v. 4, n. 16, 2024

Journal of Agricultural Sciences Research

Acceptance date: 16/12/2024

EFFECT ON THE PHYSICOCHEMICAL PROPERTIES OF THE ADDITION OF FAT REPLACERS AND EMULSIFYING AGENTS IN SAUSAGES

Gutierrez-Torres, Martha Paola
Tecnológico Nacional de México-Instituto Tecnológico Superior del Oriente del Estado de Hidalgo, Apan, Hidalgo, México
https://orcid.org/0009-0007-0411-3634

Estrada-Fernandez, Ana Guadalupe
Tecnológico Nacional de México-Instituto Tecnológico Superior del Oriente del Estado de Hidalgo, Apan, Hidalgo, México
https://orcid.org/0000-0003-2213-4758

Mendoza Mendoza, Bethsua
Tecnológico Nacional de México-Instituto Tecnológico Superior del Oriente del Estado de Hidalgo, Apan, Hidalgo, México
https://orcid.org/0000-0001-9332-1919

Romero-López, María del Rosario
Tecnológico Nacional de México-Instituto Tecnológico Superior del Oriente del Estado de Hidalgo, Apan, Hidalgo, México
https://orcid.org/0000-0001-8121-8893

All content in this magazine is licensed under a Creative Commons Attribution License. Attribution-Non-Commercial-Non-Derivatives 4.0 International (CC BY-NC-ND 4.0).

Abstract: Sausages are a homogeneous mixture of fats, water and protein, which include spices to give a characteristic flavor, and are introduced into a natural or artificial edible casing; one product that stands out in this group is York or cooked ham, which contains nitrites, fat, protein and spices according to the type of ham.This review contemplates the effect of adding additives to improve the nutritional contribution of these meat derivatives as a strategy for improving their physical, chemical and sensory characteristics, in the specific case of the incorporation of modified starch and emulsifying agents that enhance flavor, color and texture, but with a lower fat content. Therefore, it is necessary to know the function of physically modified starches whose application is as a gelling agent, which could derive as a source of soluble fiber and influence sensory characteristics such as juiciness, while the application of emulsions as a fat substitute can better preserve the sensory and physicochemical properties in sausages. The objective is to analyze the effect on the sensory and textural properties of the final product.
Keywords: Cooked ham, Modified starch, Emulsions, Fat substitution.

INTRODUCTION

Sausages are meat products that have been processed and cured, widely consumed in various cultures around the world. These foods, including varieties such as ham, sausages, chorizos and salami, are characterized by their distinctive flavor, versatility in the kitchen and ease of preservation. They are consumed by the general population, mainly by adults and children. Texture and sensory properties are critical determinants in the acceptance and preference of meat products, particularly in the case of cooked ham. The importance of texture lies in its capacity to influence the perception of quality and freshness of the product, aspects which, as stated by Pott *et al.* (2018), have an impact on consumer liking, leading to future purchase.

One option of additives for texture modulation is the use of modified starches, among these are those that by this process form resistant starch, which has a higher portion of amylose, which allows having a compact structure and therefore less apt to enzymatic hydrolysis during the human digestive process, some of the technological properties are to act as a stabilizer, gelling agent, reduces agglomeration, improves viscosity, consistency, is stable at pH less than 4.5 and at elevated temperatures (greater than 90°C) (Villarroel *et al.,* 2018).

The incorporation of modified starch in the formulation of cooked ham has been considered a promising strategy to improve water retention, which has an important impact on the texture of the final product. According to Fennema (2017), the use of modified starch increases the stability of the product allowing it to retain its moisture content, which is related to juiciness and pleasant flavor at the tasting stage. This ability to retain water is essential not only to provide optimal organoleptic characteristics of ham, but also to prolong its shelf life, resulting in a reduction of food waste, in addition to more efficient management of the supply chain, so it is used in a wide range of food as in the meat, dairy and fermented food industries, including as fat substitutes.

Some studies on the partial substitution of fat in sausages were carried out with chickpea flour in sausages in proportions of 20, 50 and 75%, resulting in a reduction of fat from 11 to 34%. However, negative impacts were reported on organoleptic properties such as bromatological properties, alterations in texture, juiciness of the product, proteolysis and acidification, resulting in undesirable flavors and odors (Gutiérrez and Siche, 2022);

Another study indicates that the substitution by addition of a Konjac gel at 50 and 91% showed a decrease in fat content up to 3%, in addition to slowing down the degradation process of the product (prolongation of shelf life), having as a counterpart influencing the acidification of pH, changes in color with a deficit in the stability of the emulsion, while in a test with algae at 3%, it is indicated that it allowed a stabilization of the emulsion in the final product (Quitral *et al.*, 2019).

Growing health concerns have led consumers to purchase products with lower fat content. In this sense, fat substitution by means of emulsions represents a viable solution. García *et al.* (2019) indicate that the decrease in fat in meat products is not only due to consumption trends, but also means a challenge not to affect the organoleptic properties of meat derivatives. Emulsions, therefore, could be a viable option for improving or enhancing flavor and texture in comparison with a product added only with fat, thus opening up a field for the development of healthy products.

