International Journal of Food Science +Technology

Original article

Film preparation with high protein defatted peanut flour: characterisation and potential use as food packaging

Cecilia G. Riveros,[1] M. Paula Martin,[1] Alicia Aguirre[2] & Nelson R. Grosso[1]*

1 Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba (UNC), Instituto Multidisciplinario de Biología Vegetal (IMBIV), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Ing. Agr. Félix Aldo Marrone 746, CC 509, X5016GCA, Córdoba, Argentina

2 Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba (UNC), Instituto de Ciencia y Tecnología de Alimentos Córdoba (ICYTAC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Av. Filloy S/N, Ciudad Universitaria, CP. X5000HUA, Córdoba, Argentina

(Received 14 October 2017; Accepted in revised form 16 October 2017)

Summary The purpose of this study was to prepare a defatted peanut flour-based film (DPFF); to characterise their physicochemical, optical, barrier and mechanical properties; and to evaluate the defatted peanut flour package efficacy to preserve the chemical quality of sunflower oil during storage. The film presented high lightness values (L^* = 86.83). The water vapour permeability was 5.44×10^{-11} g m^{-1} s^{-1} Pa^{-1}. Tensile strength and percentage of elongation were 1.01 MPa and 84.01%, respectively. Sunflower oil samples packaged in defatted peanut flour packages (DPFP) were stored during 67 days at room temperature. Peroxide value and conjugated dienes increased less for sunflower oil conditioned in DPFP and high barrier plastic pouches (EVOH) during storage than sunflower oil conditioned in Petri dishes (C). The use of DPFP improved the chemical stability of sunflower oil during storage. The DPFF showed suitable film properties, and also, the capacity to be incorporated in food packaging applications.

Keywords Barrier, film, flour, peanut, preserving, protein, rancidity, stability.

Introduction

Edible films and coatings have an important function in protecting the quality of food products from food deterioration. The film or coating provides a semipermeable barrier against gases, water vapour, movement of oils and fats and loss of volatile flavours and aromas (Scarlat *et al.*, 2015). Edible films and coatings can also act as a carrier of food additives, such as antimicrobials, antioxidants, flavours and colours (Balaguer *et al.*, 2014). The application of these kinds of films can also improve the mechanical properties and keep the structural integrity of the food products (Han, 2014).

Oxidative deterioration, particularly lipid oxidation, during storage of food commodities produces toxic aldehydes that are associated with rancidity and off-flavours processes (Guillen & Goicoechea, 2008). Due to their properties, biodegradable packages can retard oxidative processes, improving food safety and shelf life (De Moraes Crizel *et al.*, 2016). Biodegradable edible films and coatings are prepared using natural polymers. Consequently, they represent an alternative to replace synthetic materials in packaging applications (Balaguer *et al.*, 2014; Scarlat *et al.*, 2015) and reduce the environmental pollution issues associated with nondegradable and nonrenewable packages (Piñeros-Hernandez *et al.*, 2017).

Proteins have been predominantly used as film-forming materials. They are macromolecules that form a tightly packed and ordered hydrogen-bonded network structure. Due to those particularities, proteins show excellent barrier to gases (O_2 and CO_2), as well as mechanical and structural properties (Yang & Paulson, 2000). An alternative is to produce films from mixtures of starch, protein, lipid and fibre, namely, flours, obtained from agricultural sources (Valderrama Solano & Rojas de Gante, 2014). For instance, biodegradable films have been developed from amaranth flour (Tapia-Blácido *et al.*, 2005), achira flour (Andrade-Mahecha *et al.*, 2012), blue corn flour (Valderrama Solano & Rojas de Gante, 2014), triticale flour (Borneo *et al.*, 2016) and *babassu mesocarp* flour (Maniglia *et al.*, 2017).

Peanuts are characterised by a high lipid and protein content and low percentage of carbohydrates and ash, containing approximately 45–54% lipids and 25–31%

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

doi:10.1111/ijfs.13670

proteins (Grosso *et al*., 2002). Peanuts represent an important source of protein that is characterised by its good functional properties and high nutritional values (Gong *et al*., 2016).

Previous studies have developed films elaborated with peanut proteins. Most of these studies have investigated the physiochemical properties, as well as the improvement of functional properties of peanut proteins isolates (PPI) and films. (Liu *et al*., 2004; Sun *et al*., 2013; Li *et al*., 2014, 2015; Gong *et al*., 2016). Generally, PPI used in the elaboration of a film have been prepared according to the method of alkaline extraction and acid precipitation (Liu *et al*., 2012). However, there are no reports on the development of a simple film-forming methodology, which could become a source of new films, with applications in different industries and processes. Also, the ability of defatted peanut flour-based films, to provide protection against lipid oxidation, has not been studied when this coating or biopackaging material is used on food product preservation.

