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González Rodríguez, Diana Marcela; Giraldo Lopera, Elizabeth; Restrepo Molina, Diego Alonso
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Efecto del calentamiento pos-elaboración sobre las propiedades texturales de un salchichón estándar que contiene un extensor cárnico para pasta de pollo

Diana Marcela González Rodríguez[1]; Elizabeth Giraldo Lopera[2] and Diego Alonso Restrepo Molina[3]

***Abstract**. The objective of this study was to evaluate the texture properties of a standard sausage that contained a chicken meat extender at a replacement percentage of 35% of the PMD when subjected to postproduction heating. An experimental design that looked at the combination of three extenders in ten mixture points was used; the extenders were composed of fiber, pig skin, and carrageenan, respectively, and there was one product without an extender. Five days after production, the sausages were cooked for two hours at 80°C. An instrumental texture analysis and a firmness and elasticity evaluation were carried out on the recently produced samples and on samples after the subsequent thermal treatments. Hardness, masticability and firmness decreased with the application of the thermal treatments. In addition, a synergistic interaction was seen between the fiber and the carrageenan at the two temperature levels. It was concluded that the fiber, the pig skin and the carrageenan did not exhibit properties that were similar to those of chicken paste because their applications demonstrated a marked decrease in the texture properties, a decrease that was more pronounced when the product was subjected to postproduction heating.*

Key words: Thermal treatment, mechanically deboned chicken, meat derivative, texture.

***Resumen**. Con el objetivo de evaluar las propiedades de textura de un salchichón tipo estándar que contiene un extensor para pasta de pollo (PMD), en reemplazos del 35% de PMD, cuando es sometido a calentamiento térmico después de su elaboración, se realizó un diseño experimental que contempló la combinación de tres extensores en diez puntos de mezcla, cada uno compuesto por fibra, cuero de cerdo y carragenina respectivamente y una formulación sin extensor. Cinco días después de la elaboración, los salchichones fueron sometidos a cocción durante dos horas a 80°C. Un análisis instrumental de textura y evaluación de la firmeza y elasticidad, fue realizado para muestras recién elaboradas y con tratamiento térmico posterior. La dureza, la masticabilidad y la firmeza disminuyeron con la aplicación del tratamiento térmico, adicionalmente se encontró que existe una interacción sinérgica entre la fibra y la carragenina para los dos niveles de temperatura. Se concluye que la fibra, el cuero de cerdo y la carragenina no exhibieron propiedades similares a la pasta de pollo, ya que su aplicación muestra una disminución marcada de las propiedades de textura, disminución aún mayor cuando el producto es sometido a calentamiento pos elaboración.*

Palabras claves: Tratamiento térmico, pollo mecánicamente deshuesado, derivado cárnico, textura.

Sausage is a complete food matrix that contains meat and non-meat proteins, polysaccharides, fats, salts and water, in general terms. The interaction between all these ingredients is what allows for the production of a fine paste with juicy, firm textures (Pouttu and Puolanne, 2004). A thermal treatment is a fundamental step in the production of said product and is carried out with the objective of guaranteeing harmlessness and potentializing all of the chemical reactions that confer the final texture characteristics. However, this process is not only used by the industry, because fine paste sausages are consumed hot, with consumers cooking the products further by frying them, steaming them in water, or microwaving them, which can result in significant changes in the nutritional properties, such as a loss of available amino acids, taste reduction, unsavory odors and bland textures (Kovácsné *et al*., 2005; Miranda *et al*., 2010; Sun *et al*., 2011). These changes are even more significant if the food contains fat or protein extenders because the behavior of non-meat proteins, polysaccharides, and fiber are different when exposed to a new range of temperatures (Rehman and Shah, 2004).

A meat extender is a mixture that substitutes a percentage of raw material present in the formula of a meat product for various reasons; one of which is cost reduction, facilitating the acquisition of quality food for populations with few resources (Petracci *et al*., 2013). Another objective is the development of the industry through gaining new ingredients along with health objectives, such as the reduction of salts and fat in production (Pérez *et al*., 2011; Perisic *et al*., 2013).

