Research article

http://www.revistas.unal.edu.co/index.php/refame

Revista Facultad Nacional de Agronomía

Effect of a total substitution of vegetable protein and phosphates on shrinkage by cooking and purging in chopped york ham

UNIVERSIDAD NACIONAL DE COLOMBIA

Efecto de la sustitución total de la proteína vegetal y de los fosfatos sobre las mermas por cocción y las purgas en jamones de cerdo picados tipo york

doi: 10.15446/rfnam.v73n3.80131

José Alfonso Cardona-Hincapié[1]*, Diego Alonso Restrepo-Molina[1] and Jairo Humberto López-Vargas[1]

ABSTRACT

The trend with the most significant impact on food is currently clean labeling, and meat products are not exempt from it. This trend promotes the elimination of additives of inorganic origin and their replacement by natural ingredients in the formulation of products. In the present work, the effects of the total substitution of polyphosphate and vegetable protein for citric fiber and hydrolyzed pork collagen in chopped pork York ham, with an extension of 52.9% at the end of cooking, were evaluated to achieve clean labeling. Two treatments were performed with two types of brine, which had a citrus fiber A and a citrus fiber B as phosphate replacements. Additionally, as a vegetable protein replacement, the same hydrolyzed pork collagen was used for both treatments. Tumbler massaging was made to allow correcting protein extraction, then it was subjected to heat treatment by immersion in hot water at 80 °C. It was concluded that the ham made with citric fiber B and hydrolyzed pork collagen obtained better results in texture, syneresis, sensory analysis and cooking losses, with no significant differences with the standard.

Keywords:
Brine
Clean labeling
Citrus fiber
Meat products
Polyphosphates

RESUMEN

La tendencia de mayor impacto en alimentos actualmente es la del etiquetado limpio, y los productos cárnicos no están exentos de ella. Esta tendencia lo que promueve es la eliminación de aditivos de origen inorgánico para ser reemplazados por ingredientes naturales en la formulación de los productos. En el presente trabajo, se evaluaron los efectos que tuvo la sustitución total de polifosfatos y proteína vegetal por fibra cítrica y colágeno hidrolizado de cerdo en jamones de cerdo picados tipo york, con una extensión de 52.9% al final de cocción, con el fin de alcanzar la limpieza de la etiqueta. Se hicieron dos tratamientos con dos tipos de salmuera, las cuales tenían como reemplazante de fosfatos, una fibra cítrica A y una fibra cítrica B; adicionalmente como reemplazante de proteína vegetal se utilizó el mismo colágeno hidrolizado de cerdo para ambos tratamientos. Se llevó a cabo masajeo en tombler para permitir correcta extracción de proteína y tratamiento térmico por inmersión en agua caliente a 80 °C. Se concluyó que el jamón al que se le aplicó fibra cítrica B junto con el colágeno hidrolizado de cerdo, obtuvo mejores resultados en textura, sinéresis, análisis sensorial y mermas por cocción, sin presentar diferencias significativas con el control.

Palabras clave:
Salmuera
Etiquetado limpio
Fibra cítrica
Productos cárnicos
Polifosfatos

[1] Facultad de Ciencias Agrarias. Universidad Nacional de Colombia. AA. 1779, Medellín, Colombia.
* Corresponding author: <jacardonah@unal.edu.co>

Received: March 16, 2020; Accepted: July 16, 2020.
Rev. Fac. Nac. Agron. Medellín 73(3): 9333-9340. 2020 ISSN 0304-2847 / e-ISSN 2248-7026

Meat products or cold meat inlay have been designated as "not recommended" foods over time because they contain high levels of fat, sodium and additives. Currently, these products are evolving in accordance with global policies on food, health and nutrition, which establish clear guidelines for food production aimed at making them safer for consumer's health (Moreno, 2013).

Globally, processed meat products (PMP) aim at reducing concentrations of sodium, fat, nitrite, phosphates from meat formulations since they can contribute to developing non-communicable diseases (Restrepo and López, 2013), which, according to the World Health Organization, are equivalent to 71% of the deaths in the world (WHO, 2018). The European Food Safety Authority (EFSA) recommends not exceeding the doses required in meat formulations because this can trigger problems related to cancer (ANS, 2010).

