

A Natural Peanut Edible Coating Enhances the Chemical and Sensory Stability of Roasted Peanuts

María Paula Martín, Cecilia Gabriela Riveros, Alejandro Javier Paredes, Daniel Alberto Allemandi, Valeria Nepote, and Nelson Rubén Grosso 

Abstract: This study aims to assess the enhancement of the chemical and sensory properties of roasted peanuts during storage, through the application of high-protein defatted peanut flour (DPF) coatings incorporated with and without antioxidants. The control sample without coating, packed in normal atmosphere (control), showed the highest conjugated dienes (CD) increment (from 1.17 on day 0 to 3.60 on day 180). Roasted peanuts without coating, packed in high barrier bags under vacuum, reached the lowest CD at day 180 (1.92). Conjugated trienes and peroxide values were analogous to CD. The control exhibited the greatest decrease in α -tocopherol (from 27.65 mg/100 g on day 0 to 21.32 mg/100 g on day 180) and γ -tocopherol (from 21.91 mg/100 g on day 0 to 14.99 mg/100 g on day 180). 3-Methylpyridine and 2,5-dimethylpyrazine decreased with storage time only for the control, which had the highest increase in oxidized flavor (from 0 on day 0 to 13.30 on day 180), cardboard (from 7.67 on day 0 to 15.23 on day 180), and astringency. The lowest decreases in roasted peanutty scores were seen in coated samples. DPF coatings delayed roasted peanuts oxidation, enhancing their sensory properties and shelf life compared with the control sample.

Keywords: biopolymers, coating, groundnut, oxidation, sensory

Practical Application: Defatted peanut flour (DPF) is a byproduct obtained during peanut oil extraction and is a possible material for edible film preparation. This strategy adds value to the peanut industry by transforming a by-product into a material with the potential to develop biodegradable and economical films. The application of this DPF-based edible coating on the surface of roasted peanuts may have contributed to extent product's shelf life, allowing for coated products to be packaged in lower barrier and less expensive materials. Use of peanut material to coat peanuts avoids the risk of allergen protein cross contamination, which would be highly valuable for the food industry.

Introduction

Raw peanut kernels are used as a source of value-added products, such as roasted peanuts. In the roasting process, raw seeds are thermally treated above 125 °C to allow nonenzymatic reactions that contribute to the development of desirable flavors, textures, and colors (Chang, Sreedharan, & Schneider, 2013). Roasted peanuts display less oxidative stability than the raw peanut products that are very stable during storage (Martín, Asensio, Nepote, & Grosso, 2018a; Martín, Grosso, Nepote, & Grosso, 2018b). Consequently, thermal processes initiate reactions leading to chemical deterioration (Shi et al., 2017).

Because roasted peanuts are more affected than raw peanuts, it is crucial to preserve the product, by considering the packaging and storage conditions.

Synthetic petroleum-based materials, frequently employed as food packaging, must fulfill the requirements of protection by avoiding oxidation and water permeability and acting as a mechanical barrier, thereby increasing the storage stability. However, these packaging materials generate toxic waste and high production costs (Fortunati et al., 2017).

The increasing interest in strategies that contribute to reducing the environmental impact has led to the replacement of synthetic packaging by new biodegradable materials, including polymers, such as lipids, polysaccharides, and proteins. Among them, proteins are one of the most promising alternatives for biodegradable packaging elaboration because of their ability to form three-dimensional networks exhibiting improved properties as edible film-forming solutions with food applications. Likewise, they show widespread availability and low cost (Reddy, Chen, & Yang, 2013). For instance, innovative packaging methods using biopolymers isolated from various seed flours have been reported (Valderrama Solano & Rojas de Gante, 2014).

Peanut meal is a by-product of peanut oil extraction and can be used to prepare defatted peanut flour (DPF, 50% to 55% proteins), which is consumed as animal feed. However, it could be considered a natural source and promising raw material for the elaboration of food packaging. These novel technologies add value to the peanut industry, by transforming a by-product (peanut meal) into a material with the potential to develop biodegradable and

JFDS-2018-1722 Submitted 10/28/2018, Accepted 4/9/2019. Authors Martín, Riveros, and Grosso are with Facultad de Ciencias Agropecuarias, Univ. Nacional de Córdoba (UNC), Inst. Multidisciplinario de Biología Vegetal (IMBIV), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Ing. Agr. Félix Aldo Marrone 746, CC 509, X5016GCA, Córdoba, Argentina. Authors Paredes and Allemandi are with Unidad de Investigación y Desarrollo en Tecnología Farmacéutica (UNITEFA), CONICET and Dept. de Ciencias Farmacéuticas, Univ. Nacional de Córdoba, Haya de la Torre y Medina Allende - Ciudad Univ. - X5000HUA, Córdoba, Argentina. Author Nepote is with Cátedra de Probabilidad y Estadística, Facultad de Ciencias Exactas, Físicas y Naturales (UNC), IMBIV-CONICET, Av. Vélez Sarsfield 1611, 5000, Córdoba, Argentina. Direct inquiries to author Grosso (E-mail: nrgrosso@agro.unc.edu.ar).

economical films. The functional properties of peanut protein isolates/concentrates from DPF have been well-described (Wu, Wang, Ma, & Ren, 2009). Conversely, there is currently little information about the application of peanut flour-based edible materials, without latter purification, as oxidation protectors.

Many complex and expensive technologies are available to produce biodegradable films, but an easier and more cost-effective alternative is the application of edible substances directly on the food surface by using methods, such as immersing and spraying (Kang, Kim, You, Lacroix, & Han, 2013). Even if these edible coatings (EC) do not completely substitute for the use of primary packaging, they could be effective in blocking the oxygen flow and avoiding water permeability, thereby extending the product's shelf life. Coated products can be packaged in materials that exhibit lower barrier properties and are less expensive than those required for uncoated products. A previous work successfully produced cassava starch and soy protein-based ECs to extend the shelf life of toasted groundnuts (Chinma, Ariahu, & Abu, 2014).

Currently, there is a great concern about nut (peanut, soy, and walnut) protein-based ECs because of their facility to act as allergens in susceptible individuals (Calhoun, 2013). To avoid the synergic effect produced by proteins belonging to various allergenic sources on a food product, it is interesting to consider the oxidation protection afforded by the application of ECs prepared with components obtained from only one type of nut.

In light of all the above information, the present study was conducted to assess the improvement afforded by high-protein DPF-based ECs incorporated with and without antioxidants on the chemical and sensory preservation of roasted peanuts during storage.

Materials and Methods

Materials

Blanched peanuts type Runner (cv. Granoleico), size 38/42 kernels per ounce (2016 crop), were obtained from the Lorenzati, Ruetsch & Cia company (Ticino, Prov. Córdoba, Argentina).

DPF elaboration

DPF was prepared according to the method of Riveros, Martin, Aguirre, and Grosso (2018). Blanched peanut kernels were firstly grounded using a mill (Moulinex, model AD5663C9, Colombia) and then defatted using *n*-hexane for 12 hr in a Soxhlet apparatus. The product obtained was oven-dried for 24 hr at 60 °C in an air circulation oven (Garmont, Alta Gracia, Argentina) and then subjected to a soluble carbohydrates extraction in the Soxhlet using an ethanol/water (70:30) solution for 6 hr. After oven drying, the product was milled and forced through a 60-mesh sieve to standardize the final DPF granulometry.