[1] Ingeniera Química. Investigadora. Universidad Nacional de Colombia - Sede Medellín - Facultad de Ciencias Agrarias. A.A. 1779, Medellín, Colombia. <dmgonzalr@unal.edu.co>

[2] Ingeniera Química. Asistente de Aseguramiento de la Calidad. CORNARE, km 54 Autopista Medellín-Bogotá. Medellín, Colombia. <elgiraldolo@unal.edu.co>

[3] Profesor Asociado. Universidad Nacional de Colombia - Facultad de Ciencias Agrarias - Departamento de Ingeniería Agrícola y de Alimentos. A.A. 1779, Medellín, Colombia. <darestre@unal.edu.co>

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Proteins, fats and polysaccharides are the principal ingredients in meat production that interact with and have the ability to modify the matrix stability, conferring texture and improving the emulsification ability and the water retention ability (Ackroyd *et al*., 2010; Borneo *et al*., 2010; Choe *et al*., 2013; Deng *et al*., 2011).

Changes in the texture of food that is subjected to a thermal treatment are due to changes that occur in the proteins present in the meat matrix, the myofibrils (myosin and actin) and the stroma (collagen), which have gelification properties, water retention capacity properties, and emulsion formation properties (Kong *et al*., 2008). The production process induces the formation of gels with temperatures that partially denaturalize proteins and give rise to the aggregation process of polypeptide bonds that form the tridimensional complex and chemically and physically capture water and fat; however, irreversible, stable, and firm gels form the myofibrillar proteins, such as myosin, and, in sausage meat extenders that contain non-myofibrillar proteins such as collagen from pig skin, give rise to an irreversible process at the moment the heating process is started again (Liu and Li, 2010). Therefore, the gels lose their structure, losing the retained fat and water and giving rise to unsavory flavors and bland or soft textures that have low acceptance among consumers (Kuwahara and Konno, 2010; Liu *et al*., 2010; Molina *et al*., 2001; Savadkoohi and Farahnaky, 2012).

Postproduction heating processes for meat sausages have not been rigorously studied. Consumers commonly use frying, cooking, and microwaving. These processes denature proteins, diminish the water retention capacity, and modify the gelification behavior of the food matrix, some authors have reported on heat transference models for the interior of cylindrical meat matrixes (Pietromonaco, 2011; Wu *et al*., 2010) and others have reported on the calculation of diffusion coefficients for lyoner-type sausages (Markowski *et al*., 2004). Recently, Heir *et al*. (2013) conducted a study on postproduction thermal treatments with fermented sausages in order to evaluate the effects on the sensorial and microbiological characteristics of the product; parameters such as acceptance, color, salty flavor, fatty flavor and texture were measured and they found that all of the samples presented scores that were similar or superior to those for consumption. This study used 38 panelist for the analysis of the samples after 1, 2, and 4 days of storage and 68 panelist for the same analysis after six weeks of storage. For other food types, such as ricotta cheese, tests have been carried out for postproduction heating by evaluating sensorial and microbiological properties in order to find the temperature/time ratio that extends the shelf-life of the product to 180 days. The researchers concluded that statistically significant differences existed in the sensorial acceptance of the product between the postproduction thermal treatment and the control (Spanu *et al*., 2015). However, in general terms, attention has not been given to the behavior of sausages that are subjected to postproduction heating in terms of the fundamental properties of texture. The common focus of the reviewed researchers was to analyze the microbiological behavior and, in some cases, the sensorial behavior. Therefore, this study aimed to evaluate the texture properties of a standard-type sausage that contained an extender composed of fiber, pig skin, and carrageenan at a chicken paste replacement rate of 35% when said sausage was subjected to postproduction heating.

MATERIALS AND METHODS

The meat protein (10% fat), the bacon, and the chicken paste were acquired from local markets and refrigerated (2 ± 2°C) for 24 hours. The other ingredients, such as the potato starch, protein isolated from soy, 6% Nitrate (mixture of sodium chloride and sodium nitrate), Tecnas condiments (mixture of species), Natural sausage coloring and fiber, pig skin, and carrageenan extenders were supplied by Tecnas S.A.

