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# Development of fat-reduced sausages: Influence of binary and ternary combinations of carrageenan, inulin, and bovine plasma proteins

**Yanina Baracco, Laura T Rodriguez Furlán and Mercedes E Campderrós**

**Abstract**

The aim of this work was to study the influence of the binary and ternary combinations of bovine plasma proteins (BPP), inulin (I) and κ-carrageenan (C) in the overall quality of fat-reduced sausages. The influence of these components over different properties (chemical composition, weight loss after cooking, emulsion stability, texture profile and sensory analysis of fat-reduced sausages) was studied and compared against two samples, one without fat reduction and another a fat-reduced sample without addition of texturing agents. In this sense, a full factorial experimental design of two levels with central point was used. The samples containing BPP+I and BPP+C showed a synergy in which the binary combinations presented higher values of moisture and protein content than the samples containing the individual components. The reduction of fat content increases the values of hardness and decreases the values of springiness. Samples with 5% BPP (w/w) and binary combinations of BPP+C and BPP+I had the best stability values (low total fluid loss), demonstrating a significant synergistic effect by combining BPP+C. Similar results were obtained from the study of weight loss after cooking. However, both studies showed a destabilization of the sample BPP+I+C as emulsion stability decreased and weight loss increased after cooking compared to binary combinations ($P < 0.05$). Samples with a binary combination of BPP+C and BPP+I do not present a statistically significant difference in the chewiness with respect to a not-fat-reduced commercial sample ($P > 0.05$). The less acceptable sample for flavor and texture was the one containing only BPP. However, when BPP combined with I or C, a major acceptability was obtained, demonstrating the synergistic effect of these binary combinations. Therefore, our studies revealed that the binary combinations of BPP with I or C are good alternatives for the development of fat-reduced sausage.

**Keywords**

Fat-reduced sausage, inulin, bovine plasma protein, κ-carrageenan, quality characteristic

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## INTRODUCTION

Study of consumers in recent years has shown that consumption is being increasingly influenced by nutritional and health considerations. The high fat content of our diet results in adverse effects promoting obesity, diabetes, cardiovascular disease, and certain types of bowel cancer. The recommended dietary fat intake should not exceed 20 to 35% of total caloric intake

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(Dietary Guidelines for Americans, 2010). Traditional meat products such as sausages may contain up to 30% of fat (Choi et al., 2013). However, from a technological point of view, fats play an important role in meat products. They interact with other ingredients and help in the development of texture, tenderness, juiciness, affect the stability of meat emulsions, reduce losses during cooking, improve mouthfeel and provide a lubricating effect in processed meats, as well as contribute to the flavor (Choi et al., 2013; Tobin et al., 2012). Therefore, to improve the health of consumers, the fat content of processed meat products has to be reduced, but this should not impact negatively on the functionality and quality of the product or adversely affect the consumer acceptability. In this sense, fat content of meat products can be replaced with ingredients such as replacing dietary fiber, protein isolates, and carrageenan for healthier products. The incorporation of compounds such as inulin, which acts as a fiber, improves the nutritional value and enhances the quality characteristics of the product, such as texture, increasing water and fat binding capacity (Choe et al., 2013). Carrageenan and bovine plasma proteins (BPPs) have been used for their gelling, thickening, and stabilizing properties in food products (Brewer, 2012; Rodriguez Furlán et al., 2010a, 2010b).

Extensive research has been carried out between proteins and carrageenan in different systems. Combinations between kappa-carrageenan and milk protein, or soy proteins have been studied (Baeza et al., 2002; Carp et al., 2004; Molina Ortiz et al., 2004). Researches performed by Ipsen (1995) and Baeza et al. (2002) found a synergistic effect between κ-carrageenan and soybean protein due to the improvement of texture and viscoelasticity of gels. However, few studies have been conducted in combinations of inulin and carrageenan or inulin and BPP as texturing agents or fat replacers in a meat product.