ECs preparation

The DPF-based ECs were formulated as described by Borneo, Alba, and Aguirre (2016) with slight modifications. The DPF was dispersed in distilled water (4.0 g/100 mL) under stirring conditions at 60 °C for 15 min. pH was adjusted to 9 using 0.1 N sodium hydroxide and glycerol (30 g/100 g flour) was added as plasticizer. Butylated hydroxytoluene (BHT; Sigma-Aldrich, St. Louis, MO, USA) was used as a synthetic antioxidant and added at a concentration of 0.02% w/v according to the limiting value allowed by the Argentinean Food Code (CAA, 2014). BHT was water insoluble, so it was previously dissolved in 1 mL (70:30) ethanol/water solution and then added into the coating disper-

sion. The stirring was continued for 15 min at 70 °C. Afterward, coating forming solutions were cooled at room temperature and centrifugated (500 rpm for 30 s). Finally, air bubbles were removed from the products using an ultrasonic treatment for 60 min. The concentrations used in ECs preparation were based on previous results (Riveros, Mestrallat, Quiroga, Nepote, & Grosso, 2013).

Roasted peanut coating procedure and storage stability study

Blanched peanuts were roasted in an air circulation oven (Garmont, Alta Gracia, Argentina) for 20 min at 170 °C.

The coating procedure was achieved by a spraying method in a rotative stainless steel pan with external air circulation (Erweka GmbH, Heusenstamm, Alemania). A total of 0.5 kg of roasted peanuts was placed in the coating pan and the rotation speed was set to 200 rpm. The coating solutions at a concentration of 3% w/w were then applied using a compressed air-assisted sprayer (Downen Pagio, Bell Ville, Córdoba, Argentina) at 1.4×10^5 Pa pressure. Simultaneously, a continuous air stream (72 m³/hr) at 60 °C was applied to the system (Caleva Process Solution Ltd, Dorchester, UK) using a 40 mm hose. As a final step, coated peanut kernels were kept in rotation for 10 min with air circulation (60 °C) in order to achieve the characteristic humidity values for roasted peanut kernel (between 1.2% and 2.0%). The prepared samples were: uncoated peanuts (control), peanuts coated with peanut flour-based EC and peanuts coated with peanut flour-based EC + 0.02% BHT (ECBHT). All these samples were packed in normal atmosphere polyethylene bags. In addition, an uncoated peanut sample was packaged in high barrier bags made from ethylene-vinyl-alcohol under vacuum (control-V) using an industrial packaging machine with vacuum (-760 mmHg). This treatment was chosen as comparative reference because this packaging material has demonstrated to have excellent oxygen and water barrier properties exhibiting good resistance to lipid oxidation in peanuts (Martín et al., 2018a; Martín, Nepote, & Grosso, 2016). In addition, this packaging material is highly used by food industry to protect foods with high lipid content.

Controls and coated peanut samples (control, control-V, EC, and ECBHT) were placed randomly on shelves and stored for 180 days in an air circulation oven at accelerated oxidative rancidity conditions (40 °C). Three pouches of each treatment were retrieved from storage every 60 days, to perform chemical analysis and descriptive sensory analysis.

Chemical analysis

Roasted peanut samples were compressed using a hydraulic press (HE-DU, Hermes I. Dupraz S.R.L., Córdoba, Argentina) to extract the oil. Oxidative lipid indicators like conjugated dienes (CD) and trienes (CT), peroxide value (PV), tocopherols' content, and volatile compound analysis were determined.

CD and CT

CD and CT were measured following the COI method T 20/Doc n° 19/Rev 1 (COI, 2001) with a UV-vis diode array spectrophotometer (Spectrum SP-2100 UV, Zhejiang, China) at 232 and 268 nm, respectively. The results were expressed as the sample extinction coefficient E (1%, 1 cm).

Peroxide value

PV was evaluated by the iodometric assay according to the AOAC method number 965.33 (AOAC, 2006) using 5 g oil from

each sample and expressed as milliequivalents of active oxygen per kilogram of oil (mEq O₂/kg).

Tocopherol analysis

Quantification of tocopherols was performed by HPLC with a Zorbax RX-SIL column (5 µm particle size, 4.6 × 250 mm, Agilent Technologies, Palo Alto, CA, USA) as described by Martín et al. (2016). The mobile phase was an isopropanol solution in hexane 0.5% v/v with a flow rate of 1.5 mL/min. The detection wavelength was 298 nm. The tocopherol content and quantification were done by external standard curves of α -, β -, γ -, and δ -tocopherols (Sigma-Aldrich).

Volatile compounds analysis

The volatile analysis was carried out according to Martín et al. (2016). Headspace solid phase microextraction (HS-SPME) was used for the concentration of volatile compounds of peanut samples. A divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS) fiber (Supelco, Bellefonte, PA, USA) was used. GC/MS analysis was done using a GC system Perkin Elmer Clarus 600 equipped with an Elite 5MS (30 m × 0.25 mm i.d., 0.25 µm film thickness; Perkin Elmer) capillary column.

Descriptive sensory analysis

A well-trained (Grosso & Resurreccion, 2002) 10-person sensory panel (eight women and two men) with 7 years of experience in descriptive analysis participated in the peanut samples evaluation. All panelists were selected on the following criteria: (a) people with natural dentition; (b) people without food allergies; (c) nonsmokers; (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. 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 flavors (Meilgaard, Civille, & Carr, 2006). All 10 judges were trained and calibrated in four sessions for 4 days according to Nepote, Olmedo, Mestrallet, and Grosso (2009). During those training sessions, panelists were asked to taste standard solutions (sucrose, sodium chloride, citric acid, and caffeine) used as a reference point of intensity rating for a determined sensory attribute (Plemmons & Resurreccion, 1998). Subsequently, the sensory panel worked together to develop a list of attribute definitions in roasted peanuts and identified references to be used to describe each one. The “consensus” training was aided by providing initial attribute definitions using a standardized peanut lexicon (Johnsen, Civille, Vercellotti, Sanders, & Dus, 1988). After choosing roasted peanut references and definitions, panelists were calibrated by obtaining a mean intensity rating with a standard deviation within 10 points. Afterward, medium roasted peanuts were presented as the initial sample (warm-up) to be used during training and tasting sessions for each panelist. This warm up is proven to enhance panelists’ response reliability (Plemmons & Resurreccion, 1998). A 150 mm unstructured linear scale was used to measure the attribute intensity rating. The panelists were trained to use this scale identically by anchoring it with reference points generated by the standard references used. A “hybrid” descriptive analysis method combining the Quantitative Descriptive Analysis (QDA; Tragon Corp., Redwood City, CA, USA) and Spectrum TM analysis (Sensory Spectrum, Inc., Chatham, NJ, USA) was adopted for evaluating samples. This hybrid method uses a combination of

procedures of both the QDA and Spectrum methods and was referred by Lawless and Heymann (2010) as “generic descriptive analysis.” Although procedures of panelists selection and subsequent evaluation of samples are analogous in QDA and Spectrum analysis, the principal characteristic of this generic method is that during the training sessions, a combination of panelists’ consensus about sensory attribute definitions and references (from QDA) and a standardized lexicon of terms previously defined (from Spectrum analysis) is performed. In addition, the line scale was performed in order to calibrate panelists by using a series of standard references with intensity ratings representing points on this scale. Consequently, it helps panelists to score specific attributes of a specific sample similarly. This is a characteristic that comes from Spectrum analysis, as in QDA, judges make their determinations using different portions of the line scales because are the relative differences among samples that offer relevant information.

Peanut evaluation was conducted in partitioned booths under fluorescent light at room temperature. Three replications of each peanut sample (10 g) were placed into plastic cups with lids coded with three-digit random numbers. Before beginning each evaluation of samples, the sensory panel revised the list of attributes and definitions. In addition, the warm-up sample was presented before beginning the test sessions and was introduced as a blind sample during the samples evaluation to check panel consistency throughout the 180 days of sensory evaluation (Lawless & Heymann, 2010; Wang, Adhikari, & Hung, 2017a). The final lists of warm-up and reference intensity ratings and definitions were posted in each booth for all test sessions. A completely randomized block design was used for testing samples. The data were registered on paper ballots (Martín et al., 2018b).

