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Influence of chicken protein isolate and heating temperature on textural properties of low-fat frankfurters

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Primary Audience: Food Processors, Nutritionists, Food Researchers

SUMMARY

The effects of chicken protein isolate (CPI) addition and heating temperature on the textural properties of low-fat frankfurters were investigated. Frankfurter quality was determined by measuring textural, color, and sensory characteristics. A high temperature caused an increased firmness, breaking force, and gel strength of the frankfurters, and CPI concentration intensified the gel strength. The commercial chicken frankfurters had a greater acceptability and purchase intention than the experimental frankfurters with CPI when evaluated by panelists. The frankfurters with CPI addition (without pork lard) had a lower fat content than the commercial chicken frankfurters. The total replacement of fat by CPI in the experimental frankfurters contributed to the production of a low-fat product because it had a 60% lower lipid content than the commercial chicken frankfurters while maintaining good textural characteristics.

Key words: chicken, frankfurter, low-fat, protein isolate, texture

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DESCRIPTION OF PROBLEM

Sausage preparation is one of the oldest forms of food processing. Sausages are characterized by a high degree of constituent division [1]. Ingredient selection is the first step in the production of uniform-quality sausages. Although beef and pork are the main raw materials used in sausage-making, lamb [2, 3], poultry [1, 2], and fish surimi [4] can also be used. The main requirement for choosing the raw material is that it should have an appropriate emulsifying ability [2].

An emulsion is defined as a colloidal system containing 2 immiscible liquid phases, mutually dispersed in each other as small droplets [5]. Although the classical definition of an emulsion implies that both immiscible liquids are dispersed in the colloidal state, the structure and physical properties of the paste used in the making of frankfurters are so similar to true emulsions that they have come to be called meaty emulsions [6]. Two phases constitute a meaty emulsion: a continuous phase represented by water, and a discontinuous phase represented by fat droplets. Although immiscible, both phases are stabilized and kept in smooth contact because of the active role of stabilizers. Those stabilizers produce stabilization when they fully cover the dispersed fat droplets, thus avoiding

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their coalescence. Emulsification allows fat to play a role in the taste and texture of the meaty product [1].

The growing demand by consumers for healthier products is stimulating the development of meat products with a reduced fat content [7–9]. An excessive intake of meat products is not recommended from a health point of view, at least for some population groups, because of their level of animal fat [10]. The apparent relationship between dietary fat and the development of cardiovascular disease has prompted consumers to become more aware of and concerned about the amount of fat in their diets [11–13]. Great effort by the meat industry is put into the development of new products with better nutritional properties than traditional ones [10].

However, the role of fat is an important consideration in any formulation. Fat also plays a major role in the texture, juiciness, and flavor of comminuted meat products. Fat is vital to the rheological and structural properties of meat products and in the formation of a stable emulsion. Technological aspects associated with the processing of low-fat meat products include problems with texture, flavor, and mouthfeel [8, 14].

Approaches used to minimize problems related to fat reduction include the use of leaner raw materials, the physical manipulation of the meat by way of massaging or mincing, and the incorporation of nonmeat ingredients into the formulation [15, 16]. The use of leaner meats, in addition to a high cost, creates products that are firmer, dryer, less succulent, and less tasty than standard products [14]. Direct replacement of fat with nonmeat proteins is an attractive means of approaching fat reduction because of the excellent functional and nutritional properties these nonmeat proteins can impart. Such ingredients include water [9], carbohydrates [9, 11, 17], vegetable oils [11], soy proteins [8, 18–20], milk proteins [7, 17, 19, 21, 22], and fish protein isolate [23]. Proteins are used as fat replacements because of their ability to bind water and form gels. In addition, they act as emulsifying agents and are used to alter the appearance, flavor, and texture of food products [24].

Therefore, the aim of our research was to study the influence of chicken protein isolate (**CPI**) and heating temperature on the textural properties of low-fat frankfurters.