The purpose of this research was to prepare a film based on defatted peanut flour (DPF) and to characterise its physicochemical, optical, barrier and mechanical properties, and to evaluate the defatted peanut flour package efficacy to preserve the chemical quality of sunflower oil during storage.

Materials and methods

Materials

Sound and mature seeds of blanched peanuts (*Arachis hypogaea* L.) type Runner (cv. Tegua), size 38/42 kernels per ounce (2016 crop), were provided by Lorenzetti, Ruetsch & Cia company (Ticino, Córdoba, Argentina). Before processing, damaged and bruised peanuts were manually removed.

Preparation of defatted peanut flour (DPF)

For preparing DPF, blanched peanuts were ground using a mill (Moulinex, model AD5663C9, Colombia). Then, the DPF was obtained after an oil extraction with n-hexane for 12 h, and a soluble carbohydrates extraction with 70% ethanol for 6 h, both using Soxhlet apparatus. After each extraction process, the sample was oven-dried at 60 °C for 24 h. For completion of the formulation process, the flour was ground using a mill and passed through a 60-mesh sieve to standardise the final granulometry.

Film formulation

Film-forming solutions (FFS) were prepared according to the method described by Borneo *et al*. (2016), with modifications. The DPF (4.0 g/100 mL) was mixed with distilled water and magnetically stirred at 60 °C for 15 min. The dispersion was adjusted to pH 9, with 0.1 N sodium hydroxide, to dissolve the protein. Glycerol (25 g/100 g flour) was added as the plasticizer, and the obtained dispersion was then magnetically stirred at 60 °C for 15 min. The FFS was cooled at room temperature, centrifuged (500 rpm for 30 s), and degassed under vacuum. The casting technique was used to form the films. The FFS (10 mL) was poured onto a horizontal flat silicone tray (5.5 cm diameter) and dried at 35 °C in a forced air oven (model 600, Memert, Schwabach, Germany) for 20 h. The thickness of the films was measured using a micrometre (Schwyz SC1). The mean thickness was used to calculate the mechanical and barrier properties (Romero *et al*., 2016).

Chemical analysis

The centesimal composition (moisture, lipids, proteins and ash) of DPF was analysed according to AOAC (2006). The nitrogen content was estimated by the Kjeldahl method and multiplied by 5.46 to convert to protein percentage. Carbohydrate content was estimated by the difference of the other components, using the following formula, carbohydrate content = 100% – (% protein + % oil + % ash) (Mestrallet *et al*., 2004). Fibre content was determined based on the AOCS method (AOCS, 2017). This method determines crude fibre, which is the organic residue remaining after digesting with 0.255 N sulphuric acid and 0.313 N sodium hydroxide. The compounds removed are predominantly protein, sugar, starch, lipid and portions of both the structural carbohydrates and lignin.

Sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE)

The protein fraction from the DPF and the FFS were analysed by SDS-PAGE (Mini Protean II Dual Slab Cell, Bio-Rad Laboratories, USA), under reducing and nonreducing conditions, using a discontinuous buffer system, 4% stacking gel and 12% separating gel (Laemmli, 1970). The electrophoresis was performed at 150 V. The gel plates were fixed and stained with a Coomassie Blue solution and then detained with a 10% acetic acid in methanol solution.

Analysis of amino acids

The DPF and DPF film (DPFF) samples were acid hydrolysed with 6 N chlorhydric acid for 24 h according to the AOAC method (AOAC, 2006). The hydrolysates were filtered, derivatized with diethyl (ethoxymethylene) malonate and analysed by high-performance liquid chromatography (HPLC), using a

Perkin Elmer HPLC system (Series 200), equipped with a UV detector and Zorbax Eclipse Plus C18 column (4.6 × 150 mm; particle size 5 μm) from Agilent Technologies, according to Alaiz *et al.* (1992). The amino acids content was measured by comparison of the HPLC chromatogram peak areas with external standard curves and was expressed as g/100 g protein of DPF and DPFF, respectively.

Properties of films

Moisture content (MC) of the film

The MC of the DPFF was determined, as described by Aguirre *et al.* (2011). All determinations were performed in triplicate, and the average values were reported.

Colour evaluation of the films

The colour analysis was performed using a colorimeter (Minolta CM-508d, Tokyo, Japan). The CIELab parameters (L^*, a^* and b^*) were measured at five points on each film. The colour parameters range from $L^* = 0$ (black) to $L^* = 100$ (white), $-a^*$ (greenness) to $+a^*$ (redness) and $-b^*$ (blueness) to $+b^*$ (yellowness). The instrument was calibrated using a standard white plate with colour coordinates of $L^* = 91.73$, $a^* = 0.64$ and $b^* = -6.97$ (Romero *et al.*, 2016).