Currently, the industry is working on changing this concept with consumer education and product proposals that, from their design, are intended to be healthier; controlling, for example, the amount of fat they contain, finding products with up to 99% fat-free (Moreno, 2013). Several techniques have been developed for the replacement of phosphates, ranging from partial or total elimination, for the application of new technologies such as high pressures to avoid the use of this additive. A big obstacle presented by the use of these technologies is related to meat protein functional properties because phosphates help improve texture, cohesiveness, water holding, and to reduce salt concentrations (Resconi *et al.*, 2015). Other controversial additives, like nitrates, are a multifunctional ingredient in matured and cooked meat products such as minced or York ham; however, it performs its functions at extremely low concentrations (Restrepo, 2018). This additive is responsible for the color, odor, and cured taste (Honikel, 2004) to protect the flavor avoiding rancidity (as an antioxidant) (Sebranek, 2009) and among other functions to inhibit microbial growth of anaerobic bacteria, especially *Clostridium botulinum*. It also contributes to the control of other pathogenic microorganisms such as *Listeria monocytogenes* (Restrepo, 2018).

Regarding the application of starches in meat products, different concentrations and cooking temperatures can be used, allowing the retention of moisture and providing other characteristics that help meat products functionality such as texture, sensory characteristics, color, among others (Resconi e*t al.*, 2016). Therefore, different origin starches are being used to replace phosphates in order to analyze their behavior in the meat matrix and establish if they comply with the parameters to be classified as clean labeling.

The rejection or acceptance of food is directly related to the ingredients specified on the label, so those that are more familiar to consumers tend to be chosen. In the case of vegetable protein, the discrimination in the purchase of products containing it is due to the excess of chemical origin ingredients present on the label. So, techniques for the inclusion of other materials of animal origin such as hydrolyzed collagen, an emulsion of skins, and materials coming from the smooth muscles of different species are being developed, which are easy for consumers to read in the list of ingredients, as well as to improve flavor and add succulence to meat products (Bueno, 2008).

Collagen, being a product of animal origin, plays an important role in human diet due to its content of some essential amino acids and for its contribution to the prevention of some joint diseases (Sousa *et al.*, 2017). The addition of collagen in meat formulations can provide additional biological value and interesting sensory attributes for consumers (Neklyudov, 2003). In fact, this material has been incorporated into this type of derivatives in order to improve water holding capacity and increase the protein content of different formulations (Prestes *et al.*, 2012).

As part of this new trend to provide more "natural" foods called "Clean Labeling", there is the idea including healthier additives in the elaboration of York hams, without affecting the sensorial image the consumer has of this type of product (Tarte, 2009).

The objective of this research is to evaluate the effect of the total substitution of vegetable protein and phosphates for hydrolyzed collagen and citric fibers, respectively, on losses by cooking and syneresis of a chopped York ham, in order to achieve a product with partial clean labeling.

MATERIALS AND METHODS

Ham preparation

Two formulations of cooked cured ham with a 52.9% extender and water added were prepared from a standard formulation (Table 1). Polyphosphate was replaced by two different commercial citrus fibers, citrus fiber A and Citrus fiber B, whereas vegetable protein was replaced by dehydrated pork collagen. Citrus fiber A contains guar gum, different from citrus fiber B that contains commercial hydrolyzed collagen (commercial name ScanPro T92) as main component.

Meat preparation began with pH measurement to determine if there was a pale, soft and exudative meat (PSE); six different measurements were made in the different muscles that make up the leg. Once this defect was ruled out, meat was cut (equivalent to 80% of the total meat) in pieces of 50 g to be later tenderized twice with the JACCARD equipment. The remaining 20% of meat was passed through the 22-liter EG - 22 Al 1HP grinder and cut using an 8 mm disc. TECNAS Company provided the additives (including pork meat) mentioned in Table 1.

Table 1. Formulations used for ham preparation.