Statistical analysis

The experiment was carried out in three repetitions. All data were expressed as means $\pm$ standard deviations performed using the INFOSTAT software Version 2017 (Facultad de Ciencias Agropecuarias, Univ. Nacional de Córdoba, Córdoba, Argentina). Significant differences among different coatings and days of storage on different quality parameters were analyzed via a two-way analysis of variance (factors: “treatment” and “time”) on a completely randomized design. The level of significance for all analysis was set up at $P < 0.05$. The difference of means between treatments was solved via least significant difference test. Correlations between variables were determined by the Pearson coefficient. Finally, a principal component analysis (PCA) was run to provide a general description of the relationships occurring between variables and samples. Chemical and sensory variables were normalized (standardized) before conducting the PCA in order to give them equivalent weight in the analysis (Nepote et al., 2009).

Results and Discussion

Storage stability study

Chemical analysis. Figure 1 shows the lipid oxidation indicators (CD, CT, and PV) of peanut kernels treated with high-protein DPF-based ECs, increased as a function of the storage time ($P < 0.0001$) for all samples. Chinma et al. (2014) found similar trends, in a study of roasted peanuts coated with starch and soy protein-based ECs.

There were significant differences ($P < 0.0001$) between samples during storage. Initially, all samples presented low average CD (1.17; Figure 1A). Control showed the highest CD increment, reaching 3.60 at the end of storage (day 180). Beginning with day

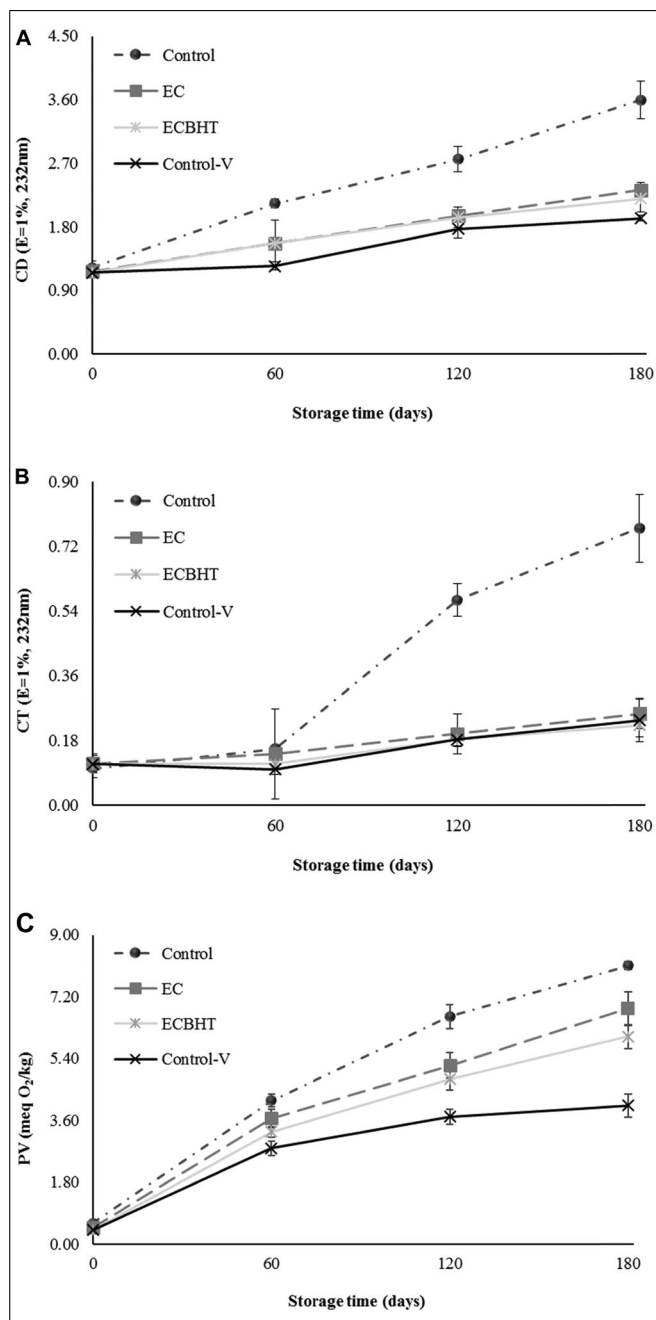


Figure 1—(A) Conjugated dienes (CD), (B) conjugated trienes (CT), and (C) peroxide value (PV), in blanched roasted peanuts samples stored during 180 days at 40 °C ($\alpha = 0.05$, $n = 3$). Treatments: uncoated peanuts (control), peanuts coated with peanut flour-based edible coating (EC), peanuts coated with peanut flour-based EC + 0.02% BHT (ECBHT), and uncoated peanuts packaged in high barrier bags under vacuum (control-V).

60, peanuts coated with peanut flour-based EC showed lower CD increment compared to control samples. Considering that these treatments were both packed in normal atmosphere polyethylene bags, results indicated that ECs acted as a barrier reducing the oxygen attack in EC and decreased the propagation of lipid oxidation reactions during storage of these coated seeds in comparison with the control without ECs (control). Sabaghi, Maghsoudlou, Khomeiri, and Ziaifar (2015) also reported the extension of oxidation protection in walnuts treated with ECs. However, peanuts treated with ECBHT did not exhibit significantly different CD

regarding EC, which meant that the addition of this antioxidant to ECs did not increase the oxidation protection of the seeds. In contrast, several authors have investigated the antioxidant action of BHT on products coated with edible films enriched with this synthetic antioxidant (Bodbodak & Rafiee, 2016; Larrauri et al., 2016; Su et al., 2012).

Finally, CD of control-V rose slowly, reaching the lower content at day 180 (1.92) with respect to the other samples.

CT values ($P < 0.0001$) presented analogous trends to CD between the control (from 0.10 to 0.77 on days 0 and 180, respectively) and EC (from 0.10 to 0.25 on days 0 and 180, respectively). Besides, in the same way as with CD, no significant differences appeared between EC and ECBHT (Figure 1B). For PV, there were less remarkable differences between control and the other treatments (Figure 1C) but similar tendencies to CD and CT were kept.

The high-protein content in the coating material was responsible for improving the coated peanut preservation (Grosso, Nepote, & Grosso, 2018a, 2018b). The method of DPF production led to a protein and carbohydrate content of 53.22g/100 g and 23.90 g/100 g, respectively (Riveros et al., 2018). As a result of the extraction process used, proteins and carbohydrates are the major components of the DPF (Riveros et al., 2018). Some earlier investigations indicated the oxygen and water barrier properties of protein and carbohydrate-based edible films for food application (Chinma, Ariahu, & Abu, 2012; Li et al., 2015). The defatted process used to prepare DPF achieves a significant reduction in the fat content of DPF (4.06 g/100 g; Riveros et al., 2018) relative to raw peanuts (49.24 g/100 g; USDA, 2018). Noshirvani, Ghanbarzadeh, Mokarram, and Hashemi (2017) indicated the beneficial effects of lipids on the hydrophobicity of coatings prepared from carboxymethyl cellulose, such as reducing the water vapor permeability by the addition of oleic acid. The current research followed the same procedure for DPF film-forming solution preparation developed by Riveros et al. (2018). Those authors characterized DPF-based films (DPFF) and evaluated the ability of DPF packaging to preserve the chemical quality of sunflower oil during storage. They observed excellent water vapor barrier of DPFF (water vapor permeability: 5.08×10^{-11} g/m²·s·Pa) and the use of DPF as packaging material delayed the lipid deterioration of sunflower oil during storage. Those findings in combination with the higher protein and carbohydrate contents as well as the residual oil in the DPF could supported the use of DPF as a suitable raw material to develop ECs with protection against damages caused by oxygen or water on susceptible foodstuffs like roasted peanuts.

