LWT - Food Science and Technology 101 (2019) 374–381

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

# Flavored oven bags for cooking meat based on proteins

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ARTICLE INFO

*Keywords:*
Protein films
Soybean protein
Bovine gelatin
*Curry*
Meat

ABSTRACT

This work deals with the activation of protein films with a flavoring and their evaluation as oven bags for cooking meat. Two protein sources, very different in origin, structure and functionality, such as bovine gelatin (BG) and soybean proteins isolate (SPI); and a *curry* powder were used to prepared films by casting. *Curry* addition to protein film significantly affected their appearance, activated them with important antioxidant properties and improved their mechanical resistance without modifying their water susceptibility. Oven bags were prepared by heat sealing the films. Those of SPI successfully resisted cooking treatments in both conventional and microwave ovens, while those of BG were disintegrated during cooking possibly due to their higher sensitivity to humidity. Furthermore SPI bags managed to transfer the flavor to chicken meat during cooking, without affecting their texture and water content.

## 1. Introduction

There are several brands in the market that sell oven bags for cooking based on different synthetic polymers. Those intended for cooking meat, such as chicken, turkey, beef, fish or pork, would have the advantage of maintaining the authentic flavor of the food, since it would retain their natural aromas, minerals and vitamins. They also avoid the use of cooking oil and keep the oven clean once the bag is removed together with the food. Some products include an envelope containing a flavoring, so that the meat is sprinkled with the flavoring, placed in the bag, and finally cooked in the oven inside the sealed bag (Carroll, 2016; Kanemura, 2002; Schmal & Bachert, 2008; Winiarski & Saad, 2004).

Any material intended to come into contact with food must be sufficiently inert to prevent the transfer of substances into food in quantities large enough to endanger human health and alter the organoleptic characteristics of food. Their use is strictly regulated by European Union's Regulation No. 1935/2004, 2023/2006, 282/2008, 450/2009, and 10/2011 among others (European Union's Regulation, 2004, 2006, 2008, 2009, and 2011). Thermal treatments such as heating, pasteurization and sterilization, as well as the microwaves facilitate migration, permeability and sorption processes. Among these mass transfer processes, migration is the most relevant according to the possible consequences that may have on human health. Other factors also influence the migration process, such as the concentration of the migrant in the packaging material and their characteristics (polarity, molecular weight), food type and composition, plastic type and processing, and time and temperature conditions for food processing, distribution and storage (Vom Bruck, Bieber, & Figge, 1986).

As far as we know, edible biopolymers have not been reported for the development of oven bags and should not present the health risk associated to migration. Numerous animal and vegetable proteins have been studied for their ability to form edible and/or biodegradable films and coatings (Baldwin, Hagenmaier, & Bai, 2016; Gennadios, 2002). Their functionality depends on the protein origin and initial conformation and the methodology and process conditions used to obtain them (Denavi et al., 2009; Salgado et al., 2017). Protein structure (primary, secondary, tertiary and quaternary) establishes the ability of the polypeptides to interact with each other and with other components present in the formulation, determining the cross-linking degree and the hydrophilic-hydrophobic character of the films (Mauri & Añón, 2006 and 2012). Some post thermal treatments were carried out on protein films already formed in order to modify their physicochemical properties, but at significantly lower temperatures than those used during cooking ($> 160\,^{\circ}C$). There are no studies in the literature in which protein materials were submitted to cooking conditions in traditional and microwaves ovens.

Protein films can also act as vehicle of bioactive compounds or additives with specific characteristics, constituting controlled release systems, with the advantage that in addition to their ability to form films, proteins can also stabilize emulsions and have the ability to retain aromas (Kim & Morr, 1996; Ouassalah, Caillet, Salmiéri, Saucier, &

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https://doi.org/10.1016/j.lwt.2018.11.002
Received 3 August 2018; Received in revised form 25 October 2018; Accepted 1 November 2018
Available online 02 November 2018
0023-6438/ 

Lacroix, 2004; Rhim & Ng, 2007). These films may be used to carry or support flavors at the product surface.

The objectives of this work was to activate protein films with a flavoring, evaluate their use as oven bags for cooking meat and analyze if the bag managed to flavor the meat during cooking. Two protein matrices, very different in origin, structure and functionality were selected to evaluate this application: bovine gelatin and soybean proteins. A *curry* powder was used as flavor. As far as we know this flavoring has not been used with this function so far, although some of its components such as curcumin and garlic powders have been studied to activate protein films (Ket-on, Pongmongkol, Somwangthanaroj, Janjarasskul, & Tananuwong, 2016; Musso, Salgado, & Mauri, 2017).

## 2. Materials and methods

### 2.1. Materials

A commercial soybean protein isolate (**SPI**) SUPRO 500E, kindly supplied by DuPont N and H (Brazil) and a bovine gelatin (**BG**, Rousselot150H4, Rousselot Argentina SA, Argentina) were used as protein sources. Glycerol (Anedra, Argentina) was used as plasticizer. A commercial *curry* powder (La Parmesana, Argentina) formed by a mixture of turmeric, fenugreek, ginger, black pepper, mustard, cinnamon and garlic without salt addition, was used as flavoring. Cooking tests were performed on boneless chicken breasts purchased at a local market (La Plata, Argentina). All the other reagents used in this study were of analytical grade.

### 2.2. Preparation of films

Films were prepared by casting from aqueous dispersions containing **SPI** or **BG** (5% w/v), glycerol (1.25% w/v) and different concentrations of *curry* powder (0, 2 and 4% w/v). In order to achieve these formulations, water or *curry* broths were used as solvents. These broths were prepared by dispersing: 2 and 4 g of *curry* powder in 100 ml of water at 90 °C, and left in magnetic stirring (DragonLab MS-H-Pro, DragonLab, China) approximately for 45 min at room temperature until reaching 25 °C.

Film-forming dispersions prepared with water or broth as solvents, were stirred in magnetic stirring (DragonLab MS-H-Pro, DragonLab, China) at 450 rpm for 45 min at room temperature, and their pH was adjusted to 10 with 2 N NaOH. Aliquots (25 g) of each film-forming dispersion were poured on acrylic plates (180 mm × 90 mm) and dried at 40 °C for 12 h in an oven with air flow circulation (Yamato, DKN600, USA). Resulting films were conditioned during 48 h at 20 °C and 59% relative humidity (RH) prior to characterization.

