saltiness	Taste on the tongue associated with sodium chloride solutions.	2 g kg^{-1} NaCl solution	25	5	5.05 ± 0.25
		3.5 g kg^{-1} NaCl solution	50		
		5 g kg^{-1} NaCl solution	85		
Sourness	Taste on the tongue associated with acid agents such as citric acid solutions.	0.5 g kg^{-1} citric acid solution	20	3	3.11 ± 0.51
		0.8 g kg^{-1} citric acid solution	50		
		1.5 g kg^{-1} citric acid solution	100		
Bitterness	Taste on the tongue associated with bitter solutions such as caffeine.	0.5 g kg^{-1}% caffeine solution	20	6	5.83 ± 1.44
		0.8 g kg^{-1} caffeine solution	50		
		1.5 g kg^{-1} caffeine solution	100		
Feeling factors					
Astringent	The puckering or drying sensation on the mouth or tongue surface	8 g of Coffee[f] in 250 mL distilled water	60	10	10.45 ± 0.39
Texture					
Hardness	Force needed to compress a food between molar teeth.	Almonds[g]	80	43	42.96 ± 0.89
Crunchiness	Force needed and amount of sound generated from chewing a sample with molar teeth.	Corn flakes[d]	95	40	40.99 ± 0.52

[a]Attributes listed in order as perceived by panellists.
[b]Intensity ratings are based on 150-mm unstructured line scales.
[c]Medium (lightness value, $L = 50 \pm 1$) roasted peanuts (RP): blanched, size 40/50, type Runner.
[d]Corn flakes, Granix, Buenos Aires, Argentina.
[e]Dry roasted peanuts, type Runner, JL SA, Ticino, Córdoba, Argentina.
[f]Coffee, Nescafé® Clásico, Nestlé Argentina S.A. Buenos. Aires, Argentina.
[g]Almonds, Grandiet, Córdoba, Argentina.
[h]RP-CMC, roasted peanuts coated with carboxymethyl cellulose; RP-WPI = roasted peanuts coated with whey protein and RP-MC, roasted peanuts coated with methyl cellulose. Same letter between samples means that there are no significant differences ($\alpha = 0.05$).

(Facultad de Ciencias Agropecuarias, Universidad Nacional de Cordoba, Cordoba, Argentina). Means and standard deviations were calculated. Analysis of variance and Duncan tests ($\alpha = 0.05$) were used to detect significant differences in sensory attributes and chemical analyses between sampling days. Pearson coefficients were used to calculate correlations between dependent variables. Linear equations were used for regression analyses (Sokal & Rohlf, 1994).

Results and discussion

Sensory descriptive analyses

Mean intensity ratings of the sensory attributes from roasted peanuts (RP) and coated roasted peanuts with edible coatings (RP-CMC, RP-MC and RP-WPI) obtained from descriptive analysis at day zero (fresh product) are presented in Table 1. Glossiness was the only attribute that showed significant differences ($\alpha = 0.05$) in the intensity rating among samples. Coated roasted peanuts showed higher intensity ratings in glossiness than roasted peanuts (16.17 ± 1.83 in 150-mm line scale) measured. Between coated samples, RP-CMC and RP-MC had higher intensity ratings of glossiness with 23.50 and 23.75 (in 150-mm line scale), respectively, than in RP-WPI (19.33 in 150-mm line scale). The coating process improved the glossiness in the product.

Roasted peanutty flavour is the attribute used to characterise typical roasted peanut flavour 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. It was reported that a decrease in this sensory attribute is correlated with a decrease in the *alquilpyrazine* content (Bett & Boylston, 1992). The roasted peanutty intensity rating was about 77.5 (scale 0–150 mm) in peanut samples analysed in this study (RP, RP-CMC, RP-MC and RP-WPI). In previous works, roasted peanuts coated with prickly pear and 'algarrobo' pod syrup had a roasted peanutty flavour intensity of 49.5 (Mestrallet *et al.*, 2009). Nepote *et al.* (2004) showed that roasted peanuts coated with honey had 48 (scale 0–150 mm) in roasted peanutty intensity rating. Grosso & Resurreccion (2002) observed 67 and 63 (scale 0–150 mm) roasted peanutty intensity ratings in roasted peanuts and cracker coated peanuts, respectively.