Experimental design. A mixture design was used (Cornell, 2011). Eleven standard sausage formulation were created following the NTC 1325 standard (ICONTEC, 2008). One formulation without a chicken paste extender (control for all the replacements) and ten formulations with 35% replacement were used. Table 1 and Figure 1 present each of the treatments.

Preparation of the sausages. The sausages were prepared using the industry standards from the pilot plant of the Foundation INTAL (Instituto de Ciencia y Tecnología Alimentaria, Itagüí- Colombia) under the supervision of the innovation and development team of Tecnas S.A. As can be seen in Table 2, eleven standard sausage recipes were created for each level of replacement, following the standard: Norma Técnica Colombiana NTC 1325, of which ten had a chicken paste extender composed of fiber, pig skin, and carrageenan at some proportion and one was the control, which did not have a chicken paste replacement.

The meat and the fat were cut up and put through a grinder with 3 mm discs (Torrey®, Reference M12FS) separately and at refrigerated temperatures with

Table 1. Experimental design: 35% chicken paste extender replacement.

	35% Replacement					
No.	Ingredient (%)			Ingredient (g)		
	Fiber	Pig skin	Carrageenan	Fiber	Pig skin	Carrageenan
1	16.7	16.7	66.7	18.7	18.7	74.7
2	33.3	33.3	33.3	37.3	37.3	37.3
3	100.0	0.0	0.0	112.0	0.0	0.0
4	0.0	100.0	0.0	0.0	112.0	0.0
5	0.0	0.0	100.0	0.0	0.0	112.0
6	50.0	50.0	0.0	56.0	56.0	0.0
7	66.7	16.7	16.7	74.7	18.7	18.7
8	50.0	0.0	50.0	56.0	0.0	56.0
9	0.0	50.0	50.0	0.0	56.0	56.0
10	16.7	66.7	16.7	18.7	74.7	18.7

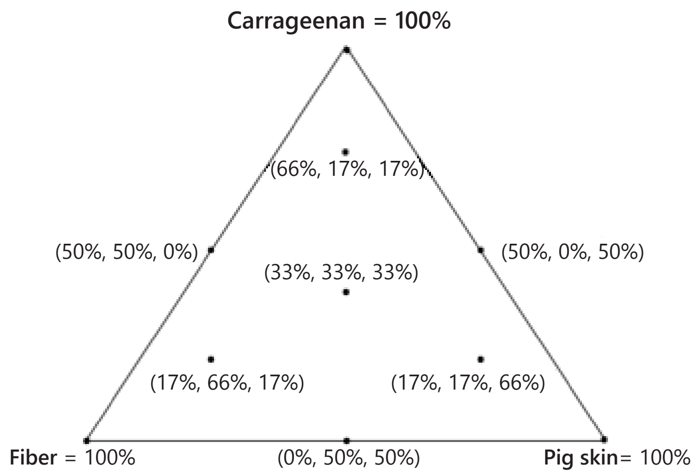

Figure 1. Region of experimental design (carrageenan, fiber, pig skin).

subsequent weighing for the exact quantities of each recipe. Finally, they were refrigerated for later use.

The chicken paste, meat, nitrate, condiment, coloring, and water were homogenized in a cutter (Mainca®, model CM-14). One minute later, the other non-meat proteins were added, including the extender, and, finally, the fat, the starch, the remaining water, and the condiments were added. The entire process was carried out at temperatures below 5°C, maintaining the temperature through the addition of water and ice. After obtaining a homogenized paste, the sausage process was carried out in a PVC case with zero loss and impermeability to water vapor. Sausages of approximately 400 g were obtained, which were subsequently cooked in water at a temperature of 80°C for one hour until the product reached an internal temperature above 73°C. Afterwards, the sausages were cooled with ambient-temperature water until the product reached an internal temperature of or below 30°C, with subsequent placement in a cold room for later analysis.

Table 2. Ingredients for the production of the sausages.