Opacity of the films

The opacity of the films was measured, according to Cao *et al.* (2007). Rectangular pieces of film samples were placed into a spectrophotometer test cell. Air was used as reference. A spectrum of each film was obtained in a UV–Vis spectrophotometer (Spectrum SP-2100 UV, Zhejiang, China). All determinations were performed in triplicate.

Mechanical properties of the films

Tensile strength (TS) and per cent of elongation at break (%E) were determined according to the American Society for Testing and Materials (ASTM) standard method D882-02 (ASTM, 2012). The Instron Texturometer (model 3342, Norwood, MA, USA) was equipped with a 500 N cell and operated at 0.5 mm s^{-1}. The films were cut into rectangular strips (15 mm wide × 50 mm length) and mounted between the grips of the texture analyser. The TS (force/initial cross-sectional area) and %E (percentage of the change in the original length of the specimen between the grips at break) were determined directly from the stress versus strain curves (Aguirre *et al.*, 2011).

Water vapour permeability (WVP) of the films

The WVP was measured gravimetrically, according to the standard method E96-80 (ASTM, 2012) reported by Aguirre *et al.* (2011).

Oxidative test with sunflower oil

The DPFFs were cut in 9.5 × 9.5 cm pieces, sealed (polyethylene sealer, CLI, model CC400, LIPARI, Rosario, Argentina) to form packages (DPFPs) of (4.75 × 9.5 cm) with each one containing 9 g of sunflower oil; and then, stored at room temperature (23 °C) for 67 days. Samples were removed from storage at 0, 15, 30, 45 and 67 days, for chemical analyses. Samples of sunflower oil were also conditioned in (i) high barrier plastic pouches made of ethylene vinyl alcohol (EVOH) of 175 mm total thickness, with an oxygen transmission rate of 1–5 cm^3 m^{-2} bar^{-1} 24 h^{-1} (DISE SA, Cordoba, Argentina) as a comparative treatment prepared with synthetic material and, (ii) in Petri dishes (Ø 90 × 14 mm) as a control sample (C).

Lipid oxidation indicators, including peroxide value (PV) (AOAC, 2006) and conjugated dienes (CDs) (COI, 2001) were analysed in the sunflower oil obtained from stored samples. PV results were expressed as milliequivalents of active oxygen per kilogram of oil (mEq O_2 kg^{-1}). The CD values were expressed 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 software, version 2010p (Facultad de Ciencias Agropecuarias, Universidad Nacional de Cordoba, Cordoba, Argentina). Means and standard deviations were calculated. Analysis of variance (ANOVA) and Duncan's test ($\alpha = 0.05$) were used to detect significant differences between treatments. Linear equations were used for regression analysis between storage time and the dependent variables (Sokal & Rohlf, 1994).

Results and discussion

Chemical composition of peanut flour

The flour extraction method used produced a material containing 53.22 g/100 g ± 0.03 protein, 23.90 g/100 g ± 0.28 carbohydrate, 11.41 g/100 g ± 0.13 moisture, 4.06 g/100 g ± 0.21 lipids, 4.05 g/100 g ± 0.09 ash, and 3.36 g/100 g ± 0.02 fibre. All films produced were self-supporting and peelable. They were transparent, light yellow and had an average thickness of 102 ± 6.4 μm. The chemical composition of the flour is similar to that obtained by Wu *et al.* (2009) (55.88 ± 1.07% protein, 25.14 ± 0.04% carbohydrate, 8.12 ± 0.13% moisture, 4.85 ± 0.16% ash, and 1.50 ± 0.01% crude fat). Compared with other raw materials used in the production of biodegradable films, the DPF presents higher protein and lower carbohydrate content than achira flour (4.5 g/100 g

protein; 71.7 g/100 g starch) (Andrade-Mahecha *et al*., 2012), banana flour (3.2 g of protein/100 g; 83.2 g of starch/100 g) (Pelissari *et al*., 2013), blue corn flour (6.53% protein; 75.1% starch) (Valderrama Solano & Rojas de Gante, 2014) and *babassu mesocarp* flour (1.77 g/100 g protein; 84.57 g/100 g starch) (Maniglia *et al*., 2017).