Changes in the intensities of the sensory attributes during storage at 40 °C in RP, RP-CMC, RP-MC and RP-WPI samples are presented in Fig. 1. The sensory attributes that changed during storage ($\alpha = 0.05$) were roasted peanutty flavour and those attributes related to the lipid oxidation like oxidised and cardboard flavours. The other attributes did not show significant variations during storage.

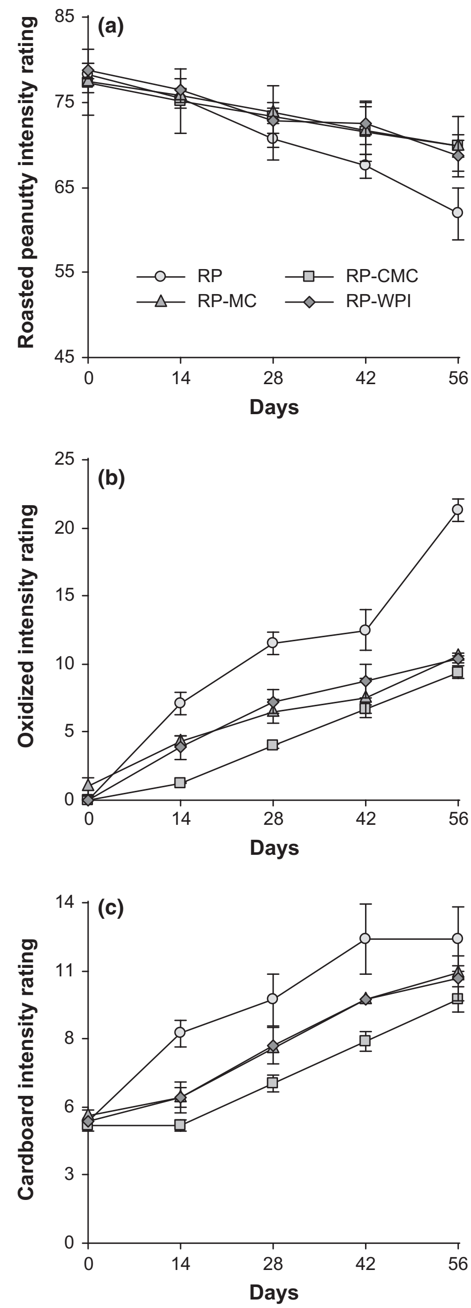

Figure 1 Intensity rating of sensory attributes: (a) roasted peanutty, (b) oxidised and cardboard (c) in roasted peanuts (RP) and coated roasted peanuts (RP-CMC, RP-MC and RP-WPI) during storage at 40 °C.

Oxidised and cardboard flavours are sensory attributes related to lipid oxidation (Grosso & Resurreccion, 2002; Nepote *et al.*, 2009). Oxidative rancidity is associated with the degradation of fatty acids from the lipids by oxygen in the air. Via a free radical process, the double bonds of an unsaturated fatty acid can undergo cleavage, releasing volatile aldehydes and ketones. These volatile compounds are responsible for rancid odour and flavour (Boskou & Elmadfa, 2011). An increase in the cardboard and oxidised intensity ratings was observed in the samples during storage. On the contrary, the roasted peanutty intensity ratings decreased with storage time in all samples. In other works, an increase in the intensity ratings of cardboard and oxidised flavours and a decrease in roasted peanutty were also observed in different peanut products during storage (Bett & Boylston, 1992; Grosso & Resurreccion, 2002; Nepote *et al.*, 2006a,b; Mestrallet *et al.*, 2009).