Tocopherol content changes. The greatest average percentage of α -tocopherol was found on storage day 0 (27.50 mg/100 g oil), followed by γ -tocopherol (22.00 mg/100 g oil). Both compounds decreased during storage time ($P < 0.0001$). This decrease could be attributed to the phenolic structure of these molecules that may contribute to their oxidative degradation (Rossi, Alamprese, & Ratti, 2007). β -Tocopherol and δ -tocopherol showed low concentrations on storage day 0 (0.43 and 0.94 mg/100 g oil, respectively) without significative variations throughout storage. Figure 2 illustrated changes in those tocopherols that showed significant decreases during storage (α - and γ -tocopherols). Control samples exhibited the greatest decrease in α -tocopherol content ($P = 0.05$; Figure 2A; from 27.65 mg/100 g on day 0 to 21.32 mg/100 g on day 180). No significant differences were observed between samples of roasted peanuts coated with and without the addition of antioxidants, but they suffered a greater decrease than that obtained for control-V (26.01 mg/100 g on storage day 180).

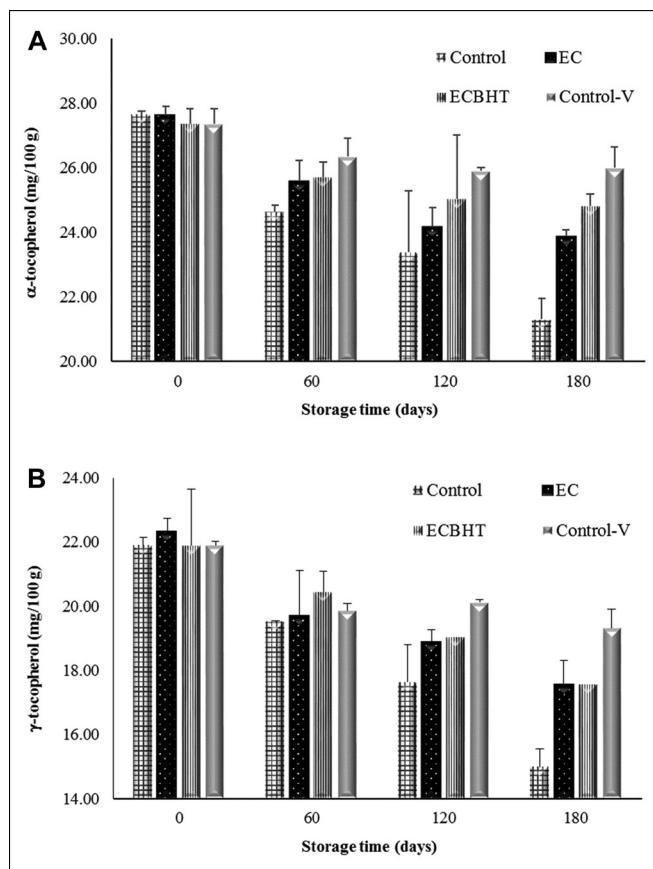


Figure 2–(A) α -Tocopherol content and (B) γ -tocopherol content, in blanch roasted peanuts samples stored during 180 days at 40 °C. ($\alpha = 0.05$, $n = 3$). Treatments: uncoated peanuts (control), peanuts coated with peanut flour-based edible coating (EC), peanuts coated with peanut flour-based EC + 0.02% BHT (ECBHT), and uncoated peanuts packaged in high barrier bags under vacuum (control-V).

A greater decrease in γ -tocopherol (Figure 2B) with respect to α -tocopherol was evident. In contrast, Elisia, Young, Yuan, and Kitts (2013) indicated that α -tocopherol is the most easily degradable isoform during heating, followed by γ -tocopherol, in vegetable oils from other oilseeds (canola, corn, sunflower, soybean, and cotton). The control presented an important decrease in γ -tocopherol between day 0 (21.91 mg/100 g) and 180 (14.99 mg/100 g) and these reductions were higher than those identified in the remaining samples ($P = 0.006$). Control-V largely preserved the γ -tocopherol content throughout the entire experiment, whereas the edible coated samples showed contents relatively lower and markedly higher with respect to control-V and control during storage, respectively. As observed for α -tocopherol, changes in γ -tocopherol for peanuts treated with ECBHT were not considerably different from those observed for coated peanuts without the addition of antioxidant during storage, indicating that the BHT included in the ECs did not improve their tocopherol protection effect.

A study undertaken by Martelli et al. (2017) revealed that α -tocopherol is stable even at high temperatures but only in the absence of oxygen and protected from light. In the current research, roasted peanuts were subjected to elevated temperatures. Therefore, the best α - and γ -tocopherols stability found in control-V during storage was attributed to a higher oxygen barrier of the ethylene-vinyl-alcohol packaging material. However,

as noted earlier, the findings indicated that peanut kernels treated with ECs had superior α - and γ -tocopherols stability over the control (sample without coating packaged in normal atmosphere). Because all coating treatments and the control were packaged in normal atmosphere, it is conceivable that the edible films acted as an oxygen barrier, decreasing deteriorative reactions of α - and β -tocopherol. Previous investigations also reported protection effects against oxidative reactions of other coated oilseeds and fruits (Dhital et al., 2017; Sabaghi et al., 2015).

Analysis of volatile compounds. Volatile compounds with large enough area detection for characterization by HS-SPME/GC–MS were 3-methylpyridine, hexanal, 2,5-dimethylpyrazine, γ -valerolactone, 4-cyanobenzophenone, 3-methyltridecane, and decane-5,6-bis(2,2-dimethylpropylidene)-(E,Z). Other peaks were observed in the chromatograms, but their small area made an appropriate identification and quantification difficult. 3-Methylpyridine, 2,5-dimethylpyrazine, and decane-5,6-bis(2,2-dimethylpropylidene)-(E,Z) were found in all roasted peanut samples. On day 0, the corresponding molecules had averages of 62×10^3 , 54×10^3 , and 73×10^3 electronic counts/g of roasted peanut, respectively. Decane-5,6-bis(2,2-dimethylpropylidene)-(E,Z) remained, in general, constant for all treatments throughout the entire storage without significant differences between them. Past studies also found this volatile compound in peanuts and other legumes (Martín et al., 2018a; Moniruzzaman, Shahinuzzaman, Haque, Khatun, & Yaakob, 2015). In contrast to the current findings, Martín et al. (2018a) found that this volatile compound showed decreases during storage were affected by the type of packaging, temperature, and storage time. Nevertheless, peanut samples used in that research were subjected to a markedly longer term storage with respect to the current work. 3-Methylpyridine and 2,5-dimethylpyrazine decreased with storage time ($P < 0.0001$), only for the control. In uncoated samples packaged in high barrier bags under vacuum (control-V) or in treated samples encapsulated in ECs with and without antioxidants (EC and ECBHT), these volatile compounds remained significantly stable throughout the analyzed period. Pyrazines and pyridines are compounds formed during the thermal roasting process between carbohydrates and amino acids by nonenzymatic browning reactions (Maillard reactions). Because these molecules provide the typical toasted flavor of roasted products, reductions in their detection are related to an oxidative and sensory quality deterioration (Liu et al., 2011).

Hexanal, γ -valerolactone, 4-cyanobenzophenone, and 3-methyltridecane were detected only in the control. The content of 3-methyltridecane increased significantly between day 0 (5×10^3 electronic counts/g) and day 180 (8×10^3 electronic counts/g). Hexanal, γ -valerolactone, and 4-cyanobenzophenone were only detected on day 180 for control (6×10^3 , 13×10^3 , and 5×10^3 electronic counts/g, respectively). Other authors identified these volatile molecules as lipid oxidation products from unsaturated fatty acids (Tzschoppe, Haase, Höhnisch, Jaros, & Rohm, 2016; Wang, Adhikari, & Hung, 2017b). The present results highlighted that peanut samples without coatings, packaged in normal atmosphere, underwent the greatest amount of fatty acid degradation during storage. Contrastingly, ECs made from DPF afforded a protective effect on volatiles associated with fresh products and low production of oxidation-derived volatiles, irrespective of the antioxidant's incorporation.