MATERIALS AND METHODS

Isolation of Protein

Mechanically deboned meat (**MDM**) of chicken was supplied by Minuano Alimentos [25]. Chicken MDM was stored frozen inside polyethylene bags at −18°C for no more than 2 wk before use. To prepare the protein isolate by using a pH-shifting process [26–28], the frozen chicken MDM was tempered at 6 to 10°C overnight and became partially thawed. The chicken MDM was mixed with chilled distilled water (1:4, wt/vol), and the mixture was homogenized for 60 s by using a homogenizer [29] at a speed of 500 rpm. The homogenate was adjusted to pH 11 by using 1 *N* NaOH over a 20-min period. After the pH adjustment, the homogenate was centrifuged at 4,000 × *g* for 25 min (0 to 10°C). Three layers were formed after centrifugation: an upper fat layer, a middle aqueous layer of soluble proteins, and a bottom sediment layer. The middle protein supernatant layer was carefully removed and the other 2 layers were discarded. The resulting protein supernatant was adjusted to pH 5.4 by using 1 *N* HCI over a 10-min period. The precipitated proteins were then dewatered by centrifugation at 4,000 × *g* for 25 min. The precipitated protein, called CPI, was stored at 4°C for no more than 24 h before further processing.

Frankfurter Preparation

Chicken thighs were obtained from a commercial market and stored frozen at −18°C. To prepare the frankfurters, frozen chicken thighs were tempered at 6 to 10°C, manually deboned, and then processed with a cutter [30] to obtain a viscose paste. The formulation used was based on one used industrially [31], with fat being replaced, partially or totally, by CPI. The meat and ice content remained in constant proportions of 70.0 and 15.0%, respectively, in the sausage formulation. Other ingredients [31] were 0.25% cure 101, 0.20% taste enhancer, 0.20% sugar, 0.25% color fixer, 0.03% carmine dye, 1.35% salt, 2.0% potato starch, 0.25% stabilizer, 0.50%

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spice (wet weight basis). The batter temperature did not exceed 10°C. The CPI was then added in a range from 0 to 10% (wt/wt), replacing pork lard so that the proportion of CPI and lard accounted for 10% of the sausage formulation. Heating temperature varied between 75 and 90°C (Table 1). The frankfurter batter was chopped until it attained a silky texture and was then manually stuffed in a 25 mm diameter × 10 cm length artificial tripe [32] with the ends tied. Frankfurters were cooked by immersion in an ultrathermostatic bath [33] for 30 min at different temperatures, followed by cooling in an ice-water bath for 30 min. Samples were stored at 0°C.

Textural Properties

Penetration and cutting tests were performed to obtain breaking force, distance to rupture, and firmness with a texture analyzer [34], according to the method of Pietrasik and Duda [8]. For breaking force, frankfurters were compressed until the structure disrupted. Most samples were ruptured after compression to 50 to 70% of their original height. Gel strength was obtained by the multiplication of breaking force and distance to rupture [35]. The penetration test was performed using a spherical probe with a 5-mm diameter, pretest speed of 1 mm/s, test speed of 0.83 mm/s, posttest speed of 10 mm/s, and distance of 11 mm. The cutting test was performed by using an open-plate probe. Frankfurter samples were cut lengthwise at a pretest speed of 1 mm/s, test speed of 0.83 mm/s, posttest speed of 10 mm/s, and distance of 11 mm.

Characterization of Raw Material and Low-Fat Frankfurters

Moisture (method 950.46), protein (method 928.08), fat (method 960.39), and ash (method 920.153) contents of frankfurters were determined in triplicate according to AOAC [36] procedures. Carbohydrate content was calculated by difference (100 g − moisture, protein, fat, and ash). The pH values were measured [37] on a homogenate of a 50-g sample in 50 mL of distilled water. Microbiological analysis was conducted to identify *Staphylococcus* (coagulase positive), *Salmonella*, and *Escherichia coli* [38].

Interior Color

The interior color of frankfurters was measured using a reflectance colorimeter [39] and expressed as Commission Internationale de l'Éclairage Lab color space L* (lightness), a* (redness), b* (yellowness). An average value was determined using observations from 6 different cut surfaces of the same frankfurter.