Ingredient	Formulation A	Formulation B	Control
		(%)	
Leg in pieces of 50g	56.87	56.87	48
Ground leg 8 mm disc	14.22	14.22	12
Hydrolyzed collagen	0.4	0.4	0
Ham flavoring	0.4	0.4	0.3
Sodium erythorbate	0.05	0.05	0.05
Colorant	0.025	0.025	0.03
Citrus fiber A	1	0	0
Citrus fiber B	0	1	0
Sodium lactate	1.9	1.9	2.5
Refined salt	1.25	1.25	1.2
Carrageenan	0.7	0.7	0.7
Potato starch	4	4	4
Curing salt	0.325	0.325	0.35
Ice/water	18.825	18.825	27
Milk protein	0	0	0.5
Vegetal protein	0	0	3
Sodium tripolyphosphate	0	0	0.4
Smoke powder	0	0	0.05

Initially, curing salt was incorporated into cold water by following the limits established by ICONTEC (Colombian Institute of Technical Standars) through NTC 1325, completely dissolved and then, refined salt was added. Subsequently, phosphates or citrus fibers A or B were added as appropriate. Color, sodium lactate, hydrolyzed collagen or vegetable protein were added to the water according to the formulation, ham flavoring, and finally, carrageenan and potato starch were mixed. After preparing the brine, it was incorporated along with the meat to the TORREY vacuum tumbler MV25, allowing the meat matrix to absorb all solids and liquids. Mechanical and vacuum mixing were carried out for 1 h, allowing to stand for 30 min; this process was performed twice. After this time, the dough was removed from the equipment and left in refrigeration at 3 °C for 24 h. Then, an additional mechanical blend was performed in a CI TALSA mixer with a capacity of 10 L for 15 min, after was taken to heat treatment.

For cooking, a CI TALSA kettle with a capacity of 200 L was used, with the aim of cooking by immersion for 2.5 h. Conditions were: hot water at a temperature not higher than 80 °C (but higher than the internal) and until reaching a core temperature of 72 °C. Once the cooking was finished, the cooked ham was removed from hot water, leaving it to rest for 2 h, subsequently, it was left in refrigeration at a temperature of 3 °C for 24 hours, reaching a final extension of 52.9%. Finally, the mass of processed ham was determined, chopped and packed in FE225557 vacuum plastic bags that fulfill the Colombian Technical Norm NTC171 (size 18×22 cm) with weights between 250 g and 280 g.

Syneresis evaluation

Samples were taken in triplicate for each treatment on days 0 and 10. Syneresis was measured by means of a SHIMADZU electronic balance, taking the initial weight of ham on day 0 and the final weight on day 10, after removing supernatant fluid. Syneresis results are presented as a percentage of its initial weight (Lowder *et al*., 2011; Prahbu, 2004).

Texture analysis

The analysis of compression force measurement was performed in a texture analyzer TA-XT2i (Stable Micro Systems). The Warner-Bratzler blade attachment was used with the following specifications: Pre-test speed 2.00 mm s^{-1}, test speed 2.00 mm s^{-1}, post-test speed 1.5 mm s^{-1}, with a distance of 40.0 mm and a cell of 50 kg. Samples of ham were cut into 4 cm wide by 10 cm long strips in order to carry out five repetitions for each treatment, looking for the maximum point of force exerted by the equipment for ham break (Prestes *et al*., 2012).

Sensory evaluation

A hedonic test was carried out with a panel of expert technicians composed of 16 people aged between 25 and 35 years, who were given three coded samples (M1 - control, M2 - citrus fiber A and hydrolyzed pork collagen, and M3 - citrus fiber B and hydrolyzed pork collagen) previously. They were asked to rate each of the products on a scale from 1 to 9, where 9 corresponded to "I like it very much," and 1 corresponded to "I dislike it a lot."

Statistical analysis

Fisher's test was implemented for analysis. A two-by-one factorial design was carried out, where phosphates were replaced by citrus fiber A and B, and vegetable protein by dehydrated pork collagen. This design was analyzed by statgraphics XVI statistical software, and ANOVA. Results were considered significant when $P<0.05$.