Descriptive sensory analysis. The sensory attribute intensity ratings of fresh roasted peanuts samples without coatings packaged in normal atmosphere (Control at day 0) were 38.94 ± 0.69

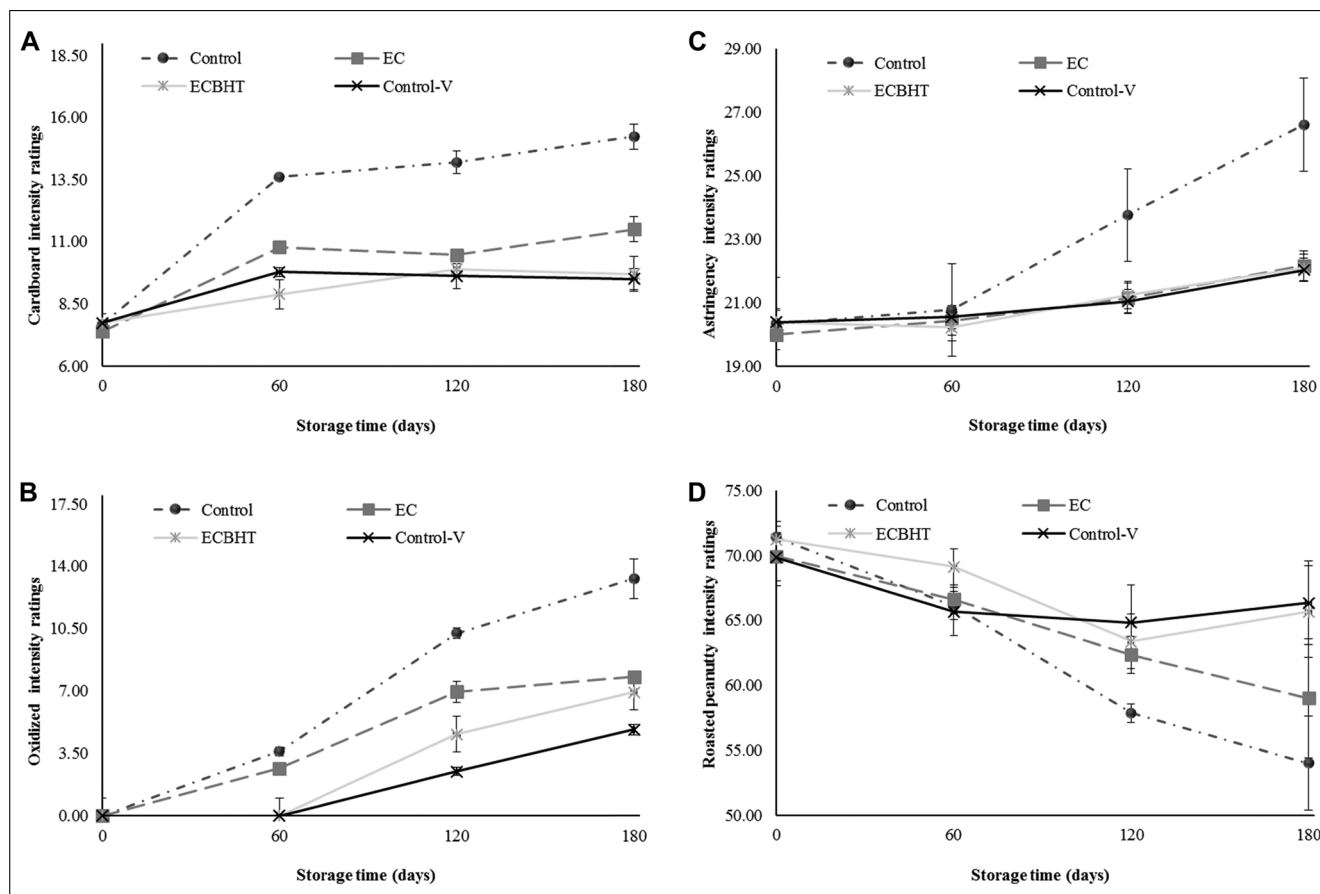


Figure 3—(A) cardboard, (B) oxidized, (C) astringency, and (D) roasted peanutty intensity ratings, in blanched roasted peanuts samples stored during 180 days at 40 °C. ($\alpha = 0.05$, $n = 3$). Treatments: uncoated peanuts (control), peanuts coated with peanut flour-based edible coating (EC), peanuts coated with peanut flour-based EC + 0.02% BHT (ECBHT), and uncoated peanuts packaged in high barrier bags under vacuum (control-V).

(brown color), 12.50 ± 0.00 (brightness), 14.83 ± 2.86 (roughness), 0.00 ± 0.00 (oxidized), 7.67 ± 0.44 (cardboard), 71.39 ± 0.35 (roasted peanutty), 7.44 ± 0.48 (bitter), 2.33 ± 0.16 (sour), 2.83 ± 0.16 (salad), 22.94 ± 1.11 (sweetness), 20.33 ± 0.58 (astringency), 43.72 ± 0.51 (hardness), and 41.61 ± 0.84 (crunchiness). These sensory attributes were observed and defined in roasted peanuts by Nepote et al. (2009). The coated samples presented higher brightness intensity ratings (EC = 23.89 ± 1.54 and ECBHT = 23.44 ± 1.50) than the uncoated samples (control and control-V), inferring that ECs are responsible for increasing the intensity rating of this attribute. The panelists did not detect oxidized intensity ratings on storage day 0, as expected for fresh peanut samples.

Figure 3 illustrates the intensity ratings of some sensory attributes that changed significantly throughout storage. The intensity ratings of cardboard, oxidized, and astringency rose with storage and showed significant differences between treatments ($P < 0.0001$, $P < 0.0001$, and $P = 0.0008$, respectively). Likewise, Larrauri et al. (2016) recorded similar increments for cardboard and oxidized attributes in coated almonds. Oxidized and cardboard attributes are associated with oxidative deterioration and the occurrence of undesirable compounds. The control suffered a significant increase in both mentioned attributes during the studied period: from 7.67 on day 0 to 15.23 on day 180 for cardboard and from 0.00 on day 0 to 13.30 on day 180 for oxidized (Figure 3A and 3B, respectively). Panelists could not distinguish significant differences between coated roasted peanuts during storage, and

the intensity scores were lower and closer to control-V than control.

The findings in the present section correlated well with the volatile profile mentioned previously. Coated peanut samples with and without antioxidants delayed the occurrence of lipid oxidation substances to a similar extent as those packaged in high barrier bags under vacuum (control-V). Unlike these samples, the control without coating packaged in normal atmosphere was not able to retard the deleterious effect of oxygen and the production of unpleasant flavors from oxidation reactions.