Sensory Evaluation

Sensory analyses were conducted by 50 panelists experienced in the sensory evaluation of foods. However, they received no specific training relevant to these products. Panelists were asked to indicate how much they liked or disliked each product on a 9-point hedonic scale (9 = like extremely; 1 = dislike extremely) according to the method of Lawless and Heymann [40]. Samples (1 cm thick) of both low-fat experimental and commercial frankfurters were distributed on white polystyrene plates and presented to each panelist in random order with 3-digit product codes. Mineral water was supplied to panelists for rinsing between samples. Experiments were conducted in an appropriately designed and lighted room. Panelists also indicated their consumption frequency and purchase intention of these products [41].

Experimental Design

Response surface methodology was used to study the simultaneous effects of 2 variables, CPI (%) and heating temperature (°C; Table 1). The experiment was based on a central composite rotatable design [42]. Five levels of each factor (variable) were chosen in accordance with principles of the central composite design, with the analysis of 11 combinations of 2 variables

Table 1. Levels of independent variables used in the response surface methodology

Variable[1]	Level −1.41	−1	0	+1	+1.41
CPI, %	0	1.45	5.00	8.54	10.00
Heating temperature, °C	75.0	77.2	82.5	87.8	90.0

[1]CPI = concentration of chicken protein isolate in frankfurters.

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Table 2. Estimates (i.e., coordinates) of the effects for variable frankfurter firmness, breaking force, and gel strength from the second-order response model

		Linear		Quadratic			Interaction	
Response[1]	Variable[2]	Effect	*P*-value	Effect	*P*-value	Variable	Effect	*P*-value
Firmness	CPI	−0.10	0.9249	0.70	0.6053	CPI × HT	−2.08	0.2235
	HT	−0.24	0.8281	5.36	0.0082[a]			
Breaking force	CPI	7.42	0.7329	36.61	0.1958	CPI × HT	−20.41	0.5134
	HT	88.23	0.0078[a]	−11.12	0.6693			
Gel strength	CPI	31.72	0.8313	426.41	0.0041[a]	CPI × HT	−162.21	0.4533
	HT	705.81	0.0526[b]	25.37	0.8863			

[a]Variable is significant at the 95% confidence level.

[b]Variable is significant at the 90% confidence level.

[1]Firmness (R^2 = 0.80337); breaking force (R^2 = 0.81573); gel strength (R^2 = 0.86636).

[2]CPI = concentration of chicken protein isolate on frankfurters; HT = heating temperature (°C);

being performed. Assessment of error was derived from 3 replications of 1 treatment.

For each parameter evaluated (e.g., firmness, breaking force, and gel strength), compositional variables were analyzed for linear, quadratic, and interaction coordinates, and lack of fit and error components were used to determine the suitability of the second-order polynomial function and the significance of variables being assessed. The significance of model equation parameters for each response variable was assessed using the *F*-test. Finally, the optimal low-fat meat formulation identified from the response surface methodology was compared directly with the commercial sample.

Color data and sensory analysis were assessed by using Student's *t*-test, which was considered significant when $P < 0.05$. The results obtained in the experiments were analyzed using Statistica software, version 6.0 [43].

Analysis of the Effects, and Statistical Models

Data were analyzed to fit a second-order polynomial model for the dependent variables firmness, breaking force, and gel strength. A response surface of the model coordinates was drawn to assess the effects of CPI concentration and heating temperature on the gel strength of frankfurters made with CPI.

RESULTS AND DISCUSSION

Firmness of Frankfurters with CPI

The variable that most affected the firmness of the frankfurters was heating temperature, having a quadratic influence at a 95% confidence level (Table 2). The temperature variation (75 to 90°C) caused an increase in the firmness of the frankfurters. Different concentrations of CPI, as a replacement for fat, in the formulation of the frankfurters did not ($P > 0.05$) affect the firmness response.