Film protein

The film formulation procedure prepared a film containing 53.06% protein. The SDS-PAGE patterns of nonreduced and 2-mercaptoethanol-reduced samples of DPF and DPFF showed a disappearance of protein bands from the DPFF samples that were observed in the DPF (Fig. 1). These bands corresponded to proteins with a molecular weight >200 kDa, and about 116 and 31 kDa (marked by arrow). Loss of these proteins in the DPFF samples could be attributed to the centrifugation process of the FFS, during the film formulation. However, there were no significant differences in the proportion of protein between the DPF and DPFF samples. The pattern also indicated that nonreduced DPF and DPFF samples were composed of a group of protein that presented structures with molecular weights >200 kDa and between 45–66 and 31–45 kDa (marked by arrow) that possibly enhanced the establishment of the three-dimensional network structure of the film.

Amino acid composition

Glutamic acid (Glx) and arginine (Arg) were the major amino acids in DPF and DPFF samples (Table 1). DPFF had a higher percentage of aspartic acid (8.16%), serine (4.07%), histidine (His; 5.37%), threonine (4.21%) and cysteine (9.36%). Davis & Dean (2016) also reported Glx and Arg were the main amino acids in the peanut seed. Gayol *et al*. (2013) observed peanut oil cake and peanut concentrate with high percentages of Asp, Glx, and Cys + Val + Met. Amino acid composition reported for others raw materials commonly used in the preparation of biodegradable films, showed Glx (9.11%) and aspartic acid (5.91%) as the major amino acid in defatted soy flour and, Glx (12.48%) and Arg (6.73%) in cottonseed flour (USDA, 2017).

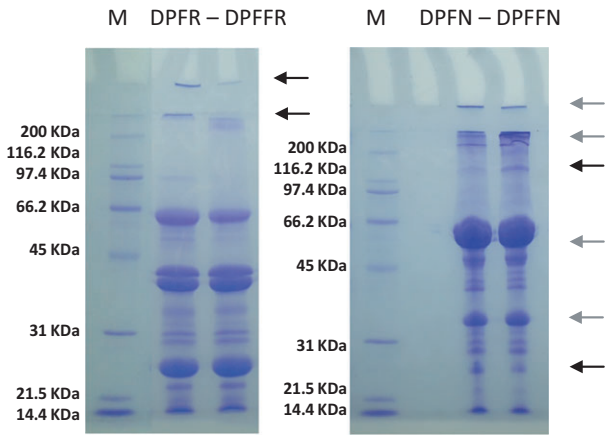

Figure 1 SDS-PAGE patterns of nonreduced and 2-mercaptoethanol (2 ME) reduced samples of DPF and DPFF. M = Molecular weight marker; DPFR = reduced defatted peanut flour; DPFFR = reduced peanut film; DPFN = nonreduced defatted peanut flour; and DPFFN = nonreduced peanut film.

Properties of films

MC of DPFF was 21.10% (Table 2). This value was similar to that determined by Borneo *et al*. (2016) for triticale flour-based films. Other authors recorded MC values of 16.50% for blue corn flour-based films (Valderrama Solano & Rojas de Gante, 2014) and 18.8% for achira flour-based films (Andrade-Mahecha *et al*., 2012). The characteristics of MC are related to the polymer's polarity and the plasticizer used (Valderrama Solano & Rojas de Gante, 2014). In the current research, glycerol was the plasticized used. The MC observed is related to the polarity of the biopolymer form with the DPFF. The glycerol proportion in the film solution with its thickness (102 μm) allowed the formation of a film with good WVP, a relevant property of films, due to the important role of water in deteriorative reactions.

Table 1 Amino acid composition (g/100 g protein) of defatted peanut flour (DPF) and peanut film (DPFF)

Amino acid	DPF[b]	DPFF[b]
Asx (aspartic acid)	7.51 ± 0.34	8.16 ± 0.26
Glx (glutamic acid)	16.18 ± 0.59	10.37 ± 0.17
Ser[a] (Serine)	2.69 ± 0.05	4.07 ± 0.06
His[a] (Histidine)	5.06 ± 0.09	5.37 ± 0.15
Gly (Glycine)	7.59 ± 0.04	5.32 ± 0.08
Thr[a] (Threonine)	3.45 ± 0.078	4.21 ± 0.05
Arg (Arginine)	12.27 ± 0.15	11.86 ± 0.29
Ala (Alanine)	3.90 ± 0.05	3.86 ± 0.16
Pro[a] (Proline)	3.54 ± 0.16	2.09 ± 0.28
Tyr[a] (Tyrosine)	4.56 ± 0.05	4.05 ± 0.07
Val[a] (Valine)	4.68 ± 0.04	4.35 ± 0.07
Met[a] (Methionine)	0.89 ± 0.04	0.38 ± 0.04
Cys (Cysteine)	5.97 ± 0.29	9.36 ± 0.09
Ile[a] (Isoleucine)	4.06 ± 0.04	3.577 ± 0.039
Leu (Leucine)	7.41 ± 0.05	6.89 ± 0.08
Phe[a](Phenylalanine)	6.47 ± 0.07	5.49 ± 0.11
Lys[a] (Lysine)	3.28 ± 0.02	2.94 ± 0.03

[a]Essential amino acids.