The aim of this work was to study the influence of the binary and ternary combinations of BPPs, inulin, and κ-carrageenan over the overall quality of fat-reduced sausages. The influence of these ingredients on different properties such as cooking loss (CL), emulsion stability and texture profile analysis (TPA) of fat-reduced sausages was studied and compared against a control sample of non-fat-reduced products. For this study, a full factorial design that allows the study of interaction effects between factors was used.

## MATERIALS AND METHODS

### Raw materials

Spray-dried bovine blood plasma has been provided by a local supplier (Yerubá S.A., Esperanza, Argentina). The molecular weights of proteins were in the range of 15,000 to 80,000 Da. The proximate composition provided by the manufacturer was: 76 ± 5% proteins, 0.1% fat, 10% ash, 4% water, and 1% low-molecular weight compounds.

Inulin obtained from chicory was provided by Orafti Chile S. A. The commercial inulin employed was mainly constituted of linear chains of fructose molecules with a terminal glucose unit. It has a molecular weight of 2400 g/mol and a polymerization grade of 12.

Carrageenans are sulfated polysaccharides that have a strong electrolyte character due to their sulfate groups. κ-carrageenan has one sulfate group per repeated unit of disaccharide and was provided by Sigma Aldrich.

Inulin, BPP, κ-carrageenan, and their mixtures in different proportions were evaluated to establish the effect of these components as fat replacers. The selection of the amounts was based on preliminary studies of their functional properties.

The additives used in the formulations were: sodium diphosphate, sodium triphosphate, sodium nitrite, citric acid, sodium citrate, and ascorbic acid. The ingredients employed to prepare the sausage formulations, such as meat courts, beef fat, starch, sucrose, salt, and seasonings, were purchased from a local grocery store.

### Preparation of fat-reduced sausage

The sausages were elaborated using a 2 kg batch per treatment. The formulations were: (i) a full-fat sample containing a regular amount of fat (30%, w/w), full-fat sausage and (ii) fat-reduced samples (10%, w/w), where BPPs, inulin, carrageenan, and their mixtures were used as fat replacers in different proportions according to the experimental design. Each formulation was replicated three times including the control, and all the analyses were carried out in independent form.

The ingredients used for preparing sausages are shown in Table 1. The meat used for the production of sausages was of third category (CAA), i.e. the lowest category, containing a fat content between 30% and 40%, with visible nerves and small cartilages. BPP, inulin (I), and carrageenan (C) were added in fat-reduced samples according to the experimental design (Table 2).

The steps used for preparing sausage formulation were the following: the frozen meat and fat were thawed slightly, were cut into small pieces, and ground twice in a cutter (Coolbrand, Cool 8060 model, Argentina) using first a 5 mm disk and then a 1 mm disk. The required ice, seasoning, and additives were then added and mixed for 1 min. The sausage mix was fractionated and the BPP, I or C were incorporated according to formulations without previous dissolution, and the preparation was mixed during 5 min in a planetary mixer for an adequate integration of the different ingredients. The temperature should be

**Table 1.** Formulations of full-fat and fat-reduced sausage

| Samples | | |
|---|---|---|
| Ingredients (%, w/w) | Full-fat sausage | Fat-reduced sausage |
| Pork fat | 29.7 | 9.7 |
| Bovine meat | 23.5 | 33.5 |
| Pork meat | 23.5 | 33.5 |
| Sodium chloride | 2.2 | 2.2 |
| Sodium nitrite | 0.01 | 0.01 |
| Sodium triphosphate | 0.4 | 0.4 |
| Sugar | 0.5 | 0.5 |
| Citric acid | 0.2 | 0.2 |
| Cornstarch | 1 | 1 |
| Ascorbic acid | 0.05 | 0.05 |
| Condiments | 1 | 1 |
| Water (ice) | 18 | 18 |

