Flavored oven bags for cooking meat based on proteins

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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°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, Salmieri, Saucier, &
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, Somwangthananoraj, 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, Rousselot 150H4, 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 2N 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

Thicknes, 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 N2 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 tanδ (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 tanδ 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 (Whirlpool, 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 measured 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 \( L_{\text{standard}} = 97.55 \), \( a_{\text{standard}} = -0.03 \) and \( b_{\text{standard}} = 1.73 \) provided by Minolta. Sample color was measured on the surface of this standard plate and total color difference (\( \Delta E^* \)) was calculated as follow:

\[
\Delta E^* = \left[(L_{\text{sample}} - L_{\text{standard}})^2 + (a_{\text{sample}} - a_{\text{standard}})^2 + (b_{\text{sample}} - b_{\text{standard}})^2 \right]^{0.5}
\]

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 \( \Delta E^* \)) andopacity 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. 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 (Demavi 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).

<table>
<thead>
<tr>
<th>Protein</th>
<th>Curry content (%)</th>
<th>Thickness (μm)</th>
<th>CIE-Lab color parameters</th>
<th>Opacity (AU mm$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$L^*$</td>
<td>$a^*$</td>
</tr>
<tr>
<td>SPI</td>
<td>0</td>
<td>61.00 ± 11.72 a</td>
<td>91.75 ± 0.72 c</td>
<td>-1.53 ± 0.11 a</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>109.18 ± 8.45 b</td>
<td>64.04 ± 0.49 b</td>
<td>10.84 ± 0.56 b</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>142.94 ± 12.55 c</td>
<td>47.27 ± 1.37 a</td>
<td>23.47 ± 1.02 c</td>
</tr>
<tr>
<td>BG</td>
<td>0</td>
<td>57.54 ± 2.93 A</td>
<td>95.64 ± 0.70 C</td>
<td>-0.55 ± 0.08 A</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>82.93 ± 8.72 B</td>
<td>74.44 ± 1.62 B</td>
<td>8.39 ± 1.19 B</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>117.40 ± 12.18 C</td>
<td>44.45 ± 2.42 A</td>
<td>24.90 ± 1.91 C</td>
</tr>
</tbody>
</table>

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).
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 concentration. 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 protein 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.

Considering that curry contained curcumin as one of its main ingredient, and this compound has proven antioxidant and antimicrobial properties among others (Tsnesen, 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•+ 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.

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).

<table>
<thead>
<tr>
<th>Protein</th>
<th>Curry content (%)</th>
<th>MC (%)</th>
<th>WS (%)</th>
<th>WVP (gH2O/Pa.m.s)</th>
<th>Tg (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI</td>
<td>0</td>
<td>21.86 ± 0.89 b</td>
<td>34.14 ± 3.11 a</td>
<td>1.05 ± 0.16 a</td>
<td>−32.0 ± 0.5 c</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>18.9 ± 2.08 b</td>
<td>34.02 ± 2.23 a</td>
<td>1.15 ± 0.03 a</td>
<td>−26.8 ± 0.2 b</td>
</tr>
<tr>
<td>BG</td>
<td>0</td>
<td>14.03 ± 0.78 a</td>
<td>31.19 ± 0.49 a</td>
<td>1.44 ± 0.06 a</td>
<td>−22.9 ± 0.9 a</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>15.98 ± 1.95 A</td>
<td>95.9 ± 1.53 A</td>
<td>1.70 ± 0.06 A</td>
<td>−39.2 ± 0.7 C</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>15.44 ± 1.08 A</td>
<td>90.48 ± 1.58 A</td>
<td>1.91 ± 0.11 A</td>
<td>−36.0 ± 0.9 B</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>13.29 ± 0.49 A</td>
<td>88.03 ± 2.98 A</td>
<td>2.37 ± 0.05 B</td>
<td>−31.7 ± 0.5 A</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>15.44 ± 1.95 A</td>
<td>122.1 ± 2.98 A</td>
<td>2.84 ± 0.06 A</td>
<td>−29.1 ± 0.5 C</td>
</tr>
</tbody>
</table>

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.

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).

<table>
<thead>
<tr>
<th>Protein</th>
<th>Curry content (%)</th>
<th>TS (MPa)</th>
<th>EB (%)</th>
<th>YM (MPa)</th>
<th>HSS (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI</td>
<td>0</td>
<td>5.24 ± 0.59 a</td>
<td>57.31 ± 8.26 c</td>
<td>1.95 ± 0.35 a</td>
<td>1.15 ± 0.19 b</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.93 ± 1.29 a</td>
<td>11.28 ± 3.44 b</td>
<td>2.78 ± 0.56 b</td>
<td>0.53 ± 0.12 a</td>
</tr>
<tr>
<td>BG</td>
<td>0</td>
<td>5.66 ± 1.19 a</td>
<td>2.84 ± 0.70 a</td>
<td>3.54 ± 0.58 c</td>
<td>n.d.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.66 ± 1.19 a</td>
<td>289.32 ± 28.97 C</td>
<td>0.02 ± 0.01 A</td>
<td>2.91 ± 0.41 A</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5.66 ± 1.19 a</td>
<td>114.12 ± 14.47 B</td>
<td>0.03 ± 0.01 A</td>
<td>1.64 ± 0.73 A</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.61 ± 0.45 A</td>
<td>29.66 ± 2.38 A</td>
<td>0.14 ± 0.03 A</td>
<td>2.40 ± 0.72 A</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1.54 ± 0.20 A</td>
<td>29.66 ± 2.38 A</td>
<td>0.14 ± 0.03 A</td>
<td>2.40 ± 0.72 A</td>
</tr>
</tbody>
</table>

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 glycite (Speroni, Milesi, & Afón, 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 adhesiive 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 ($\pm 60$ 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
meat during cooking, a fact that was verified through color parameters observation and with a preliminary sensory panel.

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References


Further reading