### 2.3. Films characterization

Thickness, Color, Opacity, Moisture Content (MC), Solubility (WS), Water Vapor Permeability (WVP), scanning electron microscopy (SEM), mechanical and antioxidant properties (by ABTS•+ assay) of SPI and BG films added with different concentrations of curry were determined according to the methods described by Salgado, López-Caballero, Gómez-Guillén, Mauri, and Montero (2013).

Glass transition temperature (Tg) was determined using a dynamic mechanical thermal analyzer (DMA Q800, TA Instruments, New Castle, USA) equipped with a tension clamp and a liquid $N_2$ cooling system. Film probes with a rectangular geometry (30 mm length, 6 mm width) were assayed. Amplitude sweeps from 1 to 200 μm at fixed frequency (5 Hz), temperature (25 °C) and pre-load (0.1 N) were performed. Multifrequency sweeps (at 1, 3, 5 and 10 Hz) at a fixed amplitude (0.05% deformation) and pre-load (0.1 N) from −100 to 100 °C at 5 °C/min were carried out, with an isotherm of 5 min at −100 °C. Storage (E′), loss (E″) modulus, and tan δ (E‘‘/E′) curves as a function of temperature were recorded and analyzed using the software Universal Analysis V4.2E (TA Instruments, New Castle, USA). Tg was determined through the inflection point of the storage modulus E′ curve as well as the maximum peak in both the loss modulus E″ and tan δ curves. Tests were carried out at least in duplicate.

Heat seal strength was measured according to ASTM F88-00 (2004). Two film stripes (76 mm × 15 mm) were cut and thermo-sealed on a hot wire-sealing machine (Lipari CC400, Argentina). Sealing width was 3 mm. The thermo seal strength was evaluated in a texturometer (TA.XT2i, Stable Micro Systems, England). The samples were attached on both ends sides of the seal area with two grips A/TG and subjected to a tensile test (Grip separation was 50 mm and the crosshead speed was 0.4 mm $s^{-1}$). The force (N) required for thermo-seal failure was recorded. The stripes were visually inspected to determine the nature of the failure (adhesive, cohesive or delamination), according to ASTM F88-00 (2004). The measurements were made at 20 °C. Five samples were evaluated for each film formulation tested.

### 2.4. Oven bags formation for cooking test

Bags were prepared by thermo-sealing protein films using a hot wire-sealing machine (Lipari CC400, Argentina). The protein film (180 mm × 90 mm) was folded in half and thermo-sealed at one end, then carefully placed the chicken meat piece (boneless chicken breast cylinders 40 mm in diameter, 50–70 mm high) inside and finally the two remaining ends were thermo-sealed.

### 2.5. Cooking test

Chicken meat was cooked inside the protein bags in a microwave oven (Whirpool, JT359, Argentina) at 500 W and in an electric convection oven (Ariston, FM87FC, Italia) at 180 °C. Different cooking times were tested: 2, 4, 6, 8 and 10 min for conventional oven and 1, 2, 2.5, 3 and 4 min to microwave to find the optimal cooking condition, which were selected considering the sensory properties of cooked chicken meat.

### 2.6. Evaluation of the quality of chicken cooked in SPI bags flavored or not with curry

Chicken pieces with the dimensions mentioned in the previous test, were cooked directly (control) or inside SPI bags with 0 and 2% curry for 3 min in a microwave oven and 8 min in a convection oven. After cooking, the chicken pieces were removed from the bags and characterized according to their appearance, moisture content, texture, color and taste as described below.

#### 2.6.1. Moisture content

It was measured according to Salgado et al. (2013), using small cooked chicken pieces.

#### 2.6.2. Texture

Texture of cooked chicken meat was evaluated in a texturometer (TA.XT2i, Stable Micro Systems, England) equipped with Volodkevich bite jaws (HDP/VB). This probe simulates the bite action of incisive teeth (Szczesniak, 1987). The cooked chicken samples cut into rectangular pieces (10 mm in thickness, 10 mm in width and 20 mm in length) and placed in base of jaws taking into account that the muscle fibers were in the direction of the longest axis. The compression/cut of each sample was performed in the center thereof and perpendicular to the longitudinal direction of the fibers. Force (N) *vs.* distance (mm) curve was recorded. In each case, the maximum force reached was determined when a compression/cut is made up to 25% relative deformation, using a compression/cut speed of 1 mm $s^{-1}$. The measurements were made at 20 °C. Determinations were performed in quintuplicate.

*2.6.3. Color*

Once the cooked chicken took room temperature, it was taken out of the protein bag and color was determined to the surface without the adhered film using a CR 400 colorimeter (Konica Minolta Chroma Co., Osaka, Japan) set to C illuminant/2° observer. A CIE-Lab color scale was used to measure the degree of lightness ($L^*$), redness ($+a^*$) or greenness ($-a^*$), and yellowness ($+b^*$) or blueness ($-b^*$) of the films. The instrument was calibrated using a white standard plate with color coordinates of $L^*_{standard} = 97.55$, $a^*_{standard} = -0.03$ and $b^*_{standard} = 1.73$ provided by Minolta. Sample color was measured on the surface of this standard plate and total color difference ($\Delta E^*$) was calculated as follow:

$$\Delta E^* = [(L^*_{sample} - L^*_{standard})^2 + (a^*_{sample} - a^*_{standard})^2 + (b^*_{sample} - b^*_{standard})^2]^{0.5}$$

Values were expressed as the means of nine measurements on different areas of each sample.

*2.6.4. Sensory evaluation (preliminary test)*

A preliminary sensory evaluation test was carried out consulting six potential consumers. Each participant was given to taste four pieces of chicken: one cooked directly without bag (control), another cooked inside SPI bag, and other two cooked inside SPI bag flavored with 2% curry with and without the film adhered to one meat surface, and were asked if any of the samples tasted different than the control.

*2.7. Statistical analysis*

Results are expressed as mean ± standard deviation and were analyzed by analysis of variance (ANOVA). Means were tested with the Tukey's honest significance test (HSD) for paired comparison, with a significance level $\alpha = 0.05$, using the Statgraphics Plus version 5.1 software (Statgraphics, USA).