Ingredients	g in 4 kg of standard sausage formulation	
	0% (control)	35%
Beef 90/10 3MM	520	520
MDM	1920	1248
Meat extender	0	112
Pig fat	320	420
Isolated soy protein	80	80
Potato starch	200	200
Curing salt (6% Nitrate)	13.2	13.2
Tecnas Condiment	146	146
Natural coloring p/sausage	16	16
Water	784.8	1244.8

Postproduction thermal treatment. For the postproduction heating stage, a pot was filled with ambient-temperature water and brought to 80°C; afterwards, the sausages were added. The heating process lasted two hours. Subsequently, samples were prepared in order to measure the texture properties.

Instrumental measurement of the texture. The texture profile analysis (TPA) was carried out with a TA-XT Plus texturometer (Stable Micro Systems®). Three samples of each sausage per treatment, cold and hot, were analyzed. Morsels, 20 mm in diameter and 25mm in height, were taken at ambient temperature for the cold treatment and at an approximate temperature of 45°C for the hot treatment, which were axially compressed to 70% of their original height. The deformation-time force curves were obtained using a load cell of 30 kg and pre-test, test, and post-test speeds of 2.0 mm s^{-1}. During the analysis, the following parameters were determined: hardness and masticability; which were obtained with the use of Software Exponent Stable Micro System, version 3.0.5.0. The registered values for each parameter corresponded to the mean of 3 measurements. The firmness and elasticity properties were evaluated. For measuring the elasticity, a uniaxial force was applied to the sample until 10% deformation of its height. The recovered height after releasing this force facilitated the estimation of the elasticity. To measure the firmness, this force was applied until it almost generated sample-rupture by controlling the distance and speed (less that 2 mm s^{-1}). The last four response variables are of interest in the instrumental analysis of texture.

Statistical Analysis. According to the proposed mixture design, a cubic regression model with an intercept and subtracting the mean of each variable was established for each response variable because this allowed for the analysis of the significance of the effects of the treatments in the ANOVA table and for the estimated parameters in the regression model. The data for each measurement of the different treatments were subjected to a one-way analysis of variance ($P \leq 0.1$) and Tukey test. These regression models were used for a response surface Simplex analysis {3,2} with 4 points in the center. All of the analyses were carried out using version 2.15.1 of the statistical program R (2012-06-22) "Roasted Marshmallows" Copyright© (2012).

RESULTS AND DISCUSSION

Instrumental Analysis of the texture. Table 3 presents the results for each response variable: hardness, masticability, firmness, and elasticity, for each level of temperature, cold, and heat. A statistically significant decrease was seen for the hardness, masticability and firmness variables in the recipes that contained an extender level of 35% with respect to the control; a decrease that was more marked when these sausages were subjected to postproduction heating, contrary to the case of the elasticity variable. The quality of the texture was affected when the compositions of protein and fat were decreased and the quantity of water increased, a situation that occurs when a meat sausage is extended. Ayadi *et al*. (2009) demonstrated that, depending on the type of protein that is utilized in the formulation of prepared meats or vegetables, the textural responses of the matrix varied when subjected to diverse thermal interactions. They concluded that firmness, chewability and elasticity can increase or decrease when the primary material that is used is changed. A similar outcome was seen in research done by Sorapukdee *et al*. (2013), which had the objective of evaluating the quality and stability of a pork emulsion in terms of the composition and structure of the muscle and found that a higher quantity of myofibrillar protein resulted in higher stability in an emulsion subjected to a thermal treatment.

Table 3. Parameters evaluated in the Texture profile analysis (TPA) of the standard sausages produced with different extenders and at different temperatures.