[b]Results expressed as mean ± standard deviation (n = 3).

With respect to the colour, the L^* values (86.83) observed in DPFF (Table 2) were close to those reported for triticale films (Borneo *et al*., 2016), while higher values were reported for amaranth flour films (Tapia-Blácido *et al*., 2005) and lower values for *babassu mesocarp* flour films (Maniglia *et al*., 2017). Compared to triticale flour-based films (Borneo *et al*., 2016), the a^* value (−0.98), indicative of red–green chromaticity, was lower; while the yellow–blue chromaticity value (b^* 5.89) was higher in the present study. Liu *et al*. (2004) researched the colour characteristics of peanut protein films modified by physical and chemical treatments (ultrasound, formaldehyde, glutaraldehyde, succinic anhydride and acetic anhydride) where formaldehyde-treated films exhibited a high lightness (L^* 76.32). The redness of the films changed from a^* values of about 5 for the control films to >13 for the glutaraldehyde-treated films, and the yellowness (b^* values) increased from about 30 to >35, respectively. Sun *et al*. (2013) reported the following colour values of PPI films: L^* 81.82, a^* 4.48 and b^* 11.8.

The opacity value (2.35 nm mm^{-1}) of the DPFF was a little high (Table 2). Other authors reported opacity values ranging from 1.1 to 2.2 for films prepared using high-pressure modified amaranth proteins (Condés *et al*., 2015) and from 1.2 to 3.0 in amaranth proteins films, reinforced with amaranth starch granules and nanocrystals (Condés *et al*., 2018).

With respect to the mechanical properties of the films, the TS and %E values of the DPFF (Table 2) were comparable to that documented in relevant literature studies. Liu *et al*. (2004) reported TS values ranging from 0.28 and 1.27 MPa and %E from 40.22 and 160.34% in peanut protein films modified using physical and chemical treatments. Furthermore, the authors concluded that heat curing was the most effective treatment, followed by UV exposure, and treatment with an aldehyde. Li *et al*. (2015) studied the physical and structural properties of peanut protein isolate-gum arabic films and reported that TS values ranging from 0.77 MPa (peanut protein isolates films) to 1.76 MPa (films prepared from peanut protein isolates-gum Arabic films) and %E ranging from 34.5% (films prepared from peanut protein isolates-gum Arabic fims) to 135.7% (peanut protein isolates films). Compared with biodegradable films made from the flour of other agricultural sources, DPFF exhibits good mechanical properties, with TS similar to those made from amaranth flour (Tapia-Blácido *et al*., 2005; Villamán Diéguez *et al*., 2015).

Table 2 Properties of defatted peanut flour film (DPFF)

Properties	Values[a]
Moisture (%)	21.63 ± 0.35
Water vapour permeability ($\times 10^{11}$ g m^{-1} s^{-1} Pa^{-1})	5.08 ± 0.97
Tensile strength (MPa)	1.01 ± 0.28
Elongation at break (%E)	84.01 ± 0.72
Opacity (nm mm^{-1})	2.35 ± 0.15
Colour	L^* 86.83 ± 1.72
	a^* −0.98 ± 0.08
	b^* 5.89 ± 0.90

[a]Results expressed as mean ± standard deviation (n = 3).

The DPFF also exhibited good flexibility (84.01%), which were close to 95.4% (Villamán Diéguez *et al*., 2015) and 83.74% (Tapia-Blácido *et al*., 2005) for amaranth flour fims, and 88.4% quinoa flour (Araujo-Farro, 2008) films.

DPFF presented an excellent water vapour barrier, with lower WVP value than PPI films (167.9×10^{11} g m^{-1} s^{-1} Pa^{-1}) and films prepared from peanut protein isolate-gum arabic mixtures (139.8×10^{-11} g m^{-1} s^{-1} Pa^{-1}) (Li *et al*., 2015). In comparison with other raw materials used in the production of biodegradable films, the DPFF also exhibited a lower WVP value than banana flour films (21×10^{-11} g m^{-1} s^{-1} Pa^{-1}) (Pelissari *et al*., 2013), amaranth flour films (37.6×10^{-11} g m^{-1} s^{-1} Pa^{-1}) (Villamán Diéguez *et al*., 2015), quinoa flour films (6×10^{-11} g m^{-1} s^{-1} Pa^{-1}) (Araujo-Farro, 2008) and achira flour films (53×10^{-11} g m^{-1} s^{-1} Pa^{-1}) (Andrade-Mahecha *et al*., 2012).