## 3. Results and discussion

*3.1. Effect of curry concentration on films properties*

Soybean and gelatin protein films with different *curry* concentrations (0, 2 and 4%) were obtained and analyzed in order to select the optimal formulation for the development of oven bags. No higher concentrations of flavorings were evaluated, because the dispersions viscosity progressively increased with *curry* addition making difficult to process the formulations by casting. Another interesting feature that was observed during films preparation was that film-forming dispersions flavored with *curry*, changed their color from orange to dark red by adjusting the pH from 7 to 10. This phenomenon could be attributed to curcumin, principal curcuminoid of turmeric (*Curcuma longa*), one of the major *curry* compounds, which has a yellow color in an acidic medium (pH 2.5–7) and turns red in basic medium (pH > 7) (Jang et al., 2007; Musso, Salgado, & Mauri, 2016).

All films were homogeneous and flexible. Those containing *curry* showed a strong coloration and some undissolved solids entrapped in the protein matrix well dispersed through the films but giving a rough surface texture to the touch (Fig. 1). Table 1 shows thickness, color parameters ($L^*$, $a^*$, $b^*$, and $\Delta E^*$) and opacity of SPI and BG films added with different *curry* concentrations (0, 2, and 4% w/v). Both protein films were thin and had similar thickness (≈60 μm) ($p > 0.05$), which increased significantly ($p < 0.05$) in proportion to *curry* concentration due to the higher percentage of solids in the formulation. But the increase was more marked for SPI films than for BG ones (134 *vs.* 105% respectively for films with 4% *curry*).

BG films were practically transparent and colorless while those of SPI were slightly yellow -as verified by the higher value of $b^*$parameter (Table 1)- and more opaque (Fig. 1). With *curry* addition, both protein films darkened ($L^*$ decreased) and took a reddish color ($a^*$increased), attributed to curcumin, which was intensified by increasing the flavor concentration. For both systems (SPI and BG films) the highest coloration change ($\Delta E^*$) was visualized for films containing 2% *curry* that present the highest $b^*$ parameter. The opacity of films also increased significantly with *curry* addition ($p < 0.05$) (Table 1), as the undissolved solids strongly interfered in the passage of light through the film.

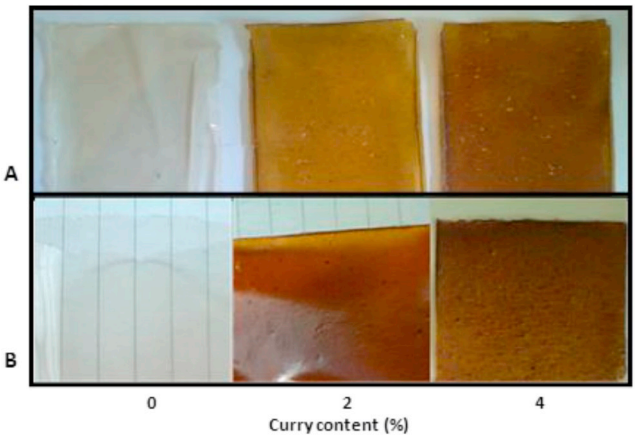


**Fig. 1.** Soybean protein isolate (**A**) and bovine gelatin (**B**) films added with different *curry* concentrations (0, 2, and 4% w/v).

Fig. 2 shows SEM micrographs of the studied films. Surface (panel A and B) and cross-sections (panel C and D) of SPI and BG films were smooth and dense. Heterogeneities appeared in both protein films added with *curry*, especially at the highest concentration (4%). Although the undissolved particles seemed to be extensively coated with proteins, certain discontinuities at the interfaces along with additional porosity were seen, that could also result from the increase in dispersions viscosities with *curry* addition. Nevertheless it should be noted that even in flavored films, the protein matrices remained dense and smooth, while their surfaces showed the roughness perceived by touch. These heterogeneities were more notorious in SPI films than in those of BG, and probably could be responsible for differences in flavored films thickness.

Table 2 shows the moisture content (MC), water solubility (WS), water vapor permeability (WVP) and glass transition temperature (Tg) of soybean protein isolate (SPI) and bovine gelatin (BG) films added with different *curry* concentrations. Moisture content of films seemed to decrease as the *curry* concentration increased for both protein systems, but the difference was only statistically significant ($p < 0.05$) for SPI films with 4% *curry*.

Despite the higher water content of SPI films, they showed lower water solubility (< 35%) and could maintain their integrity during the test while those of BG were almost totally solubilized. These differences should be attributed to the amino acid composition of each protein, and consequently to the type of interactions that stabilized the protein matrix: mainly hydrogen bonds in the case of gelatin and hydrogen and disulfide bonds and hydrophobic interactions in the case of soybean proteins, more resistant to water (Denavi et al., 2009; Mauri & Añon, 2012). *Curry* addition decreased the water solubility of BG films ($p < 0.05$) regardless their concentration ($p > 0.05$), but did not modify the WS of SPI films. In agreement with the denser microstructures observed by SEM, and the lower thickness measured, interactions between gelatin and *curry* components seemed to be more effective to reduce films water solubility.

Water vapor permeability (WVP) is one of the materials properties that most influence the ability to preserve a food until its consumption, and probably the most deficient in the biodegradable materials obtained from biopolymers. Gelatin films presented higher WVP than

**Table 1**
Thickness, CIE-Lab color parameters ($L^*$, $a^*$ and $b^*$), total color difference ($\Delta E^*$) and opacity of soybean protein isolate (**SPI**) and bovine gelatin (**BG**) films added with different *curry* concentrations (0, 2, and 4% w/v).

| Protein | Curry content (%) | Thickness (μm) | CIE-Lab color parameters | | | | Opacity (AU $mm^{-1}$) |
|---|---|---|---|---|---|---|---|
| | | | L* | a* | b* | ΔE* | |
| **SPI** | **0** | 61.00 ± 11.72 a | 91.75 ± 0.72 c | - 1.53 ± 0.11 a | 15.47 ± 1.52 a | 16.87 ± 1.22 a | 3.91 ± 0.24 a |
| | **2** | 109.18 ± 8.45 b | 64.04 ± 0.49 b | 10.84 ± 0.56 b | 61.64 ± 1.24 c | 61.40 ± 1.29 c | 7.34 ± 0.58 b |
| | **4** | 142.94 ± 12.55 c | 47.27 ± 1.37 a | 23.47 ± 1.02 c | 44.15 ± 2.79 b | 48.95 ± 2.26 b | 94.00 ± 1.06 c |
| **BG** | **0** | 57.54 ± 2.93 A | 95.64 ± 0.70 C | - 0.55 ± 0.08 A | 4.78 ± 0.63 A | 10.29 ± 0.18 A | 0.68 ± 0.10 A |
| | **2** | 82.93 ± 8.72 B | 74.44 ± 1.62 B | 8.39 ± 1.19 B | 54.11 ± 1.80 C | 53.75 ± 1.92 B | 11.67 ± 0.36 B |
| | **4** | 117.40 ± 12.18 C | 44.45 ± 2.42 A | 24.90 ± 1.91 C | 47.52 ± 4.68 B | 52.80 ± 4.04 B | 93.98 ± 6.54 C |

Reported values for each film are means ± standard deviation. Different letters in the same column indicate significant differences ($p < 0.05$) according to Tukey's test. Lowercase letters report differences between SPI films, and uppercase between BG films.