RESULTS AND DISCUSSION

Syneresis evaluation

Syneresis presented significant differences ($P<0.05$) in all treatments, as shown in Table 2. Phosphates, protein, and carrageenan help retain water in the first days of the manufactured ham, but over time, the links between hydrocolloids and meat protein become weak, letting the moisture out of the product. Treatments with citrus fiber A and B showed more stability in the water holding capacity because, once cooked and cooled, the hydrolyzed pork collagen forms a gel matrix able to trap free water strongly, as mentioned by Schilling *et al*. (2003) and Lowder *et al.* (2011) in their investigations.

Table 2. Syneresis in York hams made with and without vegetable protein and phosphates on day 10.

Sample	Initial weight	Final weight	Syneresis	Syneresis
	(g)			(%)
Control	269.33±5.13 a	263.00±5.57 a	6.33 a	2.41 a
Citrus fiber A	280.00±5.65 b	275.50±6.36 b	4.50 b	1.63 b
Citrus fiber B	244.33±8.02 c	241.67±8.08 c	2.67 c	1.10 c

Different letters in the same column denote significant differences between the York ham formulations, based on Fisher's test ($P<0.05$).

Aguilar (2011), in their study of a citrus fiber added to cooked ham, found that when replacing carrageenan with citrus fiber, it presented a greater capacity to interact with fibrillar structures of meat, forming a homogeneous network that traps high concentrations of water, being an efficient substitute for carrageenan in this type of meat product.

Data found in this study resemble those obtained by Resconi *et al.* (2016), who used rice and potato starches as partial phosphate replacements; they found that cooking loss was reduced in hams containing starches and minimal amounts of sodium tripolyphosphate. They also mentioned that the loss by cooking and positive acceptance by the sensory panel is achieved with the inclusion of 2% starch.

This study showed that when replacing polyphosphates with citrus fiber B, and vegetable protein with hydrolyzed pork collagen, there was greater moisture retention due to the low percentage of syneresis on day 10, compared to the other two treatments, thanks mainly to the interactions of these two ingredients with the specific meat proteins. The citrus fiber, a polysaccharide extracted from citrus peel, is used in meat products due to the technological functions it provides, such as water-holding, helping to improve the meat emulsion; it also reduces weight loss from cooking and dripping during the shelf life. Furthermore, the addition of fiber helps to preserve the juiciness of the product, and since the fiber flavor is neutral, it maintains the sensory properties of the product (Henning *et al.*, 2016; Kim and Paik, 2012; Mehta *et al.*, 2015; Verma and Banerjee, 2010). According to the above mentioned, it is demonstrated the superb performance and the correct interaction that is presented with myofibrillar proteins, allowing optimal results in the meat emulsion.

The hydrolyzed collagen of pork is a material obtained from different sources, among others, the skin. Its cohesive property is because of its chemical composition, which allows an interaction protein-protein with better performance. Studies have shown that using this material for better gel strength, helps retain more free water content over time (Schilling *et al*. 2003; Lowder *et al.* 2011).

Texture analysis

The three treatments have significant differences ($P<0.05$), being citric fiber B, the one that reaches higher values after the control. On day 0, the force in the control was 28.08 N and 21.35 N on day 10. Citrus fiber A showed an average force of 12.58 N and 16.02 N on days 0 and 10, respectively, while citrus fiber B reached 19.75 N and 15.56 N on day 0 and 10, approaching slightly more the data produced by the ham control. The results are shown in Table 3.

Table 3. Texture of hams made with and without phosphates and vegetable protein on days 1 and 10.

Samples	Day 1			Day 10		
	Force (N)	Distance (mm)	Time (s)	Force (N)	Distance (mm)	Time (s)
Control	28.08±2.14 a	4.65±0.08 a	4.65±0.08 a	21.35±2.94 a	4.62±0.11 a	4.62±0.11 a
Citrus fiber A	12.58±2.79 b	3.90±0.22 b	3.90±0.22 b	16.02±6.19 b	4.68±0.51 b	4.68±0.51 b
Citrus fiber B	19.75±4.34 c	4.20±0.11 c	4.20±0.11 c	15.56±6.12 c	3.92±0.29 c	3.92±0.29 c

Different letters in the same column denote significant differences between the York ham formulations, based on Fisher's test ($P>0.05$).