Oxidative rancidity test in sunflower oil

The changes in PV and CD during storage of sunflower oil for DPFP, EVOH and C samples, at 23 °C, are shown in Fig. 2. The PV increased significantly with storage time in all sunflower oil samples. Sunflower oil conditioned in Petri dishes (C) had a higher PV and showed significant differences during storage after storage day 15, compared to sunflower oil packed in DPFP and high barrier plastic (EVOH) pouches. Among the packaging treatments, EVOH presented the lowest PV and exhibited significant differences during storage than DPFP after day 45. In addition to displaying the highest PV, treatment C also exhibited the highest CD value and showed significant differences during storage after storage day 30, relative to DPFP and EVOH. In DPFP and EVOH treatments, CD did not show any marked increase throughout storage. The results of the chemical oxidation indicators during storage evidence that the DPFP helps to retard the lipid oxidation process in sunflower oil in a similar manner to EVOH pouches.

The PV values obtained at the present study were comparable to those reported from others authors, who studied films prepared with different raw material and the addition of natural antioxidants. De Moraes Crizel *et al*. (2016) evaluated the PV of sunflower oil

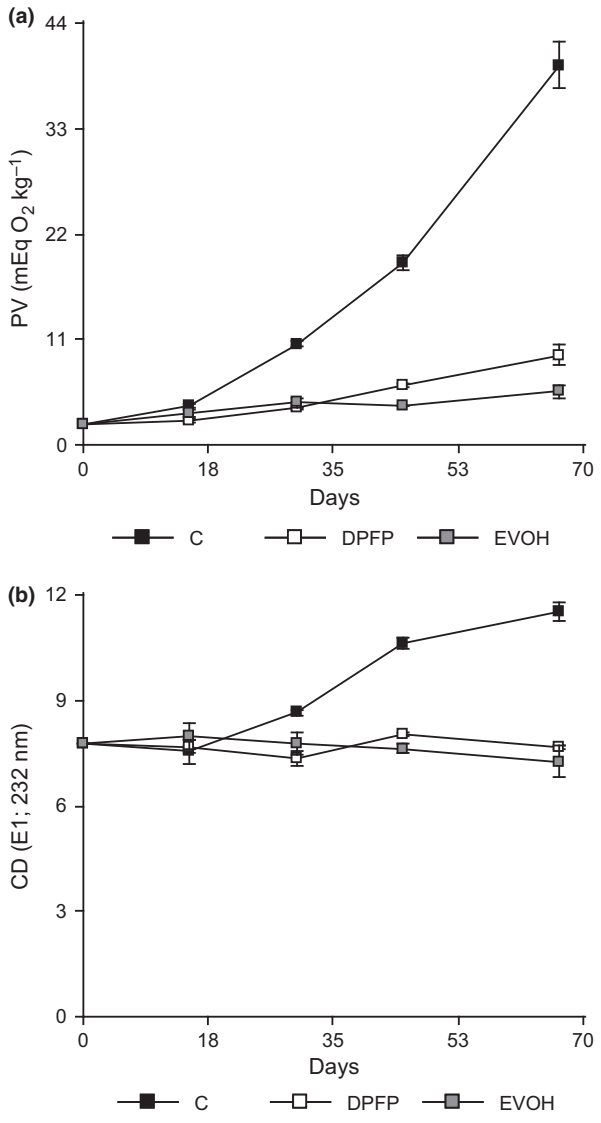

Figure 2 (a) Peroxide value (PV) and (b) conjugated dienes (CDs) in sunflower oil conditioned in plastic Petri dishes (C), sunflower oil conditioned in defatted peanut flour packages (DPFP) and sunflower oil packaged in high barrier plastic pouches (EVOH) during storage at 23 °C.

protected with gelatin film (FC), gelatin film with blueberry fibre at 0.15 g mL^{-1} (FF15), and gelatin film with 50 mL blueberry extract (FE50), stored for 13 days. These authors found that FF15 exhibited similar results when compared with the DPFF used in the present study. FC and FE50 showed higher PV values than DPFF. Atarés *et al*. (2010) studied the PV formation of sunflower oil protected with sodium caseinate films incorporated with cinnamon and ginger essential oils. The PV values obtained at the end of the storage (50 days) were lower than 10 mEq O_2 kg^{-1}. The

Table 3 Regression coefficients and adjusted R^2 for dependent variable peroxide value obtained from the storage study of sunflower oil at 23 °C

Dependent variable[a]	Sample[a]	Regression coefficients[b]		
		β_0	β_1	R^2
PV	C	−2.508681	0.554299	0.906307
	DPFP	1.304847	0.110011	0.885457
	EVOH	2.411677	0.045570	0.702530

[a]PV = peroxide value; C = sunflower oil conditioned in Petri dishes; DPFP = sunflower oil packed in defatted peanut flour pouches; and EVOH = sunflower oil packed in high barrier plastic pouches.
[b]Regression coefficients for the linear equation. $Y = \beta_0 + \beta_1 X$, where Y is the dependent variable (PV) and X is the independent variable (storage days).

results of the current study evidence that DPFP, displays a protective effect against lipid oxidation, prolonging sunflower oil shelf life, and this protective effect was generated without the incorporation of any additive in the film formulation.