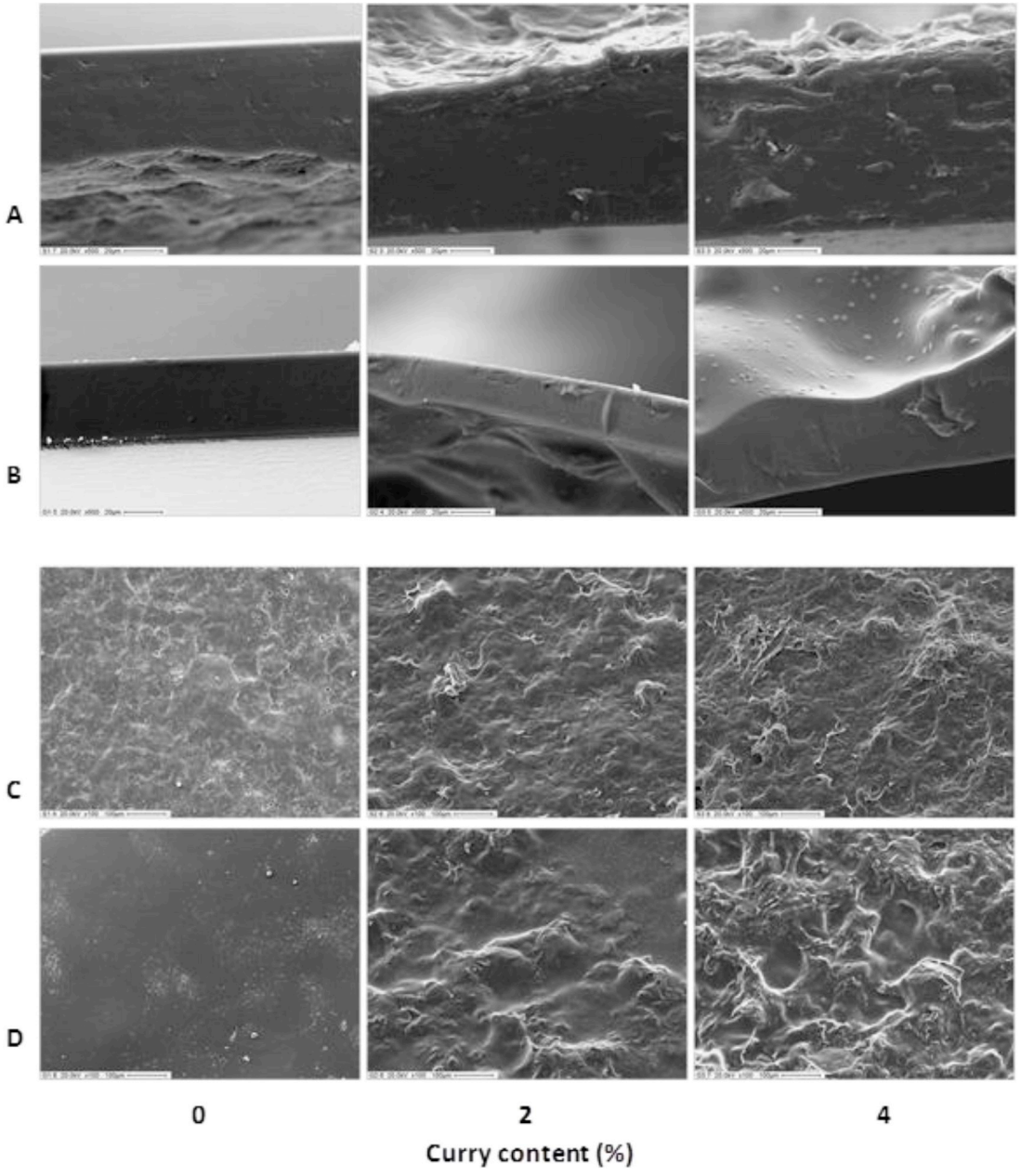


**Fig. 2.** SEM micrographs of films surfaces (**Panel A** and **B,** at 100X) and cross-section areas (**Panel C** and **D,** at 500X) prepared with soybean protein isolate (**A** and **C**) and gelatin (**B** and **D**) added with different *curry* concentrations (0, 2 and 4% w/v).

**Table 2**
Moisture content (MC), water solubility (WS), water vapor permeability (WVP) and glass transition temperature (Tg) of soybean protein isolate (**SPI**) and bovine gelatin (**BG**) films added with different *curry* concentrations (0, 2, and 4% w/v).

| Protein | Curry content (%) | MC (%) | WS (%) | WVP ($gH_2O$/Pa.m.s) | Tg (ºC) |
|---|---|---|---|---|---|
| **SPI** | **0** | 21.86 ± 0.89 b | 34.14 ± 3.11 a | 1.05 ± 0.16 a | −32.0 ± 0.5 c |
| | **2** | 18.9 ± 2.08 b | 34.02 ± 2.23 a | 1.15 ± 0.03 a | −26.8 ± 0.2 b |
| | **4** | 14.03 ± 0.78 a | 31.19 ± 0.49 a | 1.34 ± 0.06 a | −22.9 ± 0.9 a |
| **BG** | **0** | 15.98 ± 1.95 A | 95.9 ± 1.53 B | 1.70 ± 0.06 A | −39.2 ± 0.7 C |
| | **2** | 15.44 ± 1.08 A | 90.48 ± 1.58 A | 1.91 ± 0.11 A | −36.0 ± 0.9 B |
| | **4** | 13.29 ± 0.49 A | 88.03 ± 2.98 A | 2.37 ± 0.05 B | −31.7 ± 0.5 A |

Reported values for each film are means ± standard deviation ($n$ = 3 for MC and WS; n = 2 for WVP and Tg). Different letters in the same column indicate significant differences ($p < 0.05$) according to Tukey's test. Lowercase letters report differences between SPI films, and uppercase between BG films.

those prepared by soybean proteins, due to their higher hydrophilic character and also due to the type of interactions that stabilize the protein matrix. Although the addition of *curry* seemed to favor the passage of water vapor through the film, the increase in WVP was only statistically significant for BG films with 4% *curry* ($p < 0.05$). This increase could in part be attributed to the increase in thickness, as previously reported for other hydrophilic films (e.g. pectin, amylose, cellulose ethers, sodium caseinate, and soybean proteins films), whose WVP increase with film thickness (Ghorpade, Gennadios, & Hanna, 1995; McHugh, Avena-Bustillos, & Krochta, 1993).