Citric fiber A presented a different behavior regarding the control and citric fiber B, showing a greater cutting force 10 days after the ham was elaborated, while control ham and the one containing citric fiber B decreased this parameter over time.

The components of citric fibers are hemicellulose, cellulose, pectin, lignin, oligosaccharides, gums, and waxes (Trowell *et al*., 1985). Guar gum, a seed extract of *Cyamopsis tetragonolobus* (leguminous plant) (Prestes *et al*., 2012), is a component of citrus fiber A. It can contribute to the water-holding, as well as improve texture in meat products; therefore, it allows establishing that the loss of humidity and force on day 10, is due to the presence and interaction of this gum in citrus fiber A.

In the present study, treatments with citrus fibers produced lower values than the control, with respect to the force of the attachment used to cut ham slices, an analysis that agrees with studies conducted by Han and

Bertram (2017) and Verma *et al.* (2010), which found a decrease in hardness of canned products added with dietary fibers. They informed that dietary fiber in meat products interrupts the formation of protein-water or protein-protein gel, thus decreasing the resistance of gel in meat products, leading to the conclusion that poor interaction between these compounds led to softening the texture (Choe *et al.*, 2018).

According to Pereira *et al.* (2011), the addition of hydrolyzed pork collagen in fine-grained products, allows the increase in water-holding, chemically immobilizing it through a protein matrix, which swells once it makes contact with water. In addition, collagen fibers and the cohesion of the dough contribute to the final product firmness (Sousa *et al.*, 2017). In similar studies, Choe *et al.* (2013) found how pork skin collagen together with wheat fiber influences hardness in fine-grained products because the hardness increases as collagen increases its presence in this type of meat, requiring more energy to chew it.

On the other hand, Resconi *et al.* (2015) showed that hardness, cohesiveness and gumminess decreased as rice starch was incorporated, what agrees with the present study. Previous investigations (Motzer *et al.*, 1998; Schilling *et al.*, 2003) have reported a reduction in hardness, chewiness and cohesion when including starch in cooked hams; these effects were attributed basically to the moisture retention capacity of starch. Also, as phosphates are incorporated, elasticity increases, while hardness and gumminess reduce their values. The presence of phosphates increases the ionic strength of the extraction solution, which favors, even more, the availability of fibrous proteins to fulfill different quality functions.

Sensory evaluation

Significant differences were found among the three treatments ($P<0.05$) regarding the acceptability by panelists (Figure 1). The treatment containing citrus fiber A obtained the lowest rating according to experts' perception, who described a residual flavor in the ham piece as well as some unpleasant aspects. The treatment with citrus fiber B, obtained higher scores in the evaluation of product acceptance, with pleasant attributes according to 60% of attendees to the test. When related to the applied texture test, this treatment presented greater force used by the equipment to cut in ham slices, characteristic similar to that described by experts when giving their appreciation about the texture of the product.