**Table 2.** The range of levels selected for the variables: bovine plasma protein (BPP), inulin (I) and carrageenan (C)

| Factor (%, w/w) | Low level (−1) | Central point (0) | High level (+1) |
|---|---|---|---|
| BPP | 0 | 2.5 | 5 |
| I | 0 | 2.5 | 5 |
| C | 0 | 0.02 | 0.04 |

maintained below 10 °C during preparation. The sausage mix was placed into the casing filler and stuffed into cellulose casings (20 mm diameter). The sausages were hung in a convective oven at 90 °C and cooked at high relative humidity (≅90%) until an internal temperature of 72 °C was reached, which was tested by a temperature sensor. This temperature was held for 10 min. Finally, the samples were submerged in a cold bath (≅15 °C), packaged into polyamide/polyethylene laminate plastic bags, and stored over night at 4 ± 1 °C (Choe et al., 2013; Tobin et al., 2012, 2013; Zarringhalami et al., 2009).

## Chemical composition

The chemical composition of full-fat and fat-reduced sausages were performed after seven days of storage by the following methods: moisture content by gravimetric method (AOAC 925.10); ash by incineration (AOAC 945.46); and protein content by determination of total nitrogen by the Kjeldahl method using a Digestion Blocks and a semiautomatic Distiller (Selecta, Spain) with a conversion factor of 6.25 (AOAC 991.22). For the total fat determination, the technique of Bligh and Dyer (1959) was used: 20 mL methanol and 10 mL of chloroform ($CHCl_3$) were added to 5 g of sample and mixed for 2 min. Then, other 10 mL of $CHCl_3$ were added and the mixture was shaken vigorously. Eighteen milliliters of distilled water were added and the mixture was vortexed again for 2 min. The layers were separated by centrifugation at 2000 r/min for 10 min (Rolco Model 2070, Buenos Aires, Argentina, centrifuger). The lower layer was transferred to a pear-shaped flask with a Pasteur pipette. A second extraction was done with 20 mL 10% (v/v) methanol in $CHCl_3$. After centrifugation, the $CHCl_3$ phase was added to the first extract. Evaporation was carried out by rotavapor (Buchi, 451, Flawil, Switzerland), and the residue was further dried at 104 °C for 1 h.

## Emulsion stability

The emulsion was determined as follows: 5 g of each sample without casing and without cooking was placed in a centrifuge tube heated in a water bath (HAAKE, E3, Vreden, Germany) at 75 °C for 30 min and centrifuged at 3000 r/min for 30 min. The tubes containing the samples were left to stand upside down (for 30 min) to release the exudate onto a plate. Emulsion stability, defined as total fluid release (TFR), was expressed as g/100 g of initial sample weight (Jiménez Colmenero et al., 2010, Rodriguez Furlán et al., 2014).

## CL

The weights of eight sausages from each formulation were recorded before and after cooking and the differences were calculated. Before weighing, the samples were blotted with a paper towel to remove the excess surface moisture. Weight loss after cooking was calculated as the difference between weights (Choe et al., 2013; Tobin et al., 2013).

## Texture analysis

The TPA was performed at room temperature with a texture analyser TMS-TOUCH (Food Technology Corporation, USA). For each sample, three cylindrical slices were taken (20 mm × 10 mm) from the center of the sausage. The samples were subjected to a two-cycle compression test using the 50 N load cell. The samples were compressed to 40% of their original height with a cylindrical probe of 38 mm and a test speed of 100 mm/min. The texture parameters determined were (Tobin et al., 2013): hardness (N), maximum force required to compress the sample; springiness (dimensionless), ability of the sample to recover its original form after deforming force was removed; cohesiveness (dimensionless), extent to which the sample could be deformed prior to rupture, which is measured by the areas under the compression portion; and chewiness (N), work required to masticate the sample before swallowing, defined as the product hardness times cohesiveness times springiness.

### Sensory analysis

Each sample of sausage was identified with a three-digit code and randomly ordered. The samples were served in white plastic cups; water was provided for cleansing the mouth between samples. The sample was tested at room temperature by 25 semitrained panelists who judged the samples through a nine-point hedonic scale (9 = extremely like, 5 = neither like nor dislike, 1 = extremely dislike). Flavor, aroma, color, and texture were evaluated (Feng et al., 2016).