Glass transition temperatures (Tg) of the developed films are also shown in Table 2. Increasing the *curry* content in SPI and BG formulations progressively increased the Tg of the resulting films ($p < 0.05$). It seems that *curry* compounds should favor protein crosslinking and/or those particles that did not dissolve during the formulation but interacted with the proteins (as was observed by SEM) should impose rigidity to the protein matrix. The increase in Tg can also be related to the decrease of MC of flavored films, as water acts as a strong plasticizer of protein films. It should be noted that crosslinking effects suggested by Tg analysis did not affect the water susceptibility of flavor SPI films, and only a little those of gelatin with 4% of *curry*.

Table 3 shows the mechanical properties of SPI and BG films added or not with *curry* (0, 2 and 4 %w/v). It should be noted that SPI films were more resistant and less elongable than BG films ($p < 0.05$). With the addition of *curry* to both protein formulations, a very significant increase in Young's modulus ($p < 0.05$) and a decrease in film elongation were observed ($p < 0.05$), without significant modifications in tensile strength ($p > 0.05$). These results evidenced that the presence of the compounds present in *curry* powder produce an increase in film matrix crosslinking that stiffen protein films, probably due to interactions between proteins and among proteins and components and particles of *curry*. The heterogeneities at the interface between the particles and the protein matrix and cavities, observed by SEM in flavored films (Fig. 2), should act as stress concentrators that could initiate the early rupture of the films, causing a dramatic decrease in elongation at break when increasing *curry* concentration. The lower moisture content observed with the *curry* addition may also be contributing to the observed behavior, as water acts as a plasticizer in protein films. Mechanical properties could be correlated with Tg values. More resistant films showed higher Tg.

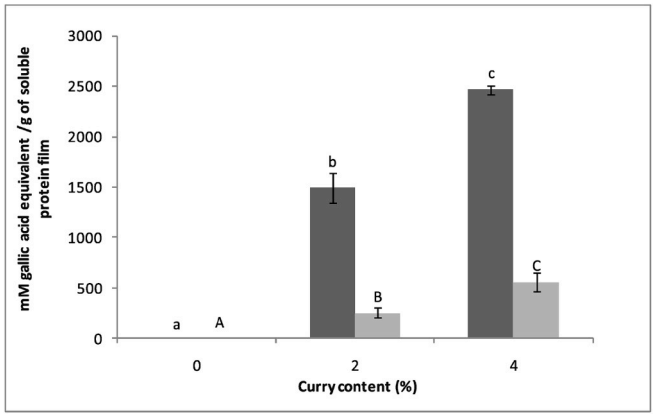


**Fig. 3.** Antioxidant properties (measured by $ABTS^{\bullet+}$ assay) of **SPI** (■) and **BG** (▩) films added with different *curry* concentrations (0, 2 and 4% w/v). Different letters indicate significant differences ($p < 0.05$) among samples according to Tukey's test. Lowercase letters report differences among SPI films, and uppercase letters report differences among BG films.

Considering that *curry* contained curcumin as one of its main ingredient, and this compound has proven antioxidant and antimicrobial properties among others (Tønnesen, De Vries, Karlsen, Henegouwen, & Beijersbergen, 1987; Banerjee & Nigam, 1978; Sharma, 1976, Kaul & Krishnakantha, 1997; Began, Sudharshan, & Appu Rao, 1998; Musso et al., 2017), the antioxidant capacity of flavored protein films was evaluated. Fig. 3 shows the antioxidant properties (measured by $ABTS^{\bullet+}$ assay) of SPI and BG films added with different *curry* concentrations (0, 2 and 4 %w/v). Protein films did not show antioxidant activity, but the addition of *curry* to the formulation gave films important antioxidant properties, that increased significantly by increasing its concentration ($p < 0.05$). But although both types of flavored films contained similar *curry* concentrations, those prepared with SPI showed significantly higher antioxidant properties than those

**Table 3**
Mechanical properties –Tensile strength (TS), Elongation at break (EB), and Young's modulus (YM)– and heat sealing strength (HSS) of soybean protein isolate (**SPI**) and bovine gelatin (**BG**) films added with different *curry* concentrations (0, 2 and 4 %w/v).

| Protein | Curry content (%) | TS (MPa) | EB (%) | YM (MPa) | HSS (N) |
|---|---|---|---|---|---|
| **SPI** | **0** | 5.24 ± 0.59 a | 57.31 ± 8.26 c | 1.95 ± 0.35 a | 1.15 ± 0.19 b |
| | **2** | 5.93 ± 1.29 a | 11.28 ± 3.44 b | 2.78 ± 0.56 b | 0,53 ± 0.12 a |
| | **4** | 5.66 ± 1.19 a | 2.84 ± 0.70 a | 3.54 ± 0.58 c | n.d. |
| **BG** | **0** | 1.91 ± 0.64 A | 229.32 ± 28.97 C | 0.02 ± 0.01 A | 2.91 ± 0.41 A |
| | **2** | 1.61 ± 0.45 A | 114.12 ± 14.47 B | 0.03 ± 0.01 A | 1.64 ± 0.73 A |
| | **4** | 1.54 ± 0.20 A | 29.66 ± 2.38 A | 0.14 ± 0.03 B | 2.40 ± 0.72 A |

n.d. not determined.
Reported values for each gelatin film are means ± standard deviation ($n$ = 6). Different letters in the same column indicate significant differences ($p < 0.05$) according to Tukey's test. Lowercase letters report differences between SPI films, and uppercase between BG films.

corresponding to gelatin ($p < 0.05$). These results suggested that *curry* active compounds probably interacted to a greater extent with the gelatin matrix, preventing their solubilization and/or inactivating its action, and/or that the presence of *curry* also facilitates the release of the active compounds present in soybean protein isolates, mainly isoflavones such as genistein, daidzein and glycyte (Speroni, Milesi, & Añón, 2010) producing a synergistic effect in these samples.