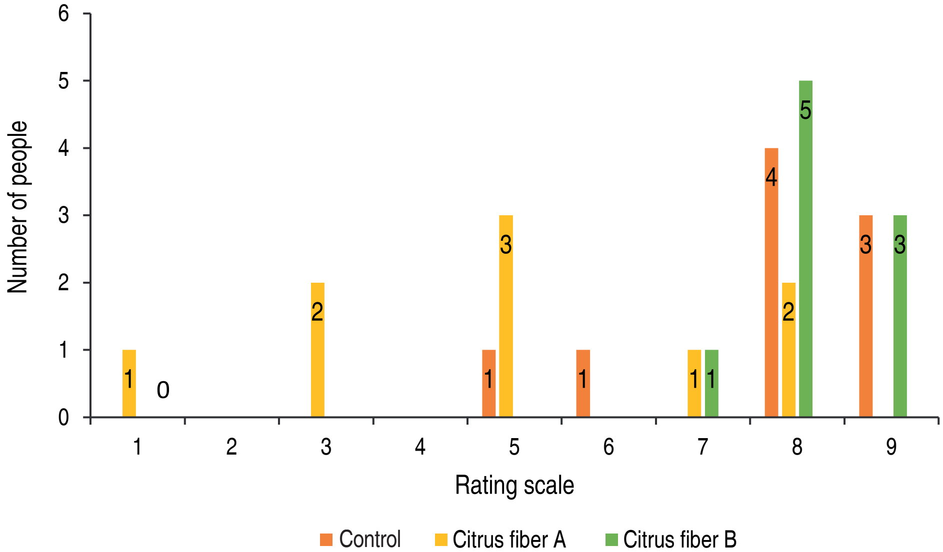

Figure 1. Sensory evaluation

In previous research, Youssef and Barbut (2011) found that Guar gum has the ability to reduce the concentration of myoglobin in meat, which is why products containing this ingredient in their formulation become more opaque, generating less acceptance in consumers.

Meanwhile, Sousa *et al*. (2017) showed similar values in the sensory test for Frankfurt sausages to which hydrolyzed collagen was applied; regarding the control, they did not differ in appearance, aroma and general acceptance when fat was substituted for hydrolyzed collagen, even when its highest concentration was incorporated. Méndez-Zamora *et al*. (2015) also replaced pork fat with collagen in sausages, found that said replacement had a greater effect on aroma and general acceptability, improving the formula of this product, concluding this way is a very interesting and viable alternative to reduce, not only fat but some other ingredients in different meat products.

For Tomaschunas *et al*. (2013), sausages to which citrus fiber was added have the potential to increase consumers' acceptability by comparing them with other products with similar characteristics, due to the interaction they generate with meat proteins, giving them a better texture. A result very similar to that obtained in the present study, where treatment with citrus fiber B (only citrus extracts), obtained the better qualification, even than the control.

In low-fat, dry-fermented sausages, orange-orange fiber had better results compared to cereal fibers and other fruits, with sensory scores similar to those of conventional sausages (García *et al*., 2002; Powell, 2017).

CONCLUSIONS

Results obtained in variables such as syneresis, sensory analysis and texture tests for treatments with citrus fiber A and B showed significant differences with the control (P<0.05), indicating that some of its components were not compatible with meat protein; the treatment with citrus fiber B presented acceptability in texture and sensorial attributes. The total replacement of the vegetable protein as well as phosphates in York hams generates an acceptable product to the consumer, showing sensory characteristics similar to those presented by a conventional product with chemical additives in its formulation. Citric fiber and hydrolyzed pork collagen allow starting partially clean labeling for this type of product. Further studies are required in order to eliminate other additives and thus establish total clean labeling.

REFERENCES

Aguilar JA. 2011. Efecto de la utilización de bagazo de naranja como extensor funcional sobre las propiedades fisicoquímicas y texturales de jamón cocido. Nacameh 5(2): 27–39. doi: 10.24275/uam/izt/dcbs/nacameh/2011v5n2/Aguilar

ANS - EFSA Panel on Food Additives and Nutrient Sources added to Food. 2010. Statement on nitrites in meat products. EFSA Journal 8(5): 1538. doi: 10.2903/j.efsa.2010.1538

Bueno RVCC. 2008. Efeito da fibra de colageno na qualidade funcional de "cooked frozen beef" (Tesis de maestria). Universidade Estadual de Campinas. Campinas, Brasil. 107 p. http://repositorio.unicamp.br/jspui/handle/REPOSIP/255342

Choe JH, Kim HY, Lee JM, Kim YJ and Kim CJ. 2013. Quality of frankfurter-type sausages with added pig skin and wheat fiber mixture as fat replacers. Meat Science 93(4): 849–854. doi: 10.1016/j.meatsci.2012.11.054

Choe JH, Lee JM, Jo K, Jo C, Song M and Jung S. 2018. Application of winter mushroom powder as an alternative to phosphates in emulsion-type sausages. Meat Science 143: 114–118. doi 10.1016/j.meatsci.2018.04.038