In addition, sensory evaluation becomes an essential component in the development of these innovative products. As Stone (2020) points out, sensory evaluation makes it possible to determine consumer preferences and ensure that consumer expectations are met. Through a detailed analysis of sensory characteristics, it is possible to obtain information on the acceptability of cooked ham formulated with modified starch and emulsions, which can be the beginning of future innovations in this sector.

Therefore, by conducting this research, we hope not only to contribute to the development of healthier and more sustainable products, but also to provide the food industry with tools and knowledge that will facilitate the creation of alternatives that are aligned with current trends towards a more balanced and conscious diet.

DEFINITION OF SAUSAGE

NOM-213-SSA1 (2018), which defines a processed meat product as one that is made from meat, viscera, fat, edible animal parts, additives or other ingredients subjected to different processes or heat treatments related to the final meat product, an example of processed meat products, are sausages consisting of a homogeneous mixture of meat, fat and water; packaged in natural or artificial casings (Atashkar *et al.,* 2018).

A meat sausage is produced by combining minced meat with various ingredients, such as spices, salt and additives, which are stuffed into natural or artificial casings. This procedure can include curing and smoking phases, which not only improve flavor and texture, but also help to preserve the product (De la Hoz & García, 2020).

CLASSIFICATION OF SAUSAGES

A classification of sausages according to Álvarez (2016), are: fresh sausages; which do not require curing or maturation processes, i.e., they are completely raw without any heat treatment; and processed sausages; their preparation involves heat treatment or cooking, curing, smoking or fermentation. Gaivor (2022) classifies sausages according to the meat source, as is the case of those that use blood (blood sausage or stuffed); there are also meat sausages, with the highest consumption demand worldwide, some examples being chorizo, salami and sausage, but also sausages made from viscera, in pieces before stuffing. Finally, there are emulsified sausages, which are distinguished by their pink color, such as hams and mortadellas, with their components homogeneously mixed.

EMULSIFIED SAUSAGE

This type of meat derivative presents a homogeneous appearance, the resulting emulsion in this food product. According to Rodríguez et al. (2015), it is made up of a discontinuous phase "Ac" (oil or fat) and a continuous phase "A" (water); these phases are united by means of an emulsifying agent (proteins), therefore, the three main ingredients, are meat, fat and water, however, additionally, ingredients such as are considered: starches, gums, texturized proteins, isolated proteins, sodium erythorbate, sodium nitrite, sodium lactate, which influence flavor, increase product yield and extend the shelf life of the finished product. Another main consideration is meat as a raw material in sausages, as it is a source of proteins, necessary for the stabilization of the emulsion, provides the characteristic flavor, contribution to texture and color (Ortega and Pino 2018).

The fat content in a meat emulsion provides organoleptic properties of great relevance in parameters such as texture, color, flavor and juiciness; therefore, by removing part of the fat content, there could be an alteration, promoting the generation of a hard, rubbery, opaque product, including browning and significantly affecting the taste stimulus at the moment of consumption (Britez *et al*., 2021). Tahmasebi *et al.* (2016) suggest that, by not having a representative amount of fat in an emulsion, a hard texture with a compact structure could be perceived; therefore, the incorporation of starches to the mixture is recommended, as gelling agents that serve as stabilizers of the emulsion, retaining water, preserving juiciness and increasing the final yield (Regina *et al.,* 2015; Herrera, 2020).

The most commonly used polysaccharides within the food industry are pectin, carrageenan, starch, chitosan, alginate and methylcellulose, which allow enhancing emulsions, due to their ability to form networks that encapsulate and preserve water molecules (Espinal *et al.,* 2014).

Starch influences the viscosity of the final product; likewise, salts and additives are essential for the preservation of a meat product, in addition to promoting the solubility of meat proteins, which gives greater stability to the emulsion (Villarroel *et al.,* 2018).

De Souza et al. (2020) mention that another fundamental component in the meat industry is nitrites, which have an inhibitory effect on pathogenic microorganisms, in addition to preserving meat pigment and extending the shelf life of processed products, developing their flavor, as explained by Ruíz et al. (2016). However, the incorporation of nitrites as preservatives implies the formation of nitrosamines, which are currently considered harmful to the health of the consumer, in turn, the regulation of sodium nitrites as a preservative is allowed in an average of 120 to 150 mg of nitrites/ kg of meat, which implies that they do not affect the health of the consumer (Selbes, 2014; Nollet & Toldrá 2015).

CHEMICAL COMPOSITION OF SAUSAGES

Sausages, according to their type and composition, are evaluated according to different parameters with techniques that are established with official documents which determine the maximum and minimum content of ingredients and additives, an example is ham, which is regulated by *NOM-158-SCFI-2003,* and the Ministry of Economy (2003), The standard specifies the percentage of protein, which must be free of fat for the different classifications of ham, percentage of fat, moisture, added protein, carrageenan and starch; the maximum and minimum percentages are shown in Table 1.