The decrease in roasted peanutty intensity ratings was lower in coated roasted peanut (RP-CMC, RP-MC and RP-WPI) than in uncoated roasted peanut (RP). Significant differences ($\alpha = 0.05$) in intensity of this attribute was observed between coated roasted peanut samples (RP-CMC, RP-MC and RP-WPI) and RP from storage day fourteen. The results indicate that CMC, MC and WPI coating improved the preservation of this important flavour for this product during storage.

The increase in the intensity ratings in oxidised and cardboard flavour was higher in uncoated roasted peanut (RP) than in coated roasted peanuts (RP-CMC, RP-MC and RP-WPI). Significant differences ($\alpha = 0.05$) in intensities of oxidised and cardboard flavour were observed between coated roasted peanuts samples (RP-CMC, RP-MC and RP-WPI) and RP from storage day fourteen at 40 °C.

Chemical analyses

The changes in peroxide value (PV), conjugated dienes content (CD) and *p*-anisidine value (AV) during storage at 40 °C in roasted peanut samples (RP, RP-CMC, RP-MC and RP-WPI) are shown in Fig. 2. Peroxide value and conjugated dienes content increased significantly with storage time in all peanut samples. Roasted peanuts (RP) had higher PV and CD and showed significant differences during storage after day fourteen with respect to coated roasted peanuts samples (RP-CMC, RP-MC and RP-WPI). RP-CMC had the lowest PV and CD and showed significant differences during storage than RP-MC and RP-WPI. In each treatment, AV did not show any marked increase along storage at 40 °C.

Lee & Krochta (2002) reported that roasted peanuts coated with WPI stored at 40, 50 and 60 °C for 31 weeks were oxidised significantly slower than the reference. Hexanal was the lipid oxidation indicator measured in that research. Wambura *et al.* (2008) studied CMC, WPI and ZEIN (corn protein) edible coating on sonicated roasted peanuts. They measured oxidative stability index (OSI) and observed that CMC had higher OSI during storage. Sonication process on roasted peanut kernels improved OSI in 11, 14 and 22% for CMC, WPI and ZEIN coatings, respectively.

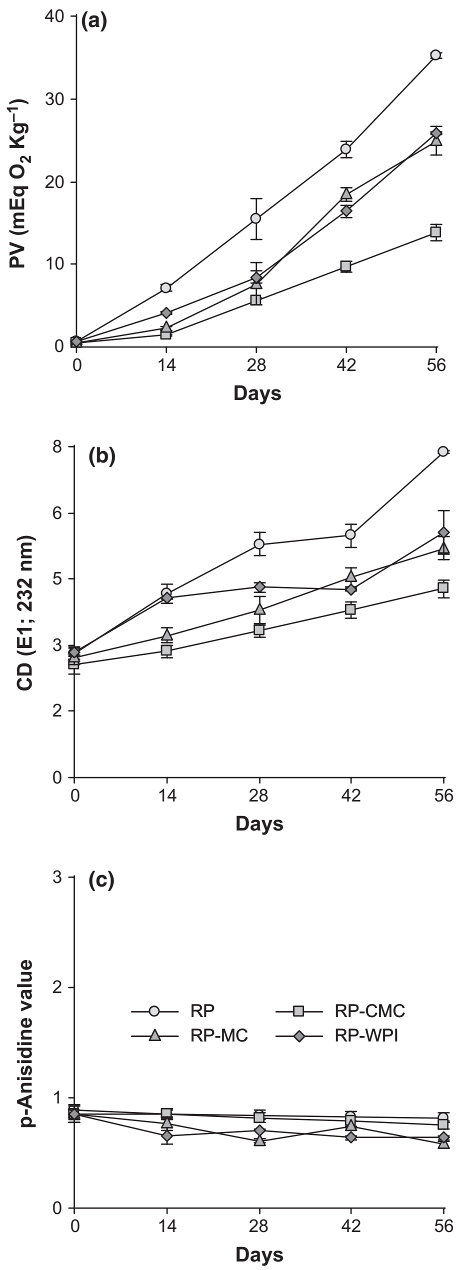

Figure 2 (a) Peroxide value (PV), (b) conjugated dienes (CD) and (c) p-anisidine value (AV) in roasted peanuts (RP) and coated roasted peanuts (RP-CMC, RP-MC and RP-WPI) during storage at 40 °C.