The regression equations of the dependent variable PV for treatments C, DPFP and EVOH are presented in Table 3. PV showed $R^2 > 0.70$ in all sunflower oil samples, which indicates that this variable is a good predictor of the storage time effect.

Conclusions

The results observed in this study demonstrated that the films formulated with DPF exhibit suitable physicochemical, optical, barrier and mechanical properties, in comparison with other films prepared with different type of raw materials. These functional properties allowed the formation of a DPFP that is able to improve the chemical stability of sunflower oil, by preventing lipid oxidation. The DPFP could represent an effective and natural method to protect other food products with similar physicochemical characteristics to sunflower oil.

Acknowledgment

We thank CONICET and SECyT-UNC for financial support.

References

Aguirre, A., Borneo, R. & León, A.E. (2011). Properties of triticale flour protein based films. *Lebensmittel Wissenschaft und- Technologie*, **44**, 1853–1858.

Alaiz, M., Navarro, J.L., Girón, J. & Vioque, E. (1992). Amino acid analysis by high performance chromatography alter derivatization with dietil ethoxymethylenemalonate. *Journal of Chromatography*, **591**, 181–186.

Andrade-Mahecha, M.M., Tapia-Blácido, D.R. & Menegalli, F.C. (2012). Development and optimization of biodegradable films based on achira flour. *Carbohydrate Polymers*, **88**, 449–458.

AOAC (2006). *Official Methods of Analysis of the AOAC*. Gaithersburg, MD, USA: Association of Official Analytical Chemists.

AOCS (2017). *Officials Methods and Recommended Practices of the AOACS*. IL, USA: The American Oil Chemists' Society.

Araujo-Farro, P.C. (2008). Development and Optimization of Biodegradables Films Made of Products Derivated from "Royal" Variety Quinoa (Chenopodium Quinoa Willdenow) Seeds (PhD thesis). Unicamp, Brazil.

ASTM (2012). *Annual Book of ASTM Standards*. Philadelphia, PA, USA: American Society for Testing and Materials.

Atarés, L., Bonilla, J. & Chiralt, A. (2010). Characterization of sodium caseinate-based edible films incorporated with cinnamon or ginger essential oils. *Journal of Food Engineering*, **100**, 678–687.

Balaguer, M.P., Fajardo, P., Gartner, H., Gomez-Estaca, J., Gavara, R. & Almenar, E. (2014). Functional properties and antifungal activity of films based on gliadins containing cinnamaldehyde and natamycin. *International Journal of Food Microbiology*, **173**, 62–71.

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.

Cao, N., Fu, Y. & He, J. (2007). Preparation and physical properties of soy protein isolate and gelatin composite films. *Food Hydrocolloids*, **21**, 1153–1162.

COI (2001). *Método de Análisis, Prueba Espectrofotométrica en el Ultravioleta. Document COI/T, 20/Doc. no. 19/Rev. 1*. Madrid: International Olive Oil Council.

Condés, M.C., Añón, M.C. & Mauri, A.N. (2015). Amaranth protein films from high pressure treated proteins. *Journal of Food Engineering*, **166**, 38–44.

Condés, M.C., Añón, M.C., Dufresne, A. & Mauri, A.N. (2018). Composite and nanocomposite films based on amaranth biopolymers. *Food Hydrocolloids*, **74**, 159–167.

Davis, J. P. & Dean, L. L. (2016). Peanut Composition, Flavor and Nutrition. In: *Peanuts. Genetics, Processing, and Utilization* (edited by T. Stalker & R. Wilson). Pp. 289–345. IL, USA: AOCS Press.

De Moraes Crizel, T., Haas Costa, T.M., De Oliveira Rios, A. & Hickmann Flôres, S. (2016). Valorization of food-grade industrial waste in the obtaining active biodegradable films for packaging. *Industrial Crops and Products*, **87**, 218–228.

Gayol, M.F., Pramparo, M.C., Nepote, V., Fernandez, H. & Grosso, N.R. (2013). Optimization of the protein concentration process from residual peanut oil-cake. *Grasas y aceites*, **64**, 489–496.