Table 3 also shows the resistance to thermal sealing of each studied film. The thermo seal strength of SPI films decrease significantly when adding *curry* ($p < 0.05$), probably due to the greater surface roughness of flavored films as was observed by SEM. These films showed an adhesive failure, as the heat-sealed specimens were completely separated leaving intact after the test. It should be noted that the heat sealing of SPI film with 4% *curry* was so weak that specimens separated immediately after starting the tensile test, making impossible to determine the measurement. BG specimens showed a different behavior. No significant differences in heat seal strength was observed by adding *curry* to the formulations, and during the test specimens were significantly lengthened until their rupture, which did not happen in the heat sealed area.

Taking into account that the desired application was the formation of bags and the materials characterization, formulations containing 2% *curry* were selected to proceed with this work, as they were flavored and showed the best mechanical properties and heat sealing resistance.

### 3.2. Evaluation of flavored oven bags behavior under cooking conditions

SPI and BG bags added with 2% *curry* were used to cook chicken meat in conventional and microwave ovens. Fig. 4 shows bags appearance before and after cooking the chicken pieces inside them during different times in a microwave and convection oven, and the resulting cooked pieces of chicken. Soybean protein films managed to maintain their integrity during cooking in both ovens and could even be manipulated later. In the case of those cooked in microwaves for longest periods, the film adhered to the chicken in the upper layer (the one that was not supported by the tray), being unable to take it off. Although initially this was not a desired characteristic, it did not seem to be entirely unfavorable, since the film was edible and resembled crispy chicken skin, which in general is not recommended to eat because of its high fat value.

Furthermore gelatin films were not suitable for use as oven bags. They were totally disintegrated during microwave cooking, probably due to the high relative humidity inside the oven during the cooking process that should destabilize the interactions that maintained the structure of the gelatin matrix according to their high solubility (Table 2). And they became brittle in some parts and “sticky” in others, breaking in contact with meat, during cooking in conventional convection oven.

These differences should be attributed to the amino acid composition of each protein and its conformation. In the case of soybean protein films, the proteins are completely denatured in the isolates prior to being used, and had an important amount of sulfur-containing amino acids (Salgado et al., 2017) capable of forming disulfide bonds during the preparation of the films and the cooking treatments studied. Salgado et al. (2017) showed that soybean protein conformation determines the rheological properties of film-forming dispersions affecting their processing and the cross-linking degree of the resulting materials. This fact mainly concerns the mechanical behavior of the films as well as their solubility in water and their effectiveness to act as a release system of active compounds. On the other hand, the gelatin was partially denatured and had a minimum content of sulfur-containing amino acids (Denavi et al., 2009). Gelatin films are stabilized mainly by hydrogen bonds, which are more easily destabilized by raising the temperature and humidity, thus being less resistant to studied cooking treatments.

Regardless of the materials' behavior, the chicken pieces were cooked in both bags at similar times, reaching its point at 3 and 8 min when cooked in a microwave or convection oven respectively. For these times chicken did not show any exudates and had a tender appearance; below this times it looked juicy and above them something hard and dried.

### 3.3. Quality of chicken cooked in SPI bags flavored or not with curry

The effect of using SPI bags flavored or not with *curry* (2 and 0%) on some characteristics of cooked chicken were analyzed in order to verify if the bags produced any change in cooked meat texture and managed to transfer the flavor to the meat.

Fig. 4 (G and H panels) shows the appearance of chicken cooked inside SPI bags flavored with *curry* during 8 min in a conventional oven. It is clearly observed that the protein film only adhered to the chicken on the upper surface (which did not rest on the cooking tray) (Fig. 4G), and how those flavored with *curry* could simulate chicken skin, giving crispy appearance and texture to the final product. Similar results were obtained for samples cooked 3 min in the microwave oven (data not shown). The use of protein bags did not significantly modify ($p > 0.05$) meat water content ($\cong$ 60 and 70% for samples cooked in microwaves and convection ovens respectively) and texture (evaluated as the maximum force that should be exerted on the food matrix to bite), regardless of whether the bag was flavored with *curry* or not ($p > 0.05$) (Table 4).

Table 4 also shows the CIE-Lab color parameters determined on the underside of chicken after the bag was peeled off. The use of protein bags during cooking modified the coloration of the final product (greater $\Delta E^*$) especially in the case of those flavored with *curry*. There was a decrease in the $L^*$ parameter and an increase of $a^*$ and $b^*$ ($p < 0.05$) in the microwave-cooked samples, and an increase in the $b^*$ parameter in those cooked in the conventional oven. These results suggested the possibility that the pigments and flavorings present in *curry* would be transferred from the bag to the meat during cooking.

Finally, in order to check if the chicken was flavored using the protein bags added with *curry*, a preliminary sensory evaluation test was carried out. Participants were asked to taste four pieces of chicken: a control cooked directly without bag, another cooked inside SPI bag, and other two cooked inside SPI bag flavored with 2% *curry* with and without the film adhered to one of the meat surfaces; and asked if any of the samples tasted different than the control. All the participants pointed out that only the chicken samples cooked in bags with 2% *curry* were perceived differently and that the flavor increased in samples that had the film adhered to meat surface, showing no displeasure when viewing the film. These results confirmed that SPI bags containing *curry* managed to flavor meat during cooking.

## 4. Conclusions

Edible oven bags based on two different protein sources, soybean proteins and gelatin, activated with *curry* were developed for cooking meats in microwave and conventional ovens.

The addition of *curry* powder to protein films significantly affected their appearance (increasing their thickness, coloration, opacity, and surface roughness); activated them with important antioxidant properties but did not modify their water susceptibility markedly. *Curry* insoluble particles seemed to act as reinforcements for the protein matrices, improving the mechanical resistance of the films in detriment of their elongation and heat-sealing capacity.

Films flavored with 2% *curry*, were used to prepare the flavored oven bags by heat sealing. Those of SPI successfully resisted the cooking treatments in conventional and microwave ovens, while those prepared with gelatin films were disintegrated during cooking possibly due to their higher sensitivity to humidity.