Han *et al.* (2008) studied WPI edible coating on roasted peanuts with the addition of tocopherols and ascorbic palmitate as antioxidants in the coating and stored the samples at 25 °C during 16 weeks. They were analysed hexanal and other volatiles by GC-MS for lipid oxidation determination. They detected that formation of hexanal from the oxidation of peanut lipids was reduced by WPI coatings, which indicates WPI coatings protected the peanuts from oxygen permeation and oxidation. Once again, the incorporation of antioxidants in the WPI coating layer did not show a significant difference in hexanal production from that of WPI coating treatment without incorporation of antioxidants. Wambura *et al.* (2010) researched about CMC edible coating with the addition of natural antioxidants. The coating procedure was the same that they used in other research (Wambura *et al.*, 2008) with the difference that included in the edible coating jujube and pomegranate extracts and tocopherol as natural antioxidants. Antioxidant effect was also determined by the measurement of oxidative stability index (OSI). After 12 weeks of storage at 35 °C, they observed that the oxidative stability of samples of roasted sonicated peanuts coated with CMC added with extracts of jujube and pomegranate was improved by 24.8 and 31.8%, respectively, in relation to the control. Those authors detected that samples with tocopherol did not have any improvement in oxidative stability of the roasted peanuts. Min & Krochta (2007) described the antioxidant effect of WPI coating with ascorbic acid as antioxidant added on roasted peanut stored at 23, 35 and 50 °C. Peroxide values, thiobarbituric acid reactive substance (TBARS) and free radical scavenging activity were determined as lipid oxidation indicator in that study. They observed that roasted peanuts coated with WPI with or without ascorbic acid retarded lipid oxidation at all storage temperatures with respect to the control sample, showing WPI –ascorbic acid treatment higher antioxidant effect than coated roasted peanuts without ascorbic acid. Those authors used carboxymethyl cellulose, whey protein isolate and corn protein as edible coatings because those coatings are capable of acting as oxygen barriers decreasing oxygen permeability to the roasted peanuts reducing peanut lipid rancidity. In roasted peanuts coated with honey, prickly pear syrup and 'algarrobo' pod syrup, PV values obtained during storage time had similar behaviour compared with those results obtained in coated roasted peanuts from this study (Nepote *et al.*, 2006c; Mestrallet *et al.*, 2009).

Correlation and regression analysis

The variables that changed during storage (PV, CD, and oxidised, cardboard and roasted peanutty flavours) were correlated using Pearson coefficient (Table 2). Positive correlations (higher than 0.60) were detected between PV, CD and oxidised and cardboard flavours. Correlation values were 0.97, 0.95, 0.94, 0.93, 0.93 and 0.91 between CD and oxidised flavour, PV and CD, PV and cardboard, oxidised and cardboard flavours, PV and oxidised, and CD and cardboard, respectively. This positive correlation between chemical variables (PV and CD) and sensory variables (oxidised and cardboard flavours) indicates that the panellists detected increasing intensity ratings of these sensory attributes during storage at time that increased peroxide and conjugate diene values. All of these variables are related to lipid oxidation process. Negative correlations were also observed between roasted peanutty and oxidised flavours (−0.93), roasted peanutty flavour and PV (−0.90), roasted peanutty flavour and CD (−0.90), and cardboard and roasted peanutty flavours (−0.84). These negative correlations indicated that roasted peanutty flavour decreased as lipid oxidation indicators increased during storage time.

The regression equations of dependent variables (PV, CD and oxidised, cardboard and roasted peanutty flavours) for RP, RP-CMC, RP-WPI and RP-MC are presented in Table 3. The dependent variables showed $R^2 > 0.60$ in all roasted peanut samples that indicate that these variables are good predictors of the time effect.