**Table 3.** Performed test done in function of the combination of the different levels of ingredients: bovine plasma protein (BPP), inulin (I) and carrageenan (C)

| Formulations | | | |
|---|---|---|---|
| Test | $x_1$ (BPP) | $x_2$(I) | $x_3$(C) |
| 1 | +1 | +1 | +1 |
| 2 | −1 | +1 | +1 |
| 3 | +1 | −1 | +1 |
| 4 | +1 | +1 | −1 |
| 5 | −1 | −1 | +1 |
| 6 | −1 | +1 | −1 |
| 7 | +1 | −1 | −1 |
| 8 | −1 | −1 | −1 |
| 9 | 0 | 0 | 0 |

### Experimental design

The influence of varying concentrations of plasma protein, inulin, and carrageenan as fat replacers and emulsion stabilizers over the quality properties of low-fat sausages (10%, w/w fat) was studied using a two-level full factorial model with center point. The experimental levels of the independent variables: concentrations of BPP ($x_1$), inulin ($x_2$), and carrageenan ($x_3$) are displayed in Table 2. Table 3 shows the different runs in function of the combination of the selected concentrations for each level (upper and lower).The design consisted of eight experiments, including three repetitions for the calculation of the pure error and for the lack-of-fit test. Second-order Scheffé polynomials were fitted for the experimental data as follows

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 \quad (1)$$

where $Y$ is the dependent variable; $\beta_0$, $\beta_1$, $\beta_2$, etc. are the coefficient estimates for each linear term, $\beta_{12}$, $\beta_{13}$, $\beta_{23}$, etc. are the coefficient estimates for each quadratic term where the interaction between components is evidenced (synergy or antagonism) for the system model, and $X_1$, $X_2$, and $X_3$ are the concentrations of BPP, inulin, and carrageenan, respectively.

The response surface studies were made based on the regression equations generated with the parameters that showed a statistical difference using the Statistical 8 program.

**Table 4.** Composition analysis (g/100 g) of different sausages formulated

| | Composition (%, w/w) | | | |
|---|---|---|---|---|
| Samples | Moisture | Ash | Protein | Fat |
| 1-BPP+I+C | 58.87 ± 0.28a | 3.76 ± 0.15a | 19.21 ± 0.10a | 16.07 ± 0.87a |
| 2-I+C | 63.32 ± 0.39b | 3.20 ± 0.04a | 16.55 ± 0.08b | 14.27 ± 3.27a |
| 3-BPP+C | 61,58 ± 0.95c | 3.84 ± 0.07a | 21.87 ± 0.11c | 13.76 ± 1.14a |
| 4-BPP+I | 70.94 ± 2.40d | 2.98 ± 0.40a | 18.89 ± 0.06a | 12.16 ± 0.28a |
| 5-C | 64.69 ± 0.50e | 3.98 ± 0.40a | 18.82 ± 0.09a | 14.93 ± 0.34a |
| 6-I | 60.45 ± 0.17c | 4.03 ± 0.07a | 17.65 ± 0.09d | 13.22 ± 0.39a |
| 7-BPP | 62.11 ± 0.06b,c | 3.87 ± 0.06a | 20.23 ± 0.10e | 14.94 ± 1.13a |
| 8-Control | 65.05 ± 0.08e | 3.35 ± 0.05a | 17.17 ± 0.09d | 14.98 ± 3.67a |
| 9-BPP+I+C | 61.41 ± 0.50c | 3.60 ± 0.08a | 18.90 ± 0.09a | 15.15 ± 0.65a |
| Full fat | 62.89 ± 0.08b | 3.77 ± 0.13a | 10.07 ± 0.06f | 26.87 ± 3.91b |

Note: Values in a column with the same letter are not significantly different from each other at $P > 0.05$.

### Statistical analysis

The test of Tukey and analysis of one-way variance were used for establishing the significance of $P < 0.05$ between the means of the analyzed values. The values of $P > 0.05$, $P < 0.01$, and $P < 0.001$ were considered not, very, and extremely significant, respectively. The statistical analysis was performed by the statistical GraphPad InStat software (1998).