Mixture	35% Replacement							
	Hardness (N)		Masticability		Firmness (N)		Elasticity (%)	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
0	46.48 ± 0.69 a	32.22 ± 4.15 a	734 ± 152 a	540 ± 162 a	2.83 ± 0.29 a	2.59 ± 0.23 a	64.90 ± 0.42 a	64.44 ± 2.01 a
1	32.59 ± 6.15 b	20.71 ± 2.88 b	482 ± 160 ab	345 ± 70 ab	2.36 ± 0.29 ab	2.23 ± 0.22 a	64.40 ± 1.43 a	66.01 ± 1.21 a
2	28.39 ± 3.74 b	22.48 ± 3.08 b	404 ± 134 b	321 ± 34 ab	2.04 ± 0.14 b	2.20 ± 0.41 a	65.91 ± 1.44 a	64.07 ± 2.81 a
3	31.80 ± 4.29 b	20.01 ± 3.19 b	377 ± 102 b	243 ± 106 b	2.32 ± 0.16 ab	1.98 ± 0.37 a	65.22 ± 1.20 a	64.05 ± 2.84 a
4	31.38 ± 3.84 b	21.69 ± 3.52 b	492 ± 90 ab	265 ± 92 b	2.52 ± 0.39 ab	2.08 ± 0.35 a	65.53 ± 1.01 a	65.09 ± 2.86 a
5	33.78 ± 4.78 b	22.33 ± 2.41 b	441 ± 148 ab	353 ± 108 ab	2.43 ± 0.35 ab	2.18 ± 0.23 a	63.81 ± 2.32 a	64.06 ± 2.02 a
6	33.01 ± 5.52 b	21.97 ± 2.54 b	614 ± 154 ab	338 ± 38 ab	2.67 ± 0.20 ab	2.23 ± 0.47 a	64.92 ± 0.41 a	64.13 ± 2.06 a
7	34.10 ± 6.21 b	20.08 ± 2.86 b	414 ± 178 b	290 ± 82 ab	2.36 ± 0.55 ab	2.14 ± 0.04 a	65.10 ± 1.22 a	67.22 ± 1.42 a
8	31.98 ± 4.15 b	20.06 ± 4.23 b	455 ± 74 ab	305 ± 170 ab	2.29 ± 0.45 ab	2.14 ± 0.26 a	63.84 ± 1.45 a	66 ± 2.23 a
9	30.11 ± 4.39 b	23.19 ± 3.64 b	417 ± 128 ab	324 ± 84 ab	2.73 ± 0.22 ab	2.07 ± 0.22 a	63.92 ± 1.63 a	66.24 ± 2.46 a
10	29.20 ± 4.88 b	18.14 ± 3.74 b	410 ± 108 b	285 ± 128 b	2.34 ± 0.16 ab	2.18 ± 0.31 a	65.92 ± 0.62 a	67.56 ± 1.62 a

Values with different values in the same column indicate statistically significant differences according to the Tukey test (P≤0.05).

The texture properties were affected by the postproduction heating due to the stability of the gels that were formed by the myofibrillar proteins of the beef and chicken paste (Brenner *et al*., 2009) and by the stroma of the pig skin (Vaquero *et al*., 2006) and gels formed by the carrageenan. The former are irreversible, firm and stable in the presence of temperature changes; the second and third ones are thermo-reversible and can experience changes for retained water, giving rise to bland textures (Cao *et al*., 2012; Liu *et al*., 2010; Sun *et al*., 2011). Carrageenans are used in meat sausages to retain water and form gels in the production process (Thrimawithana *et al*., 2010); however, the behavior of these gels when subjected to a second heating have not been studied in order to evaluate fundamental properties of texture but have been studied in terms of sensorial quality and microbiology. In the present study, the changes caused by the postproduction heating of the food matrix resulted in a destabilization of the structure, giving rise to bland sausage that accumulated water after the process.

There was an important variation in the present study: part of the chicken paste protein was replaced, which is principally formed by myosin, which is responsible for properties such as the water retention capacity, the ability to form gels, and the ability to emulsify, which are seen in the meat matrix (Brenner *et al*., 2009; Cao *et al*., 2012; Raghavan and Kristinsson, 2008), with a combination of three different natural ingredients: fiber, pig skin, and carrageenan. These three ingredients have been widely used as fat extenders and stabilizers in order to confer texture through their reactions with meat protein, to which they have responded positively (Candogan and Kolsarici, 2003; Choe *et al*., 2013; de Moraes *et al*., 2013), favoring the properties of hardness, masticability, and juiciness, among others; however, a contrary behavior was observed in the present study which might have been due to the absence of a percentage of the myofibrillar protein (myosin) due to the replacement percentage of the chicken paste. These extenders did not properly substitute for the myofibrillar protein because the texture properties experienced a marked decrease and, when they were present in meat products, are not stable in postproduction heating treatments.