In the Food Code of Argentina, 10 meqO_2 kg^{-1} is the maximum level of peroxide value allowed for peanut oil (CAA, 1996). Using the prediction equations, peroxide values higher than 10 meqO_2 kg^{-1} in roasted peanut treatments could be reached on 17, 25, 26 and 43 days in RP, RP-WPI, RP-MC and RP-CMC, respectively. The stability of RP-CMC is about double longer with respect to RP and higher than in RP-WPI and RP-MC. These results indicate that the edible coatings used in this study provide to roasted peanut higher protection against deterioration process and improve the stability of this product considerably, in special those prepared with CMC coating, preserving

Table 2 Correlation coefficients from the variables: peroxide value, conjugated dienes and sensory attributes (oxidised, cardboard and roasted peanutty) in roasted peanuts and coated roasted peanuts

	PV	CD	Roasted peanutty	Oxidised
CD	0.95*			
Roasted peanutty	−0.90*	−0.90*		
Oxidised	0.93*	0.97*	−0.93*	
Cardboard	0.94*	0.91*	−0.84*	0.93*

*Significant at $P \leq 0.01$.
PV, peroxide value; CD, conjugated dienes; RP, roasted peanuts; RP-CMC, roasted peanuts coated with carboxymethyl cellulose; RP-WPI, roasted peanuts coated with whey protein; RP-MC, roasted peanuts coated with methyl cellulose.

Table 3 Regression Coefficients and adjusted R^2 for dependent variables (peroxide value, conjugated dienes and sensory attributes obtained from the storage study at 40 °C of coated peanut samples

		Regression coefficients[b]		
Sample[a]	Dependent variable[a]	β_0	β_1	R^2
RP	PV	−0.74	0.61	0.99
	CD	3.14	0.08	0.95
	Oxidised	0.90	0.34	0.95
	Cardboard	5.95	0.13	0.91
	Roasted peanutty	78.90	−0.29	0.99
RP-CMC	PV	−0.84	0.25	0.97
	CD	2.66	0.03	0.99
	Oxidised	−0.59	0.17	0.99
	Cardboard	3.24	0.12	0.91
	Roasted peanutty	77.15	−0.13	0.99
RP-WPI	PV	−1.45	0.45	0.96
	CD	3.28	0.04	0.85
	Oxidised	0.93	0.18	0.95
	Cardboard	4.85	0.11	0.98
	Roasted peanutty	78.60	−0.17	0.96
RP-MC	PV	−2.29	0.47	0.94
	CD	2.80	0.05	0.99
	Oxidised	1.51	0.16	0.97
	Cardboard	4.92	0.11	0.98
	Roasted peanutty	77.15	−0.13	0.99

[a]RP, roasted peanuts; RP-CMC, roasted peanuts coated with carboxymethyl cellulose; RP-WPI, roasted peanuts coated with whey protein; RP-MC, roasted peanuts coated with methyl cellulose; PV, peroxide value; CD, conjugate dienes.
[b]Regression coefficients for the general regression equation $Y = \beta_0 + \beta_1 X$, where Y is the dependent variable (PV, CD and roasted peanutty, oxidised or cardboard flavours) and X is the independent variable (storage days).

longer its sensory properties. In addition, it is possible to estimate the shelf life in roasted peanut product, making a relation between oxidised flavour and consumer acceptance. 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 whether a peanut product is unacceptable for the consumer. In that research, it was reported that roasted peanuts reached the 5 points on the nine-point hedonic scale of overall acceptance when the oxidised flavour rating was 36.2 in an unstructured lineal scale of 150 mm that is the same used in this study. Using the regression equations obtained in this study and considering the value of 36.2 as a reference limit of shelf life in this product, this intensity rating of oxidised flavour should be reached after 103 days in RP, 195 days in RP-WPI and 215 days in RP-CMC and RP-CM. Using this sensory indicator, the RP-CMC and RP-CM shelf life is about double longer with respect to RP and higher than RP-WPI.