## RESULTS AND DISCUSSION

### Composition analysis

Table 4 shows the results for composition analysis of full-fat and fat-reduced sausages. No statistical significant difference in the fat content between the fat-reduced sausages was found. The approximate value of fat content for these samples was 14% (w/w), with a reduction of 50% in the fat content with respect to the full-fat sample. The fat-reduced formulations presented the differences in the moisture percentage content (%M). Table 4 shows that the incorporation of C at 0.04% (w/w) did not generate changes in the %M with respect to the fat-reduced control sample (formulation 8), ($P > 0.05$). However, the combination of C with I or BPP generated a decreased %M ($P < 0.05$ and $P < 0.01$, respectively). The increase in the moisture release can be due to electrostatic repulsion between the two negatively charged molecules Bovine Serum Albumin (BSA, majority protein of BPP) and κ-carrageenan (Molina Ortiz et al., 2004). Galazka et al. (1999) found that the addition of κ-carrageenan to BSA decreased the surface hydrophobicity of the protein by decreasing their water-binding capacity. Nieto Nieto et al. (2016) investigated the thermal gelation of oat protein in the presence of polysaccharide-like carrageenan. The polysaccharide structure significantly increased the phase-separation and gel mechanical properties; this behavior may be attributed to the strong repulsive forces caused by carrageenan molecules.

The incorporation of the individual component BPP and I (formulations 6 and 7) also generated a significant decrease of %M with respect to the control sample ($P < 0.001$). Previous research has reported that an increase in fiber content resulted in a decrease in the moisture content of chicken frankfurters (Chang and Carpenter, 1997).

From the experimental data of %M, the surface plot (fitted response) of fat-reduced sausages (Figure 1) was obtained. The results show that the highest values were observed in the right side of the experimental area for the formulation number four, where the binary combination of BPP+I was tested. The sample BPP+I showed a synergy in which the binary combination of BPP and I presented higher values than the samples containing the individual components. The increase in

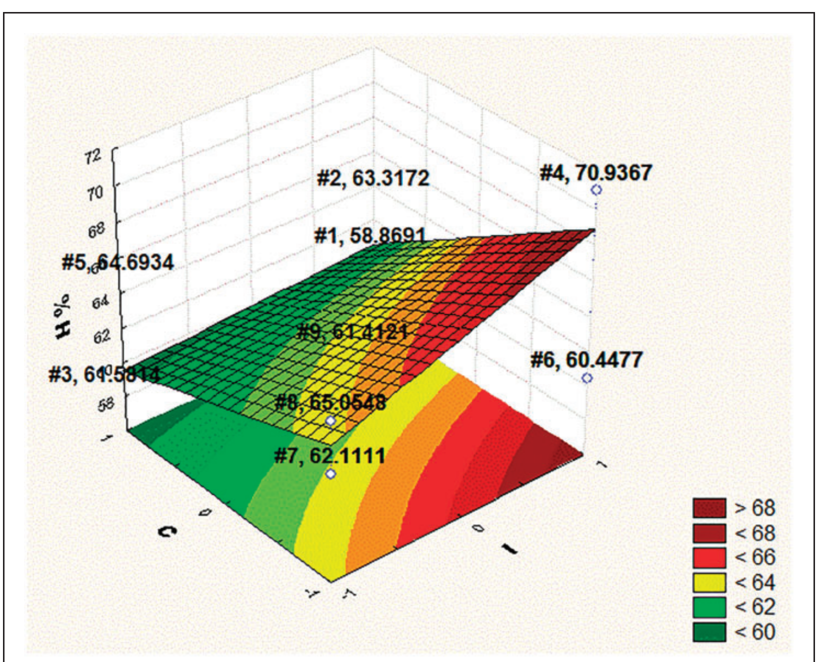


**Figure 1.** Surface plot for sausage moisture content with the incorporation of different concentrations of fat replacers: bovine plasma proteins (BPP), inulin (I) and carrageenan (C).