Fontana [23] assessed the hardness of emulsified sausages subjected to different cooking temperatures with added wet Whitemouth croaker (*Micropogonias furnieri*) protein isolate obtained through alkaline solubilization. They reported that a reduction in fat content and variations in cooking temperature had no effect on the hardness of the emulsified sausages. Cortez-Vega [35] reported increased values for the firmness of frankfurters prepared with chicken surimi when the lard content was increased in the formulation. Overall, changes in fat content can affect the textural characteristics of frankfurters. Firmness usually increases with an increase in fat level [8].

Breaking Force of Frankfurters with CPI

The variable that most affected the breaking force of the frankfurter was heating temperature, which had a linear effect at a 95% confidence level (Table 2). The temperature variation (77.2 to 87.8°C) caused an increase ($P < 0.05$) in the breaking force of the frankfurters. Altering the CPI concentration in the frankfurter formulation did not ($P > 0.05$) affect the breaking force response.

Cortez-Vega [35] assessed the effect of adding lard on the cutting force (g) of chicken surimi

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frankfurters and noted that varying the amount of added fat did not ($P > 0.05$) affect this textural characteristic. Fontana [23] reported that an increase in cooking temperature reduced the penetration force of frankfurters and indicated that increasing the cook temperature could have caused protein denaturation, thus altering the ability to form gels.

Gel Strength of Frankfurters with CPI

Factors that affected the gel strength of the frankfurters were CPI concentration and heating temperature, which had a quadratic ($P < 0.05$) and a linear influence ($P < 0.10$), respectively (Table 2).

The temperature increase (77.2 to 87.8°C) caused an increase in frankfurter gel strength. The increase in CPI concentration (0 to 10%) had a positive quadratic effect, resulting in an increase in frankfurter gel strength.

Andrés et al. [21] studied the textural characteristics of chicken frankfurters with added milk serum protein concentrate and noted that an increase in the amount of protein concentrate increased the cohesiveness of the chicken frankfurter without the addition of fat. According to the authors, the gel formation properties of the serum protein concentrate were related to the denaturation and unfolding of protein chains during thermal treatment. Intermolecular interactions were favored instead of intramolecular interactions, which facilitated the formation of a cohesive protein network, thereby increasing the gel strength and firmness of the products.

On the basis of the main effects analysis in this study, both the higher concentrations of CPI and the higher cooking temperatures increased the gel strength of emulsified sausages prepared with the addition of CPI as a replacement for fat. In this way, frankfurters with a lower fat content could be obtained by choosing formulations with 10% CPI (i.e., completely replacing pork lard in the formulation) and by using cooking at temperatures of 82.5 to 87.8°C.

To test the appropriateness of the model, this was subjected to ANOVA (Table 3). Because $F_{calculated}$ was greater than $5 \times F_{listed}$, we concluded that the regression showed the model (equation 1) was able to represent the experimental data on gel strength in the range of variables evaluated, allowing the development of the response surface presented in Figure 1:

$$\text{gel strength (g·cm)} = 3{,}024.87 + 209.51\ \text{CPI concentration}^2 + 352.9\ \text{temperature}\ (R^2 = 0.85). \quad [1]$$

The deviation percentage between observed values and gel strength results predicted by the model, which was less than 10% in all 11 experiments, confirmed the statistical validity of the model.

Because the second-order model found for variable gel strength was predictive, it was possible to find the optimal working point for the independent variables [42]. Figure 1 shows the interaction between CPI concentration and heating temperature on frankfurter gel strength. The highest gel strength values were obtained with a high CPI concentration and high heating temperature.

According to Estévez et al. [44], differences in textural properties among meat products are normally affected by several factors, such as the formulation, protein functionality, amount of fat, and fat characteristics. Different CPI concentrations tested as a fat replacement in the formulation of chicken frankfurters did not significantly ($P > 0.05$) affect frankfurter firmness or frank-

Table 3. Analysis of variance for the response gel strength at a 90% confidence level[1]

Source of variation	QS	df	QM	$F_{calculated}$	F_{listed}[2]	$F_{list \times 5}$
Regression	1,262,062	2	631,031	22.10	3.11	15.55
Residue	228,411	8	28,551.37			
Lack of fit	165,874	6				
Pure error	62,537	2				
Total	1,490,473	10				

[1]QS = quadratic sum; QM = quadratic media.