Astringency increased significantly only in control samples, from day 60 (Figure 3C). It is interesting to note that ECs contributed to hinder the intensity rating increase of this attribute. Grosso, Asensio, Nepote, and Grosso (2018b) also detected higher and lower astringency increments for uncoated walnuts and for coated walnuts with methyl cellulose, respectively. In contrast, Zhao and McDaniel (2005) mentioned that certain ECs made from chitosan could increase the intensity of astringency in coated samples. Astringency is a particular chemical mouthfeel considering as undesirable in many kinds of foods and is caused by molecules present in foods that produce a dry sensation on the tongue and mouth (Lawless & Heymann, 2010). Perez-Locas and Yaylayan (2010) highlighted that, although in the roasting process, some chemical compounds produced by Maillard reactions contribute to the improvement of the essential flavor profile, others can be produced under inappropriate conditions, such as prolonged storage, and are responsible of food flavor deterioration. For instance,

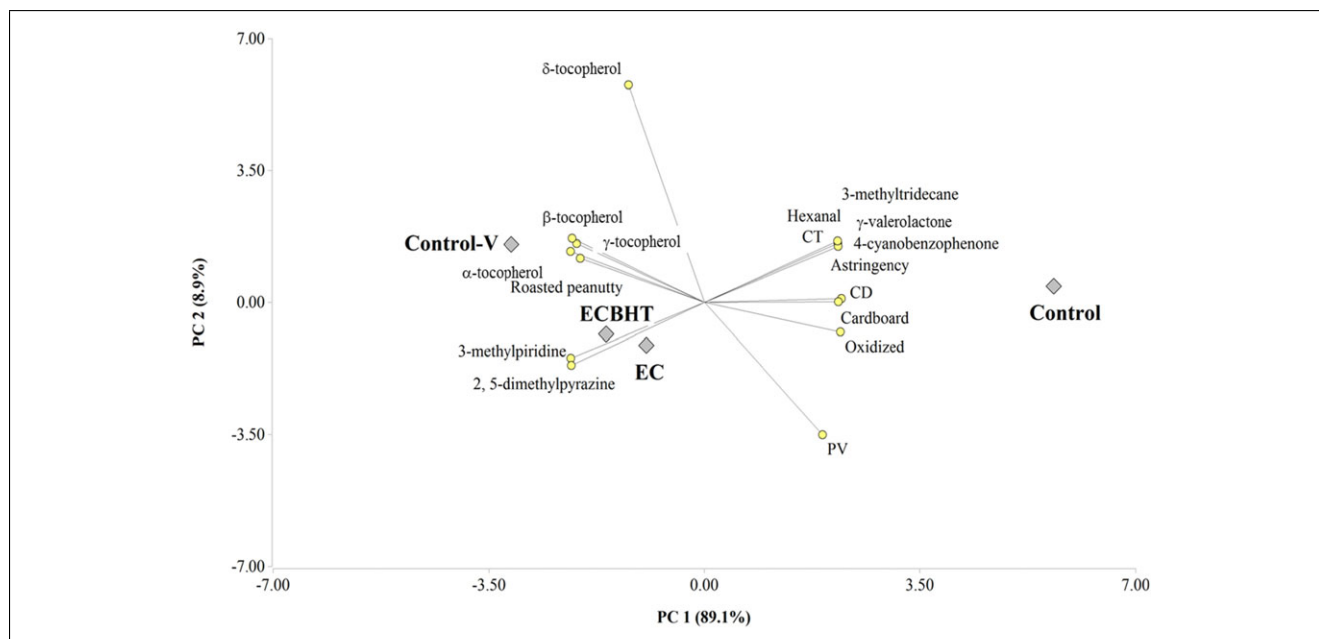


Figure 4—Biplot from the first and second principal component of PCA for blanched roasted peanuts samples stored during 180 days at 40 °C ($\alpha = 0.05$, $n = 3$). Treatments: uncoated peanuts (control), peanuts coated with peanut flour-based edible coating (EC), peanuts coated with peanut flour-based edible coating + 0.02% BHT (ECBHT), and uncoated peanuts packaged in high barrier bags under vacuum (control-V).

van Boekel (2006) reported that a high concentration of some Maillard-derived flavor products, called alkyl-pyridines, is associated to astringency characteristics. These compounds are generated from the reaction of free proline and glucose during the Maillard reaction (Paravisini & Peterson, 2019). What is more, Klevorn and Dean (2018) reported higher free proline content in roasted peanuts in comparison to the raw product. Those authors indicated that these free amino acids are liberated during the roasting process by decomposition of proteins. According to the studies mentioned above and the findings in the present research, the increase of astringency intensity during storage observed for the control samples was probably due to a higher decomposition of proteins in these samples throughout storage, which led to more production of free proline as a source of alkyl-pyridines contributing to the generation of a greater astringency sensation in these peanut samples in comparison to the other treatments.

On the other hand, roasted peanutty intensity ratings decreased significantly during the studied time, and these changes were more visible for the control than for the remaining samples ($P = 0.0003$; Figure 3D). This sensory attribute is linked to fresh products and the absence of undesirable flavors. ECBHT and EC displayed significant differences between them only at the end of storage time (day 180) are the samples that registered the lowest decreases in roasted peanutty ratings. Those results emphasized that coatings have a barrier function, promoting sensory quality preservation for roasted peanuts in the conditions of this study. Riveros, Nepote, and Grosso (2016) stated an opposite trend, with higher roasted flavor in roasted sunflower samples without coating than coated samples incorporated with essential oils as antioxidants. Those researchers concluded that the combination of ECs and essential oils created a new sensory attribute that could hinder and affect the typical roasted flavor of the final product. In the current investigation, the antioxidant used (BHT) did not produce flavors that could affect the roasted peanutty attribute.

Although sensory attributes changed in the current study, they occurred to a lower extent for the edible coated samples as com-

pared to the control sample. A consumer acceptance test is recommended for future research to clarify whether ECs provide suitable protective effect for the sensory attributes during storage.

PCA and correlation. PCA analysis was conducted to compare the ability of the different treatments of roasted peanuts to preserve the chemical and sensory kernel qualities during storage. Figure 4 shows the biplot obtained from the two principal components (PC1 and PC2), which together explained 98% total variability. PC1 was the most important variable in terms of differences among treatments as it accounted for 89.1% total variability. The studied variables were PV, CD, CT, tocopherol content (α , β , γ , and δ), volatile compounds (3-methylpyridine, 2,5-dimethylpyrazine, hexanal, γ -valerolactone, 3-methyltridecane, and 4-cyanobenzophenone), and sensory attributes that presented significant differences between samples (cardboard, oxidized, roasted peanutty, and astringency).

PV, CD, CT, cardboard flavor, astringency, oxidized, hexanal, γ -valerolactone, 3-methyltridecane, and 4-cyanobenzophenone were placed on the right side of the biplot (PC1; Figure 4), demonstrating a significant positive association between them, which, in turn, are linked to sample deterioration. At the same time, these variables were negatively associated with roasted peanutty, tocopherols, 2,5-dimethylpyrazine, and 3-methylpyridine. These last volatile compounds positively influenced the roasted peanut stability, as indicated in “Analysis of volatile compounds” section. The sample without coating and packaged in normal atmosphere (control) was located on the right side of PC1 and positively associated to variables linked to deterioration in the same quadrant. This sample showed the highest values for lipid oxidation indicators (CD, CT, and PV), while α - and γ -tocopherols suffered the greatest decomposition, inferred by the strong negative association between control and these antioxidants. In other words, peanut oil in the control underwent the greatest oxidation throughout storage, with the largest damage in its sensory quality. Control-V, ECBHT, and EC were on the left side of the biplot and close to the variables related to chemical and sensory stability, and

opposite to the oxidation variables, suffering low-quality degradation during storage.

PC2 was positively aligned to the variable δ -tocopherol and inversely related to PV. Nonetheless, the percentage of total variance explained by PC2 was considerably low (8.9%) and did not allow a visible differentiation among samples and variables.

The variables of interest for the correlation analysis were those exhibiting changes during storage time like PV, CD, CT, α -tocopherol, γ -tocopherol, oxidized, cardboard, roasted peanutty flavor, astringency, 3-methylpyridine, and 2,5-dimethylpyrazine. Pearson's correlation coefficients above 0.65 were observed among PV, CD, CT, oxidized, cardboard, and astringency. Negative correlation coefficients over -0.65 were noted between α -tocopherol, γ -tocopherol, roasted peanutty flavor, 3-methylpyridine, 2,5-dimethylpyrazine, and the variables mentioned above, for all samples. These results were due to the decreases in α -tocopherol, γ -tocopherol, roasted peanutty flavor, 3-methylpyridine, and 2,5-dimethylpyrazine, while PV, CD, CT, oxidized, cardboard, and astringency increased with storage. Previous authors also indicated positive or negative correlations between chemical and sensory variables in roasted peanuts (Wang et al., 2017a; Wei, Wang, & Zhang, 2015).