García ML, Dominguez R, Galvez MD, Casas C and Selgas MD. 2002. Utilization of cereal and fruit fibres in low fat dry fermented sausages. Meat Science 60(3): 227–236. doi: 10.1016/S0309-1740(01)00125-5

Han M and Bertram HC. 2017. Designing healthier comminuted meat products: Effect of dietary fibers on water distribution and texture of a fat-reduced meat model system. Meat Science 133: 159–165. doi: 10.1016/j.meatsci.2017.07.001

Henning SSC, Tshalibe P and Hoffman LC. 2016. Physico-chemical properties of reduced-fat beef species sausage with pork back fat replaced by pineapple dietary fibres and water. LWT 74: 92-98. doi: 10.1016/j.lwt.2016.07.007

Honikel KO. 2004. Curing Agents. pp. 195 - 201. In: Jensen WK, Devine C and Dikeman M (eds.). Encyclopedia of meats sciences. Second Edition. Elselvier, Oxford. 1712 p.

ICONTEC - Instituto Colombiano de Norma técnica. 2008. Industrias Alimentarias. Productos cárnicos procesados no enlatados. NTC 1325, quinta actualización. Colombia.

Kim HJ and Paik HD. 2012. Functionality and application of dietary fiber in meat products. Korean Journal for Food Science of Animal Resources 32(6): 695-705. doi: 10.5851/kosfa.2012.32.6.695

Lowder AC, Goad CL, Lou X, Morgan JB and Dewitt CAM. 2011. Evaluation of a dehydrated beef protein to replace sodium-based phosphates in injected beef strip loins. Meat Science 89(4): 491–499. doi: 10.1016/j.meatsci.2011.05.013

Mehta N, Ahlawat SS, Sharma DP and Dabur RS. 2015. Novel trends in development of dietary fiber rich meat products—a critical review. Journal of Food Science and Technology 52(2): 633-647.

doi: 10.1007/s13197-013-1010-2

Méndez-Zamora G, García-Macías JA, Santellano-Estrada E, Chávez-Martínez A, Durán-Meléndez LA, Silva-Vásquéz R and Quintero-Ramos A. 2015. Fat reduction in the formulation of frankfurter sausages using inulin and pectin. Food Science and Technology 35(1): 25–31. doi: 10.1590/1678-457x.6417

Moreno S. 2013. Composición en grasa total y especialmente en ácidos grasos "trans" en productos de alimentación infantil y juvenil (Tesis de doctorado). Universidad Conplutense de Madrid, Madrid, España. 274 p. https://eprints.ucm.es/22406/

Motzer EA, Carpenter JA, Reynolds AE and Lyon CE. 1998. Quality of Restructured Hams Manufactured with PSE Pork as Affected by Water Binders. Journal of Food Science 63(6): 1007–1011. doi: 10.1111/j.1365-2621.1998.tb15843.x

Neklyudov AD. 2003. Nutritive Fibers of Animal Origin: Collagen and Its Fractions as Essential Components of New and Useful Food Products. Applied Biochemistry and Microbiology 39(3): 229–238. doi: 10.1023/A:1023589624514

Pereira AGT, Ramos EM, Teixeira JT, Cardoso GP, Ramos ALS and Fontes PR. 2011. Effects of the addition of mechanically deboned poultry meat and collagen fibers on quality characteristics of frankfurter-type sausages. Meat Science 89(4): 519–525. doi: 10.1016/j.meatsci.2011.05.022

Powell MJ. 2017. Physical and chemical effects of citrus fiber as a natural alternative to sodium tripolyphosphate in uncured all-pork bologna and oven-roasted turkey breast (Master's thesis). Iowa State University. Iowa, United States. 105 p. doi: 10.31274/etd-180810-5221

Prahbu GA, Doerscher DR and Hull DH. 2004. Utilization of Pork Collagen Protein in emulsified and whole muscle meat products. Journal of Food Science 69(5): C388-C392 doi: 10.1111/j.1365-2621.2004.tb10703.x