[2]From Barros Neto [42].

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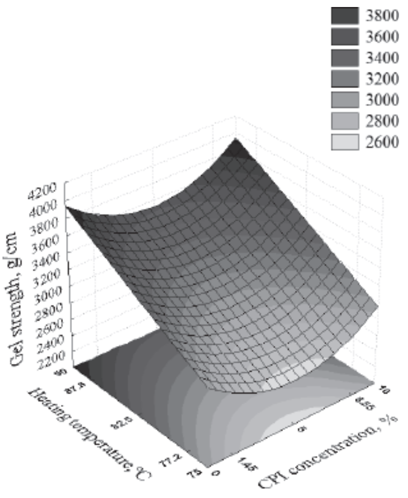

Figure 1. Effect of chicken protein isolate (CPI) concentration and heating temperature on the gel strength of chicken frankfurters when using second-order response surface model coordinates: gel strength (g·cm) = 3,024.87 + 209.51 CPI concentration^2 + 352.9 temperature.

furter breaking force. Moreover, increases in CPI concentration increased the gel strength of the frankfurters. We also noted that an increase in cooking temperature caused an increase in all the analyzed responses. This allowed us to produce frankfurters with a lower fat content by choosing a 10% CPI formulation that completely replaced pork lard from the formulation and by using a cooking temperature of 82.5°C.

Characterization of Raw Material and Low-Fat Frankfurters

The proximate composition of MDM used to prepare the CPI was 62.9% moisture, 21.0% fat, 14.2% protein, and 0.9% ash. The proximate composition of poultry (chicken thigh meat) used to prepare the frankfurters was 74.5% moisture, 20.7% protein, 4.2% fat, and 0.6% ash. These results differed from those reported by Kondaiah and Panda [45] for deboned chicken legs (69.6% moisture, 19.5% protein, 8.8% fat, and 1% ash). Compared on a dry weight basis, the protein content of whole chicken legs was 81.3% and the fat content was 16.4%, whereas the deboned chicken legs had 64.8% protein and 29.2% fat. These differences can be explained by factors that influence meat composition, such as the animal species, age, sex, and diet.

For the wet CPI obtained by the alkaline solubilization process and used as a replacement for fat in frankfurter preparation, the composition was 82.3% moisture, 13.3% protein, 1.4% fat, and 2.8% ash. The high ash content was likely due to salt formation during the solubilization process as a consequence of the addition of the acid and base used for pH adjustment. In addition, small amounts of calcium and collagen derived from mechanically separated meat (**MSM**) must be taken into account. The lipid content was reduced from 56.7% in MSM to 8% in the CPI obtained by alkaline solubilization, an 86% decrease in fat content. The solubilization process yield was 44%. In the alkaline solubilization process for extracting protein from turkey MSM, Liang and Hutlin [26] reported lower values for protein and lipids compared with those in this study. Liang and Hultin [26] obtained protein isolates with 63% protein and 3.2% fat (on a dry weight basis). In this study, the lipid content (on a dry weight basis) was reduced from 49.5 to 3.2% in the protein isolate from turkey MSM, a reduction of about 93%.

The pH value for manually deboned whole chicken legs used to prepare the frankfurters was 6.67 ± 0.01. According to Beraquet [46], chicken breast meat has pH values between 5.8 and 5.9 and chicken leg meat has values between 6.2 and 6.3. These higher pH values may contribute to an increase in microbiological meat perishability. For proteins isolated from chicken MSM by the alkaline solubilization process, the final pH value was 5.36 ± 0.02 because the protein precipitation pH used was 5.4.