water retention may be associated with the increase of binding capacity of the binary combination of BPP and inulin (Rodriguez Furlan et al., 2010a, 2010b). Additionally, previous studies have demonstrated that the combination of BPP with I increased the emulsion capacity (Rodriguez Furlan et al., 2010b). Moreover, the addition of dietary fiber at fat-reduced sausages has been reported to improve gel strength by increasing the link with water (Cardoso et al., 2008). However, the combination of the BPP+I+C (formulation 1) generated a major decrease of %M, showing an important antagonist effect (Figure 1 and Table 4). As previously was exposed, the combination of C with BPP interferes in the gel protein matrix reducing the water-holding capacity.

Table 4 shows that no differences were found in the protein percentage content between the control sample (formulation 8) and the one with the incorporation of I and combined with C ($P > 0.05$). As it is expected, the incorporation of BPP generated a significant increase on the protein content. In addition, the binary combination of BPP with C presented a synergistic effect, because this sample shows higher values than the samples containing the individual components. This may be due to the carrageenan's ability to form a complex with water and protein, decreasing the protein loss during cooking in the exudate liquid (Brewer, 2012).

## Emulsion stability and CL

The emulsion stability of the fat-reduced sausage formulations was influenced by the different ingredients (BPP, I, and C) used (Table 5). The fat reduction produced an increase in TFR around 19% (w/w), (full-fat sausage vs. formulation 8). Previous studies have demonstrated that the fat reduction of frankfurters produced an increase of TFR chiefly in the amount of water released (Jiménez Colmenero et al., 2010). This effect could be due to the reduction of the proportion of fat with respect to the water content, and therefore, the ability of proteins to form an emulsion decreases, reducing the water-binding capacity and increasing the TFR (Jiménez Colmenero et al., 2010). The incorporation of inulin in the matrix (formulation 6) generated an increase in the TFR. This suggests that there is some interference between the effects produced by this ingredient in the meat matrix, which affects the emulsion stability. However, the combination of inulin (I) with carrageenan (C) and/or BPP generated a significant decrease of TRF ($P < 0.05$). In addition, the aggregated of C (formulation 5) did not generate statistical differences with respect to the control sample (formulation 8), ($P > 0.05$). Therefore, the binary combination of I and C (formulation 2) presented a synergist effect in which the use of both ingredients presented higher values than the samples containing the individual components with the same fat content.

The incorporation of BPP to the matrix generated a decrease of TRF with respect to the control sample ($P < 0.05$). Moreover, the combination of BPP with C (formulation 3) presented the lowest values of TFR, demonstrating the presence of a significant synergistic effect between both components ($P < 0.001$). Furthermore, the TRF of this sample was lower than the full-fat sample presenting an improved emulsion stability ($P < 0.001$). The results of chemistry composition demonstrated that this sample presented a higher protein content. It is well known that higher protein concentration can form gels with a higher water holding capacity, or form more stable emulsions (Rodriguez Fulán et al., 2010a, 2010b). In previous research, it has been found that sausages with more protein content had less total fluid loss (Colmenero, 1996).

CL is an important factor, because it is responsible for the juiciness of meat products (Choe et al., 2013). The CL was reduced by the incorporation of the individual components of C and I ($P < 0.05$), and in a higher proportion by the addition of BPP ($P < 0.001$) with respect to the control sample (formulation 8). The addition of fiber to frankfurter-type sausages has been found to result in a reduction of CL (Choe et al., 2013). Similarly, previous research has found that sausages with the addition of whey protein were more stable with reduced CL (Ensor et al., 1987). Noteworthy, the binary combination of these three components (I+C, BPP+C and BPP+I) generated a statistical reduction of the CL with respect to the samples containing individual components. This behavior evidences the presence of a synergist effect between these