SPI bags did not modify the texture and moisture content of chicken meat and those containing *curry* managed to transfer the flavor to the

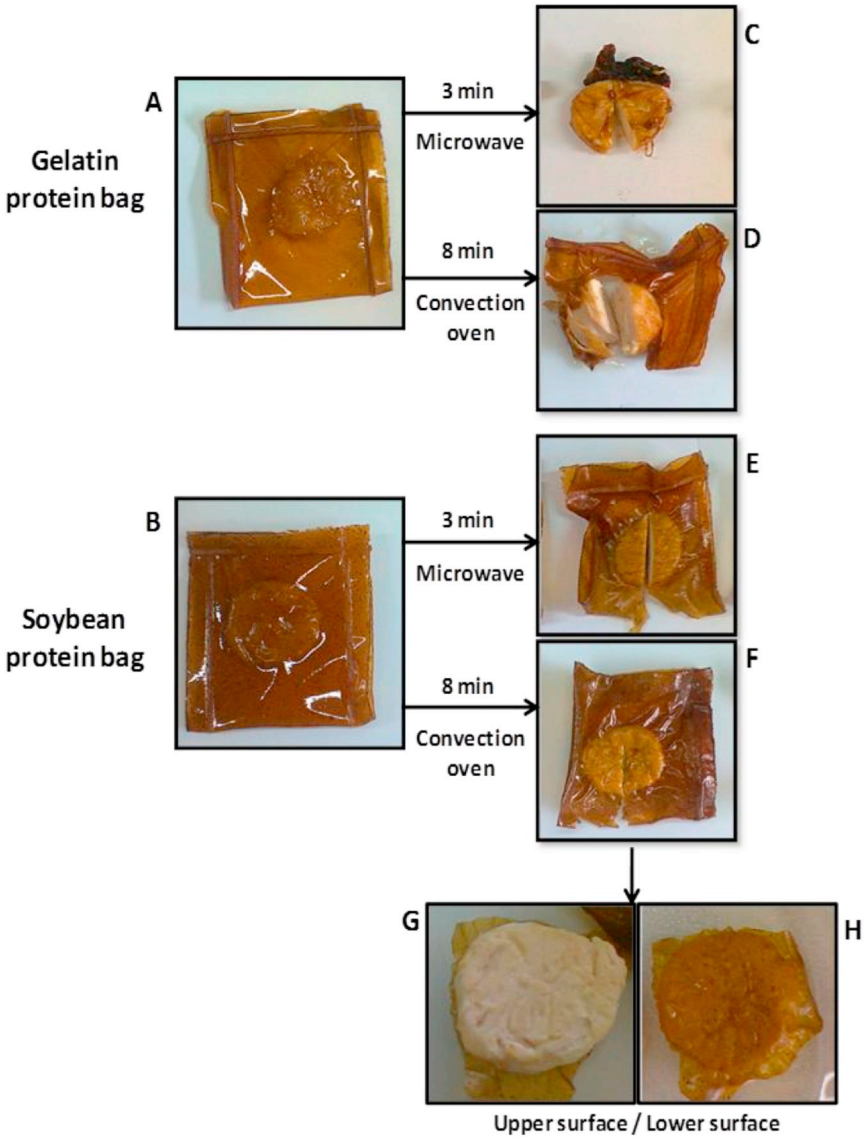


**Fig. 4.** Oven bags prepared with soybean protein isolates (**SPI**) and bovine gelatin (**BG**) films added with 2% w/v of *curry* before (**A**, **B**) and after cooking the chicken contained inside the bags during 3 min in a microwave oven (**C**, **E**) or 8 min in a conventional oven (**D**, **F**). Appearance of chicken pieces cooked inside SPI bags flavored with *curry* during 8 min in a conventional oven: **G)** upper surface (which did not rest on the cooking tray) and **H)** lower surface.

**Table 4**
Moisture content, maximum strength, CIE-Lab color parameters ($L^*$, $a^*$ and $b^*$) and total color difference ($\Delta E^*$) of cooked chicken samples without a bag (Ch-CONTROL), in a SPI bag with 0% *curry* (Ch-SPI-0) and with 2% *curry* (Ch-SPI-2) in microwave and conventional oven.

| Cooking process | Sample | Moisture content (%) | Maximum strength (N) | $L^*$ | $a^*$ | $b^*$ | $\Delta E^*$ |
|---|---|---|---|---|---|---|---|
| Microwave oven | Ch-CONTROL | 64.43 ± 0.23 a, b | 10.01 ± 4.26 a, b, c | 85.09 ± 1.64 c | 0.17 ± 0.35 a | 16.37 ± 1.2 a | 19.14 ± 1.38 a |
| | Ch-SPI-0 | 62.29 ± 2.58 a | 12.21 ± 1.89 b, c | 76.82 ± 2.43 b | 1.96 ± 0.73 b | 22.32 ± 1.1 b | 29.14 ± 2.39 b |
| | Ch-SPI-2 | 61.15 ± 1.54 a | 12.63 ± 1.45 c | 67.74 ± 1.97 a | 3.05 ± 2.12 b | 26.23 ± 1.71 c | 38.64 ± 1.13 c |
| Conventional oven | Ch-CONTROL | 70.52 ± 0.5 c | 10.25 ± 3.73 b, c | 84.88 ± 0.69 b | 1.89 ± 0.17 b | 15.02 ± 0.30 a | 18.30 ± 0.50 a |
| | Ch-SPI-0 | 67.53 ± 0.63 b, c | 5.29 ± 2.05 a | 80.71 ± 2.43 a | 2.69 ± 0.43 c | 21.07 ± 1.33 b | 25.73 ± 1.29 b |
| | Ch-SPI-2 | 68.81 ± 1.64 c | 7.34 ± 2.05 a, b | 83.94 ± 2.23 b | (−)0.28 ± 0.65 a | 25.98 ± 1.95 c | 27.79 ± 2.09 c |

Reported values for each film are means ± standard deviation. Different letters in the same column indicate significant differences ($p < 0.05$) according to Tukey's test.

meat during cooking, a fact that was verified through color parameters observation and with a preliminary sensory panel.

## Acknowledgements

The authors are thankful to the National Agency of Scientific and Technological Support (PICT-2013-2124) and the Universidad Nacional de La Plata (11/X750) for their financial support.

## References

ASTM (2004). *Annual book of ASTM standards.* Philadelphia, PA, USA: ASTM.
Baldwin, E., Hagenmaier, R., & Bai, J. (2016). *Edible coatings and films to improve food quality* (2nd ed.). Boca Raton: CRC Press.