Prestes RC, Carneiro EBB and Demiate IM. 2012. Hydrolyzed collagen, modified starch and guar gum addition in turkey ham. Ciência Rural 42(7): 1307–1313. doi: 10.1590/s0103-84782012005000037

Resconi VC, Keenan DF, Gough S, Doran L, Allen P, Kerry JP and Hamill RM. 2015. Response surface methodology analysis of rice starch and fructo-oligosaccharides as substitutes for phosphate and dextrose in whole muscle cooked hams. LWT - Food Science and Technology 64(2): 946–958. doi: 10.1016/j.lwt.2015.06.053

Resconi VC, Keenan DF, García E, Allen P, Kerry JP and Hamill RM. 2016. The effects of potato and rice starch as substitutes for phosphate in and degree of comminution on the technological, instrumental and sensory characteristics of restructured ham. Meat Science 121: 127–134. doi: 10.1016/j.meatsci.2016.05.017

Restrepo CM y López DP. 2013. Embutidos: evolución y proyección de un mercado cambiante. En: Tecnas S.A., http://tecnas.com.co/embutidos-evoluci%C3%B3n-y-proyecci%C3%B3n-de-un-mercado-cambiante Consulta: agosto 2018.

Restrepo DA. 2018. Ingredientes y aditivos empleados en la industria cárnica: Nuevas alternativas. pp. 158-159. En: La carne: ciencia, tecnología y salud. Primera edición. Editores Publicidad S.A.S., Medellín. 440 p.

Schilling MW, Mink LE, Gochenour PS, Marriott NG and Alvarado CZ. 2003. Utilization of pork collagen for functionality improvement of boneless cured ham manufactured from pale, soft, and exudative pork. Meat Science 65(1): 547–553. doi: 10.1016/S0309-1740(02)00247-4

Sebranek JG. 2009. Basic curing ingredients. pp. 1 - 23. In: Tarté R (ed.). Ingredients in meats products: Properties, functionality and applications. Springer, New York. 432 p.

Sousa SC, Fragoso SP, Penna CRA, Arcanjo NMO, Silva FAP, Ferreira VCS, Barreto MDS and Araújo ÍBS. 2017. Quality parameters of frankfurter-type sausages with partial replacement of fat by hydrolyzed collagen. LWT - Food Science and Technology 76(Part B): 320–325. doi: 10.1016/j.lwt.2016.06.034

Tarte R. 2009. Ingredients in Meat Products: Properties, Functionality and Applications. Springer, New York. 419 p

Tomaschunas M, Zörb R, Fischer J, Köhn E, Hinrichs J and Busch-Stockfisch M. 2013. Changes in sensory properties and consumer acceptance of reduced fat pork Lyon-style and liver sausages containing inulin and citrus fiber as fat replacers. Meat Science 95(3): 629–640. doi: 10.1016/j.meatsci.2013.06.002

Trowell H, Burkitt D and Heaton K. 1985. Definitions of dietary fibre and fibre-deplered foods and disease. London: Academic press. Meat Sciense 157(2): 107883. doi: 10.1016/j.meatsci.2019.107883

Verma AK, Sharma BD and Banerjee R. 2010. Effect of sodium chloride replacement and apple pulp inclusion on the physico-chemical, textural and sensory properties of low fat chicken nuggets. LWT - Food Science and Technology, 43(4): 715–719. doi: 10.1016/j.lwt.2009.12.006

Verma AK and Banerjee R. 2010. Dietary fibre as functional ingredient in meat products: a novel approach for healthy living—a review. Journal of Food Science and Technology 47(3): 247-257. doi: 10.1007/s13197- 010-0039-8

WHO - World Health Organization. 2018. Noncommunicable diseases. In: http://www.who.int/es/news-room/fact-sheets/detail/noncommunicable-diseases Accessed: August 2018.

Youssef MK and Barbut S. 2011. Effects of two types of soy protein isolates, native and preheated whey protein isolates on emulsified meat batters prepared at different protein levels. Meat Science 87(1): 54–60. doi: 10.1016/j.meatsci.2010.09.002