**Table 5.** Emulsion stability (total fluid release, TFR) and cooking loss (CL) of fat-reduced sausages

| Samples | TFR (%) | CL (%) |
|---|---|---|
| 1-BPP+I+C | 21.03 ± 0.51a | 6.6 ± 0.3a |
| 2-I+C | 18.24 ± 0.45b | 4.4 ± 0.2b |
| 3-BPP+C | 12.23 ± 0.99c | 4.5 ± 0.2b |
| 4-BPP+I | 19.03 ± 0.23b | 3.7 ± 0.2c |
| 5-C | 23.83 ± 0.44d | 8.9 ± 0.5d |
| 6-I | 28.56 ± 1.46e | 9.0 ± 0.4d |
| 7-BPP | 20.44 ± 0.83a | 5.5 ± 0.3e |
| 8-Control | 24.45 ± 0.69d | 11.2 ± 0.7f |
| 9-BPP+I+C | 22.47 ± 1.98a | 11.3 ± 0.6f |
| Full fat | 19.90 ± 2.32a | 7.7 ± 0.4g |

Note: Values in a column with the same letter are not significantly different from each other at $P > 0.05$.

components, which were lower than the control (formulation 8) and the full-fat sample ($P < 0.05$).

The binary combination of BPP+I presented the lowest values of CL, which is in agreement with the previously obtained results. This sample presented the highest moisture content (≅71%, w/w). It is of interest to notice that not only did low CL promote better technological properties but it has also entailed/involved economic benefits (Jiménez Colmenero et al., 2010).

The binary combinations of BPP+C and BPP+I present better stabilizing properties than the individual components. This may be due to the complexation of proteins with C or I, that alter the textural properties, gel-forming, and water holding abilities of the BPPs (Brewer, 2012).

## Texture analysis

The ingredients studied affected texture of the fat-reduced sausages (Table 6). The reduction of fat content increases the values of hardness and decreases the values of springiness. Previous studies reveal that the decrease in fat content of frankfurter-type sausage increases the hardness (Cengiz and Gokoglu, 2007). In addition, it has been found that the springiness of frankfurters decreased with the reduction of fat content (Mittal and Barbut, 1994; Tobin et al., 2012). No differences were observed in hardness and chewiness between the control sample (formulation 8) and the samples with individual ingredients and the binary combination of I and C. However, the samples with combination of the three ingredients presented the highest values of hardness and chewiness ($P < 0.01$).

The reduction in fat content increases the value of cohesiveness and chewiness. These results are in agreement with previous studies that reported an increased level of cohesiveness and chewiness with a decreased level of fat content in sausages (Olivares et al., 2010). No difference in the values of cohesiveness was observed between all fat-reduced samples analyzed.

The increase of values in hardness, cohesiveness, and chewiness with a decrease of fat content can be due to the fact that the reduction of fat generated an increase of protein (Table 4). The increase in protein content can create a dense and stable matrix that increases the textural parameters (Tobin et al., 2013).