Banerjee, A., & Nigam, S. S. (1978). Antimicrobial efficacy of the essential oil of Curcuma longa. *Indian Journal of Medical Research, 68*, 864–866.
Began, G., Sudharshan, E., & Appu Rao, A. G. (1998). Inhibition of lipoxygenase 1 by phosphatidylcholine micelles-bound curcumin. *Lipids, 33*(12), 1223–1228.
Carroll, C. (2016). Pre-coated seasoning bags. US20160075494A1 Patent.
Denavi, G. A., Pérez-Mateos, M., Añón, M. C., Montero, P., Mauri, A. N., & Gomez-Guillen, M. C. (2009). Structural and functional properties of soy protein isolate and cod gelatin blend films. *Food Hydrocolloids, 23*(8), 2094–2101.
European Union's Regulation (2004). *Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC*.
European Union's Regulation (2006). *Commission Regulation (EC) No 2023/2006 of 22 December 2006 on good manufacturing practice for materials and articles intended to come into contact with food*.
European Union's Regulation (2008). *Commission Regulation (EC) No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006*.
European Union's Regulation (2009). *Commission Regulation (EC) No 450/2009 of 29 May 2009 on active and intelligent materials and articles intended to come into contact with food*.
European Union's Regulation (2011). *Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food*.
Gennadios, A. (2002). *Protein-based films and coatings.* CRC press.
Ghorpade, V. M., Li, H., Gennadios, A., & Hanna, M. A. (1995). Chemically modified soy protein films. *Transactions of the ASAE, 38*(6), 1805–1808.
Jang, Hung-Der, Chang, Ku-Shang, Huang, Yung-Sheng, Hsu, Chuan-Liang, Lee, Sheng-Hsien, & Su, Min-Sheng (2007). Principal phenolic phytochemicals and antioxidant activities of three Chinese medicinal plants. *Food Chemistry, 103*(3), 749–756.
Kanemura, Y. (2002). Bag for use in microwave oven. JP2003237852A Patent.
Kaul, S., & Krishnakantha, T. P. (1997). Influence of retinol deficiency and curcumin/turmeric feeding on tissue microsomal membrane lipid peroxidation and fatty acids in rats. *Molecular and Cellular Biochemistry, 175*(1–2), 43–48.
Ket-on, A., Pongmongkol, N., Somwangthanaroj, A., Janjarasskul, T., & Tananuwong, K. (2016). Properties and storage stability of whey protein edible film with spice powders. *Journal of Food Science & Technology, 53*(7), 2933–2942.
Kim, Y. D., & Morr, C. V. (1996). Microencapsulation properties of gum Arabic and several food proteins: Spray-dried orange oil emulsion particles. *Journal of Agricultural and Food Chemistry, 44*(5), 1314–1320.
Mauri, A. N., & Añón, M. C. (2006). Effect of solution pH on solubility and some structural properties of soybean protein isolate films. *Journal of the Science of Food and Agriculture, 86*(7), 1064–1072.
Mauri, A. N., & Añón, M. C. (2012). Proteínas como envases alimentarios. In G. I. Olivas, G. González Aguilar, O. Martín-Belloso, & R. Soliva-Fortuni (Eds.). *Películas y Recubrimientos Comestibles: Propiedades y Aplicaciones en Alimentos* (pp. 95–124). México D.F., México: Clave Editorial.
McHugh, T. H., Avena-Bustillos, R., & Krochta, J. M. (1993). Hydrophilic edible films: Modified procedure for water vapor permeability and explanation of thickness effects. *Journal of Food Science, 58*(4), 899–903.
Musso, Y. S., Salgado, P. R., & Mauri, A. N. (2016). Gelatin based films capable of modifying its color against environmental pH changes. *Food Hydrocolloids, 61*, 523–530.
Musso, Y. S., Salgado, P. R., & Mauri, A. N. (2017). Smart edible films based on gelatin and curcumin. *Food Hydrocolloids, 66*, 8–15.
Oussalah, M., Caillet, S., Salmiéri, S., Saucier, L., & Lacroix, M. (2004). Antimicrobial and antioxidant effects of milk protein-based film containing essential oils for the preservation of whole beef muscle. *Journal of Agricultural and Food Chemistry, 52*(18), 5598–5605.
Rhim, J.-W., & Ng, P. K. W. (2007). Natural biopolymer-based nanocomposite films for packaging applications. *Critical Reviews in Food Science and Nutrition, 47*(4), 411–433.
Salgado, P. R., López-Caballero, M. E., Gómez-Guillén, M. C., Mauri, A. N., & Montero, M. P. (2013). Sunflower protein films incorporated with clove essential oil have potential application for the preservation of fish patties. *Food Hydrocolloids, 33*, 74–84.
Salgado, P. R., Molina Ortiz, S. E., Denavi, G. A., Bosch, M. A., Añón, M. C., & Mauri, A. N. (2017). Influence of initial protein structure on the properties of soybean protein edible films. In V. K. Thakur, M. K. Thakur, & M. R. Kessler (Eds.). *Soy-based bioplastics* (pp. 75–98). London, UK: Smithers Rapra Publisher.
Schmal, M. D., & Bachert, E. E. (2008). High temperature stand-up oven bag. US20080247683A1 Patent.
Sharma, O. P. (1976). Antioxidant activity of curcumin and related compounds. *Biochemical Pharmacology, 25*(15), 1811–1812.
Speroni, F., Milesi, V., & Añón, M. C. (2010). Interactions between isoflavones and soybean proteins: Applications in soybean-protein-isolate production. *Lebensmittel-Wissenschaft und -Technologie- Food Science and Technology, 43*(8), 1265–1270.
Szczesniak, A. S. (1987). Correlating sensory with instrumental texture measurements—an overview of recent developments. *Journal of Texture Studies, 18*(1), 1–15.
Tønnesen, H. H., De Vries, H., Karlsen, J., Henegouwen, V., & Beijersbergen, G. (1987). Studies on curcumin and curcuminoids IX: Investigation of the photobiological activity of curcumin using bacterial indicator systems. *Journal of Pharmaceutical Sciences, 76*(5), 371–373.
Vom Bruck, C. G., Bieber, W. D., & Figge, K. (1986). Interactions between food and packaging materials and its consequences on migration. In M. Mathlouti (Ed.). *Food packaging and preservation. Theory and practice* (pp. 39–66). London: Elsevier Applied Science.
Winiarski, P. B., & Saad, Z. E. M. (2004). Oven bag with pre-formed perforations. US20040252921A1 Patent.

## Further reading

Mauri, A. N., & Añón, M. C. (2008). Mechanical and physical properties of soy protein films with pH-modified microstructures. *Food Science and Technology International, 14*(2), 119–125.