Regression equations between variables are presented in Table 4. Significant regression equation with $R^2 > 0.50$ obtained from chemical variables (peroxide value and conjugated dienes) can be used for the prediction of sensory attribute ratings (oxidised, cardboard and roasted peanutty flavours) in roasted peanuts coated with edible coatings. Considering that a simple chemical analysis of a lipid oxidation indicator as peroxide value, it would be possible using the prediction equation to estimate the intensity rating of oxidised flavour in coated roasted peanuts, for example.

Edible coatings are used in foods to minimise the migration of components within the food system or between the food and its surrounding environment. For example, such coatings prevent the diffusion of water, fats and/or oxygen into, out of, or within the food system (Lee & Krochta, 2002). Coatings based on whey protein isolate (WPI), corn protein (ZEIN) and carboxymethyl cellulose (CMC) have been found to be excellent oxygen barriers. The preserving effect against lipid oxidation in coated roasted peanuts could be due to these edible coatings decrease markedly the oxygen interchange between the packaging atmosphere and the roasted peanuts. The three different edible

Table 4 Significant regression equation ($R^2 > 0.50$) from chemical variables (peroxide value and conjugated dienes) for the prediction of sensory variable ratings (oxidised, cardboard and roasted peanutty flavours) in roasted peanuts coated with edible coatings

			Regression coefficients[b]		
Chemical variable	Sensory variable	Sample[a]	β_0	β_1	R^2
Peroxide value	Oxidised flavour	RP	2.04	0.52	0.99
		RP-CMC	0.97	0.38	0.94
		RP-WPI	0.03	0.68	0.99
		RP-MC	−0.26	0.41	0.89
	Cardboard flavour	RP	8.36	0.15	0.51
		RP-CMC	3.7	0.47	0.97
		RP-WPI	6.23	0.16	0.58
		RP-MC	6.15	0.22	0.85
Conjugated dienes	Oxidised flavour	RP	−13.79	4.31	0.99
		RP-CMC	−13.3	4.89	0.95
		RP-WPI	−17.58	4.56	0.72
		RP-MC	−10.07	3.69	0.94
	Cardboard flavour	RP	3.51	1.28	0.59
		RP-CMC	−5.68	3.42	0.96
		RP-WPI	−0.45	1.77	0.58
		RP-MC	−0.55	2.22	0.91

[a]RP, roasted peanuts; RP-CMC, roasted peanuts coated with carboxymethyl cellulose; RP-WPI, roasted peanuts coated with whey protein; RP-MC, roasted peanuts coated with methyl cellulose; PV, peroxide value; CD, conjugate dienes.
[b]Regression coefficients for the general regression equation $Y = \beta_0 + \beta_1 X$, where Y are chemical variables (PV and CD) and X are sensory variables (oxidised or cardboard flavours).

coating (CMC, CM and WPI) used in this study showed a good preserving effect. To make a decision for choosing one treatment, the food industry should consider the cost and the difficulties of coating application process.

Considering the cost of the ingredients used for the edible coatings, the cost of the CM edible coating is about 50% less than WPI one; even more, the cost of the CMC edible coating is about% less than CM one. However, the increase of cost for a 100-g package of roasted peanuts would be less than 1 cent (dollar) for all treatment. This cost is not a really issue for the food industry in this kind of product. Besides the preserving effect of the edible coatings, the low cost of them is another advantage for coating roasted peanuts. Moreover, the coating and drying procedures for roasted peanuts used in this study were very simple and easy to carry out in the food industry.

Conclusions

The results of this work indicate that the use of carboxymethyl cellulose (CMC)-, methyl cellulose (MC)- and whey protein (WPI)-based film coatings for roasted peanuts improves the stability of the product, making it more resistant to lipid oxidation process and the development of rancid flavours. Carboxymethyl cellulose as edible coatings has the best protecting effect on roasted peanuts. In addition, these kind of edible coatings preserve the sensory properties of roasted peanuts, making their shelf life longer.

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