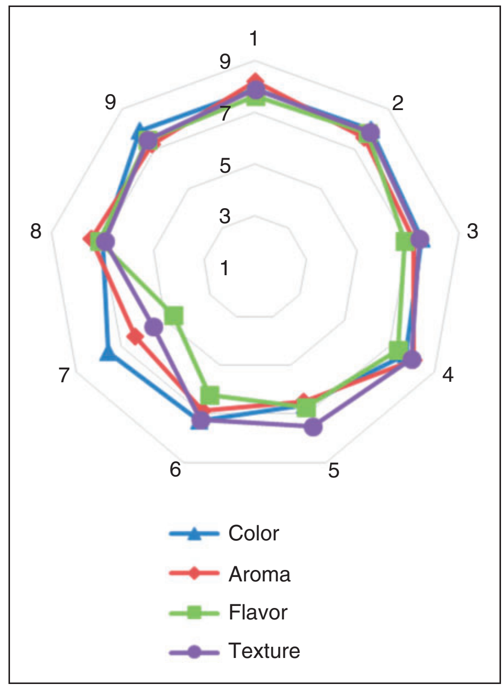


**Figure 2.** Sensory parameters of fat-reduced sausages.

**Table 6.** Texture profile analysis of the different samples of fat-reduced sausages

| Samples | Hardness (N) | Cohesiveness | Springiness | Chewiness (N) |
|---|---|---|---|---|
| 1-BPP+I+C | 41.85 ± 4.56a | 0.81 ± 0.04a | 6.7 ± 0.4a | 227.1 ± 34a |
| 2-I+C | 22.45 ± 0.77b | 0.84 ± 0.02a | 6.5 ± 0.3a | 122.6 ± 3.7b |
| 3-BPP+C | 27.30 ± 0.54c | 0.86 ± 0.05a | 6.0 ± 0.5a | 140.9 ± 4.2c |
| 4-BPP+I | 27.78 ± 1.40c | 0.84 ± 0.07a | 6.5 ± 0.4a | 151.7 ± 7.6c |
| 5-C | 21.83 ± 2.05b | 0.75 ± 0.02a | 6.8 ± 0.2a | 111.3 ± 10.0b |
| 6-I | 19.46 ± 1.68b | 0.84 ± 0.05a | 6.7 ± 0.3a | 109.5 ± 9.8b |
| 7-BPP | 22.33 ± 4.19b | 0.83 ± 0.02a | 5.7 ± 0.5a | 105.6 ± 19.3b |
| 8-Control | 20.61 ± 3.10b | 0.79 ± 0.03a | 6.6 ± 0.4a | 107.5 ± 16.1b |
| 9-BPP+I+C | 35.03 ± 4.53d | 0.82 ± 0.03a | 6.8 ± 0.4a | 195.3 ± 25.2d |
| Full fat | 14.87 ± 1.25e | 0.71 ± 0.02b | 8.9 ± 0.6b | 94.0 ± 7.5e |

Note: Values in a column with the same letter are not significantly different from each other at $P > 0.05$.

The chewiness values of the samples BPP+C and BPP+I presented similar values with respect to a commercial sample (142.5 ± 8.5 N), ($P > 0.05$).

### Sensory evaluation

Figure 2 shows the results obtained for the sensory evaluation of the different formulations of fat-reduced sausages. All samples were sensory acceptable, obtaining a higher value than 5 for the tested sensory parameters (flavor, aroma, color, and texture), among a range of 5 to 8.5. Sample with incorporation of BPP present significant differences in the taste (4.5) and texture (5.6) parameters with respect to control sample (formulation 8). No significant differences for all parameters evaluated between the other samples and the control were found. Therefore, the incorporation of these ingredients as fat substitute or stabilizers did not affect the sensory properties. Previous studies reported that the addition of dietary fiber at sausages and carrageenan to frankfurters, respectively, could be used without altering the sensory attributes of this meat products (Candogan and Kolsarici, 2003; Choe et al., 2013).

## CONCLUSIONS

From the data of chemical composition, it was observed that the formulations have a healthier design in which the fat content was reduced (≅50%) and the protein content was increased (≅100%). In addition, the development of a functional food was possible due to the incorporation of a dietary fiber as inulin.

The binary combination of BPP with C presented a synergistic effect, because this sample showed the highest values of protein content, higher than the samples containing the individual components. This increase in the protein content may be the cause of the reduction in the TFR and the increase in the sample emulsion stability. Moreover, the binary combination of BPP with I also presented a synergistic effect, because the surface plot shows higher values of water content than the samples containing the individual components. These results are in agreement with the studies of CL, where a static reduction in the fluid loss during cooking was observed. Therefore, these binary combinations resulted in a product with greater stability and reduced losses during cooking that can generate economic benefits. In addition, the chewiness values of the samples BPP+C and BPP+I presented similar values to a commercial sample. The sensorial analysis of samples showed that color, aroma, and texture were similar to the control sample. With respect to the attribute of flavor, the sample with BPP had a lower score than the control sample. However, the binary combination of BPP with C or I present highest score and similar to the control sample. The results of this experiment suggest that the binary combination of BPP+C and BPP+I present a stabilizer effect, improving the process performance by reducing the fluid loss during cooking.

## DECLARATION OF CONFLICTING INTERESTS

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