Table 4 presents the proximate composition of the experimental frankfurters with the addition of 10% wet CPI, which completely replaced the lard present in the traditional formulation. The experimental frankfurters with added CPI had a high protein content (17.8%) and low fat content (4.4%). When these results were compared with commercial chicken frankfurters that had 13.4% protein and 13.3% fat, the frankfurters with CPI had the advantages of a high protein content and low fat content. The lipid content of the experimental frankfurters was 60% lower than that of the commercial chicken frankfurters because of the complete replacement of lard by CPI in the formulation. Therefore, the frankfurter with the addition of CPI was a low-fat product

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Table 4. Proximate analysis of frankfurters

	CPI[2] addition (10%)		Commercial	
Component,[1] %	Wet basis	Dry basis	Wet basis	Dry basis
Moisture	72.7 ± 0.18[a]	—	66.6 ± 0.04[b]	—
Protein	17.8 ± 0.39[a]	65.1 ± 1.43[A]	13.4 ± 0.06[b]	40.0 ± 0.18[B]
Fat	4.4 ± 0.17[b]	15.9 ± 0.62[B]	13.3 ± 0.05[a]	39.9 ± 0.15[A]
Ash	2.9 ± 0.09[b]	10.5 ± 0.33[A]	3.4 ± 0.04[a]	10.2 ± 0.12[A]
Carbohydrate	2.3 ± 0.16[b]	8.5 ± 0.60[B]	3.3 ± 0.04[a]	9.9 ± 0.12[A]

[a,b]Different small superscripts in the same row indicate significant differences by Student's *t*-test ($P < 0.05$) on a wet weight basis.

[A,B]Different capital superscripts in the same row indicate significant differences by Student's *t*-test ($P < 0.05$) on a dry weight basis.

[1]Results are means of 3 determinations ± SE. Carbohydrate contents were calculated by difference.

[2]CPI = chicken protein isolate.

because the percentages found were in compliance with the Brazilian legislation [47], which defines low-fat products as those showing a reduction of at least 25% in the total caloric value. Madruga et al. [48], in their study on the cholesterol content in low-fat and traditional chicken frankfurters, found 13.8% lipids for traditional frankfurters and 6.2% for low-fat frankfurters.

According to Pietrasik and Duda [8], the fat content is inversely proportional to the moisture content present in frankfurters. In their study, the moisture levels in frankfurters ranged from 58.9 to 68.2% and the fat content ranged from 22.6 to 31.6%, with higher fat values for frankfurters with lower moisture contents. The protein content of their frankfurters prepared with mixes of carrageen and soy protein ranged from 8.8 to 10.5%.

The pH of the experimental frankfurters with added wet CPI was 6.46 ± 0.01. This was similar to the value found by Andrés et al. [22], who reported a pH of 6.17 for a chicken frankfurter with a lower fat content. Pietrasik and Duda [8] found a pH of 6.18 for their frankfurters prepared with pork.

The analyses for *Salmonella*, *Staphylococcus* (coagulase positive), and *E. coli* in the frankfurters were below the limits established by the Brazilian norm RDC no. 12 [49], and the results fell within the standards established by current Brazilian legislation, thus suggesting that the experimental frankfurter processing in this study was performed under adequate hygiene conditions and followed good manufacturing practices.

Interior Frankfurter Color

The color analysis of the experimental chicken frankfurters with 10% added CPI and the commercial frankfurters are presented in Table 5. Lightness values (L*) and the coordinate b* differed ($P < 0.05$) between the 2 products. The experimental frankfurters with added CPI were darker than commercial frankfurters. The commercial frankfurters were more yellow than the experimental frankfurters with added CPI. There was no difference ($P > 0.05$) between the samples for the coordinate a* (redness).

According to Andrés et al. [22], chicken frankfurters prepared with 5% fat had a lightness (L*) value of 82, indicating their frankfurters had a lighter overall color compared with the frankfurters in this study with added CPI as well as with the commercial frankfurters (Table 5). For the coordinate a*, Andrés et al. [22], found a value of 3.1, indicating a slight tendency toward redness development compared with the frankfurters containing CPI in the present study. This difference in redness might be a result of the amount of dye added in the formulation for each product. For the coordinate b*, Pietrasik and Duda [8] reported a value of 11.9, which means their frankfurter showed yellowness when compared with the experimental frankfurters with CPI reported here, possibly because these had a higher fat content. A reduction in the fat level usually favors a darker coloring (redness and low lightness). A redder appearance has been attributed to frankfurters with a low fat content [50–52].