Conclusions

High-protein DPF-based ECs applied to roasted peanut kernels contribute to delay the lipid oxidation process and enhance sensory property preservation extending the shelf life of roasted peanuts in comparison with roasted peanuts without coatings, when this product is packed in a simple and plain plastic package under normal atmosphere. Furthermore, the addition of antioxidants (BHT) in the coating does not show significant difference with respect to samples without antioxidants under these normal packaging conditions.

Current results showed that uncoated peanuts packed in high barrier bags under vacuum preserved better chemical and sensory quality during storage compared to peanut flour based ECs packed in normal atmosphere. Nevertheless, high barrier packaging and vacuum technologies are highly environment contaminant and significantly expensive for the peanut industry. These issues along with consumer demand for natural and biodegradable foodstuffs that promote sustainable development as part of the value-added chain of production systems emphasize the value of using biopolymer edible films for shelf life extension of susceptible foods. ECs made from peanut flour are a natural environment-friendly and low-cost alternative to prolong food stability and decrease the use of synthetic high barrier materials as primary packaging.

Finally, to coat peanuts using peanut flour coating should be considered by the food industry as using the same allergenic material in the same production line decreases the risk for allergen cross contamination.

Acknowledgments

This research was supported by Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and Secretaría de Ciencia y Tecnología (SECYT-UNC).

Author Contributions

María Paula Martín, Cecilia Riveros, and Alejandro Paredes performed the experiments and analyses and, also, interpreted the experimental data. Daniel Allemandi and Valeria Nepote contributed as co-advisors and Nelson Rubén Grosso as advisor.

References

- AOAC. (2006). Official methods of analysis of the AOAC. Gaithersburg, MD: Association of Official Analytical Chemists.
- Bodbadak, S., & Rafiee, Z. (2016). Recent trends in active packaging in fruits and vegetables. In M. W. Siddiqui (Ed.), *Eco-friendly technology for postharvest produce quality* (pp. 77–125). London, UK: Elsevier Inc. <https://doi.org/10.1016/B978-0-12-804313-4.00003-7>
- Borneo, R., Alba, N., & Aguirre, A. (2016). New films based on triticale flour: Properties and effects of storage time. *Journal of Cereal Science*, 68, 82–87. <https://doi.org/10.1016/j.jcs.2016.01.001>
- CAA. (2014). *Capítulo XVIII, Aditivos alimentarios. Código Alimentario Argentino. AN-MAT, Ministerio de Salud, Argentina*. Retrieved from http://www.anmat.gov.ar/alimentos/normativas_alimentos_caa.asp
- Calhoun, S. (2013). Improving the quality and safety of peanuts. In L. Harris (Ed.), *Improving the safety and quality of nuts* (pp. 330–349). Cambridge, U.K.: Woodhead Publishing Limited.
- Chang, A. S., Sreedharan, A., & Schneider, K. R. (2013). Peanut and peanut products: A food safety perspective. *Food Control*, 32(1), 296–303. <https://doi.org/10.1016/j.foodcont.2012.12.007>
- Chinna, C. E., Ariahu, C. C., & Abu, J. O. (2012). Development and characterization of cassava starch and soy protein concentrate based edible films. *International Journal of Food Science and Technology*, 47(2), 383–389. <https://doi.org/10.1111/j.1365-2621.2011.02851.x>
- Chinna, C. E., Ariahu, C. C., & Abu, J. O. (2014). Shelf life extension of toasted groundnuts through the application of cassava starch and soy protein-based edible coating. *Nigerian Food Journal*, 32(1), 133–138. [https://doi.org/10.1016/S0189-7241\(15\)30106-5](https://doi.org/10.1016/S0189-7241(15)30106-5)
- COI. (2001). Método de análisis prueba espectrofotométrica en el ultravioleta. Document COI/T 20/Doc n° 19/Rev 1. Madrid, España: International Olive Oil Council (IOOC).
- Dhital, R., Joshi, P., Becerra-Mora, N., Umagiliyali, A., Chai, T., Kohli, P., & Choudhary, R. (2017). Integrity of edible nano-coatings and its effects on quality of strawberries subjected to simulated in-transit vibrations. *LWT—Food Science and Technology*, 80, 257–264. <https://doi.org/10.1016/j.lwt.2017.02.033>
- Elisia, I., Young, J. W., Yuan, Y. V., & Kitts, D. D. (2013). Association between tocopherol isoform composition and lipid oxidation in selected multiple edible oils. *Food Research International*, 52(2), 508–514. <https://doi.org/10.1016/j.foodres.2013.02.013>
- Fortunati, E., Puglia, D., Armentano, I., Valdés, A., Ramos, M., Juárez, N., ... Kenny, J. M. (2017). Multifunctional antimicrobial nanocomposites for food packaging applications. In A. Grumezescu (Ed.), *Food preservation* (pp. 265–303). San Diego, California, USA: Elsevier Inc. <https://doi.org/10.1016/B978-0-12-804303-5.00008-0>
- Grosso, A. L., Asensio, C. M., Nepote, V., & Grosso, N. R. (2018a). Antioxidant activity displayed by phenolic compounds obtained from walnut oil cake used for walnut oil preservation. *Journal of the American Oil Chemists' Society*, 95, 1409–1419. <https://doi.org/10.1002/aocs.12145>
- Grosso, A. L., Asensio, C. M., Nepote, V., & Grosso, N. R. (2018b). Quality preservation of walnut kernels using edible coatings. *Gasas y Aceites*, 69(4), 1–9. <https://doi.org/10.3989/gya.0350181>
- 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(4), 1530–1537.
- 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(1), 9–17. <https://doi.org/10.1111/j.1745-459X.1988.tb00426.x>
- Kang, H. J., Kim, S. J., You, Y. S., Lacroix, M., & Han, J. (2013). Inhibitory effect of soy protein coating formulations on walnut (*Juglans regia* L.) kernels against lipid oxidation. *LWT—Food Science and Technology*, 51(1), 393–396. <https://doi.org/10.1016/j.lwt.2012.10.019>
- Klevorn, C. M., & Dean, L. L. (2018). A metabolomics-based approach identifies changes in the small molecular weight compound composition of the peanut as a result of dry-roasting. *Food Chemistry*, 240, 1193–1200. <https://doi.org/10.1016/j.foodchem.2017.08.058>
- Larrauri, M., Demaria, M. G., Ryan, L. C., Asensio, C. M., Grosso, N. R., & Nepote, V. (2016). Chemical and sensory quality preservation in coated almonds with the addition of antioxidants. *Journal of Food Science*, 81(1), S208–S215. <https://doi.org/10.1111/1750-3841.13164>
- Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food principles and practices* (2nd ed.). Ithaca, NY: Springer.
- Li, X., Ji, N., Qiu, C., Xia, M., Xiong, L., & Sun, Q. (2015). The effect of peanut protein nanoparticles on characteristics of protein- and starch-based nanocomposite films: A comparative study. *Industrial Crops and Products*, 77, 565–574. <https://doi.org/10.1016/j.indcrop.2015.09.026>
- Liu, X. J., Jin, Q. Z., Liu, Y. F., Huang, J. H., Wang, X. G., Mao, W. Y., & Wang, S. S. (2011). Changes in volatile compounds of peanut oil during the roasting process for production of aromatic roasted peanut oil. *Journal of Food Science*, 76(3), 404–412. <https://doi.org/10.1111/j.1750-3841.2011.02073.x>
- Martelli, S. M., Motta, C., Caon, T., Alberton, J., Belletini, I. C., do Prado, A. C. P., ... Soldi, V. (2017). Edible carboxymethyl cellulose films containing natural antioxidant and surfactants: α -tocopherol stability, in vitro release and film properties. *LWT—Food Science and Technology*, 77, 21–29. <https://doi.org/10.1016/j.lwt.2016.11.026>
- Martin, M. P., Nepote, V., & Grosso, N. R. (2016). Chemical, sensory, and microbiological stability of stored raw peanuts packaged in polypropylene ventilated bags and high barrier plastic bags. *LWT—Food Science and Technology*, 68, 174–182. <https://doi.org/10.1016/j.lwt.2015.12.031>
- Martin, M. P., Asensio, C. M., Nepote, V., & Grosso, N. R. (2018a). Improving quality preservation of raw peanuts stored under different conditions during a long-term storage. *European Journal of Lipid Science and Technology*, 120(9), 1–11. <https://doi.org/10.1002/ejlt.201800150>
- Martin, M. P., Grosso, A. L., Nepote, V., & Grosso, N. R. (2018b). Sensory and chemical stabilities of high-oleic and normal-oleic peanuts in shell during long-term storage. *Journal of Food Science*, 83(9), 2362–2368. <https://doi.org/10.1111/1750-3841.14295>
- Meilgaard, M., Civille, G., & Carr, T. (2006). *Sensory evaluation techniques* (4th ed.). Boca Raton, FL: CRC Press.
- Moniruzzaman, M., Shahinuzzaman, M., Haque, A., Khatun, R., & Yaakob, Z. (2015). Gas chromatography mass spectrometry analysis and in vitro antibacterial activity of essential oil from *Trigonella foenum-graecum*. *Asian Pacific Journal of Tropical Biomedicine*, 5(12), 1033–1036.
- Nepote, V., Olmedo, R. H., Mestraller, M. G., & Grosso, N. R. (2009). A study of the relationships among consumer acceptance, oxidation chemical indicators, and sensory attributes in high-oleic and normal peanuts. *Journal of Food Science*, 74(1), S1–S8. <https://doi.org/10.1111/j.1750-3841.2008.00972.x>