According to the results, another possible explanation of the decrease in texture properties such as hardness, firmness and, therefore, masticability may be the existence of phenomena, such as lipidic peroxidation, that are responsible for alterations in the interactions present between lipids and proteins, which could modify the structure of formed gels and, for this reason, their stability. A statistical model (equation 1) was created that took temperature into account, finding that the mixture that contained 56 grams of pig skin and 56 grams of carrageenan improved without and with being subjected to a second heating (see Figure 2), which can be explained by the interaction that existed between these ingredients. The temperature had values of 0 when the treatment lacked cooking and 1 when it included cooking.

$$Y = 4.11e^{\wedge}(-0.3) * Fiber - 1.06e^{\wedge}(-0.2) * Skin - 6.53e^{\wedge}(-0.3) * Carrageenan + 5.49e^{\wedge}(-0.5) * Temperature + 6.35e^{\wedge}(-0.4) * Skin * Carrageenan \quad (1)$$

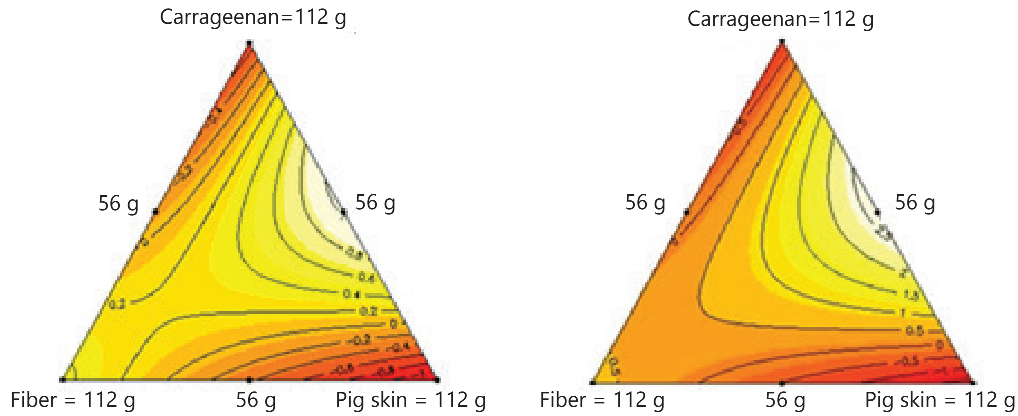

Figure 2. General instrumental response surface analysis estimated for the cold temperature (left) and the hot temperature (right).

Markowski *et al*. (2004) have reported studies on lyoner-type sausages that were geared towards finding the thermal diffusion coefficient in meat matrixes with the objective of evaluating the relevance of antimicrobial treatments carried out on sausages before they reached consumers. Other authors have studied cooking but for legumes, looking at the effect of thermal treatments on insoluble fiber (Rehman and Shah, 2004). Studies have been carried out on domestic cooking methods but with frozen fried foods, such as empanadas (Miranda *et al*., 2010) and hamburgers (Kovácsné *et al*., 2005), in order to evaluate the fatty acid compositions and temperature profiles from the center towards the outside. But, the present results could not be compared with other experiments because similar studies with the same objective have not been carried out.

CONCLUSIONS

The fiber, pig skin and carrageenan, used as chicken paste extenders, did not exhibit properties similar to those of chicken paste; the hardness, masticability and firmness decreased with respect to the sausage that did not contain any replacement; however, the 50/50 pig skin/carrageenan mixture could act better as an extender with a postproduction thermal treatment. Similarly, with an additional postproduction thermal treatment, instability was seen in the matrix, which was reflected in a larger decrease in the previously mentioned properties. Further studies are recommended for the studied ingredients but as meat protein extenders that are evaluated after being subjected to heating processes at the time of consumption.

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