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Table 5. Color parameters of frankfurters

	Color[1]		
Frankfurter	L*	a*	b*
Experimental (CPI[2] addition)	55.29 ± 1.11^b	15.55 ± 0.58^a	6.32 ± 0.28^b
Commercial	64.75 ± 0.33^a	14.68 ± 0.03^a	10.97 ± 0.26^a

[a,b]Different superscript letters in the same column indicate significant differences by Student's *t*-test ($P < 0.05$).

[1]Results are means of 6 determinations ± SE. L* = lightness; a* = redness; b* = yellowness.

[2]CPI = chicken protein isolate.

Sensory Evaluation

Of the 50 judges who participated in the sensory assessment of the experimental frankfurters with added CPI, 52% were men and 48% were women, with ages ranging from 20 to 40 yr old. Among these judges, 40% confirmed they consumed frankfurters on a regular basis. Figure 2 presents the acceptance results of the frankfurters with CPI and the commercial frankfurters.

The frankfurters with CPI had a 66% acceptance rating, which differed ($P < 0.05$) from that of the commercial frankfurters, which obtained a 79.7% acceptance rating. The intent to purchase was higher ($P < 0.05$) for the commercial frankfurters, with 71.9% indicating the intention to purchase the frankfurters with added CPI and 85.8% indicating the intention to purchase the commercial frankfurters. This difference in consumer preference may explained by the composition of the frankfurters because the experimental frankfurters with added CPI can be considered low-fat products compared with commercial chicken frankfurters. Fat is known to contribute to succulence, texture, and aroma in these types of products, and removing fat might result in changes in sensory quality [8]. Cortez-Vega [35], who prepared frankfurters with the addition of chicken surimi, obtained 72.2% acceptance of their product. Lurueña-Martínez et al. [11] studied the effect of replacing pork fat with olive oil on the quality of frankfurters with a low fat content and noted no significant difference between the acceptance of the control product and the frankfurters with a low fat content, including the sample with added olive oil. All analyzed samples had an acceptance index of approximately 80%.

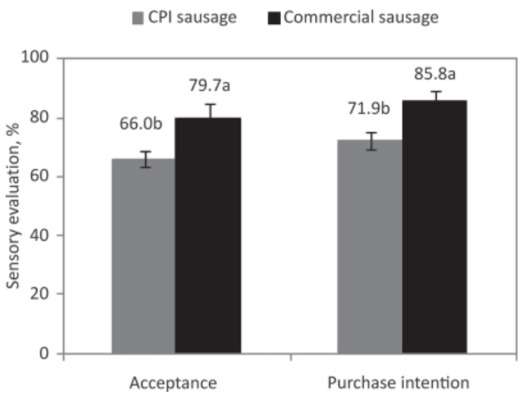

Figure 2. Sensory evaluation of frankfurters. Columns within an evaluation (acceptance and purchase intention) followed by different letters (a, b) indicate significant differences by Student's *t*-test ($P < 0.05$).

CONCLUSIONS AND APPLICATIONS

1. High cooking temperatures between 77.2 and 87.8°C resulted in increases in the firmness, breaking force, and gel strength of the chicken frankfurters.
2. The concentration of CPI did not ($P > 0.05$) affect firmness or breaking force. Gel strength increased with high CPI concentrations in the formulation.
3. On the basis of microbiological assessment, the experimental frankfurters were within the limits required by the Brazilian legislation.
4. The experimental frankfurters with added CPI were darker and less yellow than commercial chicken frankfurters.
5. The product with greater acceptance and greater intention to purchase was the commercial chicken frankfurter. The frankfurter with added CPI (without added pork lard) had a lower lipid content (4.4%) compared with the commercial chicken frankfurter, which had 13.3% fat.

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6. The total replacement of fat by CPI in the experimental frankfurters contributed to the production of a low-fat product with a 60% lower lipid content than the commercial chicken frankfurters while maintaining good textural characteristics.

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