- Noshirvani, N., Ghanbarzadeh, B., Mokarram, R. R., & Hashemi, M. (2017). Novel active packaging based on carboxymethyl cellulose-chitosan-ZnO NPs nanocomposite for increasing the shelf life of bread. *Food Packaging and Shelf Life*, 11, 106–114. <https://doi.org/10.1016/j.foodchem.2017.01.010>
- Paravisini, L., & Peterson, D. G. (2019). Reactive carbonyl species as key control point for optimization of reaction flavors. *Food Chemistry*, 274, 71–78. <https://doi.org/10.1016/j.foodchem.2018.08.067>
- Perez-Lucas, C., & Yaylayan, V. A. (2010). The Maillard reaction and food quality deterioration. In L. H. Skibsted, J. Risbo, & M. L. Andersen (Eds.), *Chemical deterioration and physical instability of food and beverages* (pp. 70–94). Cambridge, UK: Woodhead Publishing Limited. <https://doi.org/10.1533/9781845699260.1.70>
- 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. <https://doi.org/10.1111/j.1745-459X.1998.tb00095.x>
- Reddy, N., Chen, L., & Yang, Y. (2013). Thermoplastic films from peanut proteins extracted from peanut meal. *Industrial Crops and Products*, 43(1), 159–164. <https://doi.org/10.1016/j.indcrop.2012.06.051>
- Riveros, C. G., Mestrallet, M. G., Quiroga, P. R., Nepote, V., & Grosso, N. R. (2013). Preserving sensory attributes of roasted peanuts using edible coatings. *International Journal of Food Science & Technology*, 48(4), 850–859. <https://doi.org/10.1111/ijfs.12036>
- Riveros, C. G., Nepote, V., & Grosso, N. R. (2016). Thyme and basil essential oils included in edible coatings as a natural preserving method of oilseed kernels. *Journal of the Science of Food and Agriculture*, 96(1), 183–191. <https://doi.org/10.1002/jsfa.7080>
- Riveros, C. G., Martin, M. P., Aguirre, A., & Grosso, N. R. (2018). Film preparation with high protein defatted peanut flour: Characterisation and potential use as food packaging. *International Journal of Food Science & Technology*, 53, 969–975. <https://doi.org/10.1111/ijfs.13670>
- Rossi, M., Alamprese, C., & Ratti, S. (2007). Tocopherols and tocotrienols as free radical-scavengers in refined vegetable oils and their stability during deep-fat frying. *Food Chemistry*, 102(3), 812–817. <https://doi.org/10.1016/j.foodchem.2006.06.016>
- Sabaghi, M., Maghsoudlou, Y., Khomeiri, M., & Ziaifar, A. M. (2015). Active edible coating from chitosan incorporating green tea extract as an antioxidant and antifungal on fresh walnut kernel. *Postharvest Biology and Technology*, 110, 224–228. <https://doi.org/10.1016/j.postharvbio.2015.08.025>
- Shi, X., Davis, J. P., Xia, Z., Sandeep, K. P., Sanders, T. H., & Dean, L. O. (2017). Characterization of peanuts after dry roasting, oil roasting, and blister frying. *LWT—Food Science and Technology*, 75, 520–528. <https://doi.org/10.1016/j.lwt.2016.09.030>
- Su, J., Chen, J., Liao, S., Li, L., Zhu, L., & Chen, L. (2012). Composition and biological activities of the essential oil extracted from a novel plant of *Cinnamomum camphora* Chvar. Borneol. *Journal of Medicinal Plants Research*, 6(18), 3487–3494. <https://doi.org/10.5897/JMPR12.157>
- Tzschoppe, M., Haase, H., Höhnisch, M., Jaros, D., & Rohm, H. (2016). Using ion mobility spectrometry for screening the autoxidation of peanuts. *Food Control*, 64, 17–21. <https://doi.org/10.1016/j.foodcont.2015.12.017>
- USDA United States Department of Agriculture, Agricultural Research Service, Food Composition Databases. (2018). *USDA Food Composition Databases*. Retrieved from <https://ndb.nal.usda.gov/ndb/>
- Valderrama Solano, A. C., & Rojas de Gante, C. (2014). Development of biodegradable films based on blue corn flour with potential applications in food packaging. Effects of plasticizers on mechanical, thermal, and microstructural properties of flour films. *Journal of Cereal Science*, 60(1), 60–66. <https://doi.org/10.1016/j.jcs.2014.01.015>
- Van Boeckel, M. A. J. S. (2006). Formation of flavour compounds in the Maillard reaction. *Biotechnology Advances*, 24(2), 230–233. <https://doi.org/10.1016/j.biotechadv.2005.11.004>
- Wang, S., Adhikari, K., & Hung, Y.-C. (2017a). Acceptability and preference drivers of freshly roasted peanuts. *Journal of Food Science*, 82(1), 174–184. <https://doi.org/10.1111/1750-3841.13561>
- Wang, S., Adhikari, K., & Hung, Y.-C. (2017b). Effects of short storage on consumer acceptability and volatile compound profile of roasted peanuts. *Food Packaging and Shelf Life*, 13(June), 27–34. <https://doi.org/10.1016/j.foodpsl.2017.06.002>
- Wei, Z., Wang, J., & Zhang, W. (2015). Detecting internal quality of peanuts during storage using electronic nose responses combined with physicochemical methods. *Food Chemistry*, 177, 89–96. <https://doi.org/10.1016/j.foodchem.2014.12.100>
- Wu, H., Wang, Q., Ma, T., & Ren, J. (2009). Comparative studies on the functional properties of various protein concentrate preparations of peanut protein. *Food Research International*, 42(3), 343–348. <https://doi.org/10.1016/j.foodres.2008.12.006>
- Zhao, Y., & McDaniel, M. (2005). Sensory quality of foods associated with edible film and coating systems and shelf-life extension. In J. H. Han (Ed.), *Innovations in food packaging* (pp. 434–453). San Diego, California, USA: Elsevier Ltd. <https://doi.org/10.1016/B978-012311632-1/50056-5>