Gong, K.-J., Shi, A.-M., Liu, H.-Z. *et al*. (2016). Emulsifying properties and structure changes of spray and freeze-dried peanut protein isolate. *Journal of Food Engineering*, **170**, 33–40.

Grosso, N.R., Nepote, V., Giannuzzo, N. & Guzmán, C.A. (2002). Composición porcentual de ácidos grasos y de esteroles de algunos genotipos de especies silvestres de maní. *Anales de la Asociación Química Argentina (Journal of the Argentine Chemical Society)*, **90**, 45–53.

Guillen, M.D. & Goicoechea, E. (2008). Formation of oxygenated a, b-unsaturated aldehydes and other toxic compounds in sunflower oil oxidation at room temperature in closed receptacles. *Food Chemistry*, **111**, 157–164.

Han, J.H. (2014). Edible films and coatings: a review. In: *Innovations in Food Packaging* (edited by J.H. Han). Pp. 213–255 GA, USA: Elsevier Ltd.

Laemmli, U. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature*, **227**, 681–685.

Li, C., Xue, H., Chen, Z., Ding, Q. & Wang, X. (2014). Comparative studies on the physicochemical properties of peanut protein isolate–polysaccharide conjugates prepared by ultrasonic treatment or classical heating. *Food Research International*, **57**, 1–7.

Li, C., Zhu, W., Xue, H., Chen, Z., Chen, Y. & Wang, X. (2015). Physical and structural properties of peanut protein isolate-gum Arabic films prepared by various glycation time. *Food Hydrocolloids*, **43**, 322–328.

Liu, C.-C., Tellez-Garay, A.M. & Castell-Perez, M.E. (2004). Physical and mechanical properties of peanut protein Films. *Lebensmittel Wissenschaft und- Technologie*, **37**, 731–738.

Liu, Y., Zhao, G., Zhao, M., Ren, J. & Yang, B. (2012). Improvement of functional properties of peanut protein isolate by conjugation with dextran through Maillard reaction. *Food Chemistry*, **131**, 901–906.

Maniglia, B.C., Tessaro, L., Lucas, A.A. & Tapia-Blácido, D.R. (2017). Bioactive films based on babassu mesocarp flour and starch. *Food Hydrocolloids*, **70**, 383–391.

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.

Pelissari, F. M., Andrade-Mahecha, M. M., do Amaral Sobral, P. J. & Menegalli, F. C. (2013). Optimization of process conditions for the production of films based on the flour from plantain bananas (*Musa paradisiaca*). *Lebensmittel Wissenschaft und- Technologie*, **52**, 1–11.

Piñeros-Hernandez, D., Medina-Jaramillo, C., López-Córdoba, A. & Goyanes, S. (2017). Edible cassava starch films carrying rosemary antioxidant extracts for potential use as active food packaging. *Food Hydrocolloids*, **63**, 488–495.

Romero, V., Borneo, R., Passalacqua, N. & Aguirre, A. (2016). Biodegradable films obtained from triticale (*x Triticosecale Wittmack*) flour activated with natamycin for cheese packaging. *Food Packaging and Shelf Life*, **10**, 54–59.

Scarlat, N., Dallemand, J.-F., Monforti-Ferrario, F. & Nita, V. (2015). The role of biomass and bioenergy in a future bioeconomy: Policies and facts. *Environmental Development*, **15**, 3–34.

Sokal, R.R. & Rohlf, F.J. (1994). *Biometry: Principles and Practices of Statistics in Biological Research*. Pp. 1–887. San Francisco: W.H. Freeman

Sun, Q., Sun, C. & Xiong, Liu. (2013). Mechanical, barrier and morphological properties of pea starch and peanut protein isolate blend films. *Carbohydrate Polymers*, **98**, 630–637.

Tapia-Blácido, D., Sobral, P.J.A. & Menegalli, F.C. (2005). Development and characterization of edible films based on amaranth flour (Amaranthus caudatus). *Journal of Food Engineering*, **67**, 215–223.

USDA (2017). Online reference included in article [Internet document] URL https://ndb.nal.usda.gov/ndb/search/list. Accessed 10/04/2017.

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**, 60–66.

Villamán Diéguez, M. C., Pelissari, F. M., do Amaral Sobral, P. J. & Menegalli, F. C. (2015). Effect of process conditions on the production of nanocomposite Films based on amaranth flour and montmorillonite. *Lebensmittel Wissenschaft und- Technologie*, **61**, 70–79.

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**, 343–348.

Yang, L. & Paulson, A.T. (2000). Effects of lipids on mechanical and moisture barrier properties of edible gellan film. *Food Research International*, **33**, 571–578.