Table 2 shows the basic organoleptic properties that any ham classification should contain.

Commercial classification	PLG	Grease	Humidity	Added protein	Carrageenan	Starch
	%Minimum			Maximum		
Extrafine	18	6	75	0	1.5	0
Fino	16	6	76	2	1.5	0
Preferred	14	8	76	2	1.5	5
Commercial	12	10	76	2	1.5	10
Economic	10	10	76	2	1.5	10

Table 1. Ham composition

Secretaría de Economía (2003) *PLG Total protein Fat free

Parameter	Features
Color	Characteristic Pink
Odor	Pleasant, free of foreign odors
Taste	Pleasant, free of off-flavors
Consistency	Firm, compact and smooth appearance

Table 2. Organoleptic characteristics

Secretaría de Economía (2003).

CONSUMPTION OF SAUSAGES

In Mexico, meat consumption has increased over the years, reaching a per capita consumption of 29 kilograms, of which approximately 55% is used as raw material for sausage processing, while in 2015 sausage production increased by 51%, followed by cooked ham with 42% and the remaining 7% is used for processing sausage, chorizo, bacon, chops, among others. Santamaría and Bekelman (2021) report that the consumption of processed foods is frequent in the population, due to their pleasant taste and easy accessibility to consumers. However, processed products contain high levels of saturated fats, which are a risk factor for the health of consumers and are related to chronic diseases.

The intake of meat products is linked to saturated fatty acids and is related to diseases such as obesity and overweight (Wang *et al.* 2018). The meat products with the highest demand are sausages, however, they contain a high percentage of fats and salts as mentioned by Perez and Negreiros (2021), due to this, the fortification of sausages has been increasing, offering consumers healthier products.

HEALTH EFFECTS OF SAUSAGE CONSUMPTION

Meat and meat products are part of the daily diet and provide essential nutrients (Halagarda and Wójcjak, 2022; Wang *et al.* 2011), however, the meat industry is facing new challenges caused by meat components, since they are related as one of the main factors in the development of chronic diseases (Omedilla *et al.,* 2013). Like any other food, meat products contain excessive amounts of some components, whether natural or not, such as fats, cholesterol, residues of environmental contamination or drugs, which reach the product during processing or are added to improve sensory characteristics and stability (Jimenez *et al.,* 2001).

Excessive consumption of processed meat products can increase the risk of cardiovascular disease due to their high fat and sodium content. The WHO classified sausages as group 1 carcinogens, increasing the risk of colorectal cancer, in addition, regular consumption of sausages contributes to weight gain and obesity due to their high caloric content and low nutritional level (Micha *et al.,* 2017; Bouvard *et al.,* 2015; Pan *et al.,* 2021).

FAT SUBSTITUTES

There are several fat substitutes which are added in different proportions and their effect on fat content reduction varies according to the alternative applied. Yang *et al.* (2021) analyzed how soy isolate added in 10% achieved a 25-30% fat reduction, improving the sensory perception of reduced-fat sausages and maintaining the texture and juiciness of the meat product. Xu *et al*. (2022) incorporated 5% pea fiber, reducing fat by 15-20% and improving the water holding capacity and texture of the product. The incorporation of alginate at 1-3% improves the texture and water retention of the product reducing up to 25% in fat content in the product as mentioned by Dominguez *et al.* (2022). Nasir *et al.* (2023) described that the integration of oat bran at 8% improves the nutritional quality and texture of meat sausage by reducing fat content by 20%. Muratore *et al.* (2021) replaced 30% of animal fat with sunflower oil, which increased the fatty acids of the product while maintaining texture and flavor. Emulsifiers incorporated in concentrations of 0.5 and 1.5% improve texture, product juiciness and product stability, reducing between 10-15% fat in the final product as argued by Pinho *et al.* (2023).

Fat forms the emulsion together with water and proteins as an emulsifying agent, altering the texture, color, flavor and juiciness of the final product, however, solid fats damage the consumer's health leading to cardiovascular diseases (Tavernier *et al*. 2017). Alternatives have been sought to replace the fat content, one proposal is oleogels which are composed of vegetable oils, now by replacing the fat completely the texture is altered and has oil exudation, i.e. oil leaks to the outside of the ham triggering adverse visual and organoleptic effects (Pehlivanoğlu *et al.,* 2017). Shariati et al. (2016), put forward another alternative, with the use of binders as substitutes, although they are prone to self-oxidation leading to undesirable flavor and aromas in the product. Feng *et al.* (2019), state that the gels in emulsions are soft-solid and are formed by a three-dimensional network made up of a gel matrix and the emulsion, benefiting the ham by giving it properties such as better stability, moisture retention which in turn makes it juicier and gives a better flavor, however, if the texture of the gel is not adequate, it compromises the stability of the ham and therefore its quality.

EMULSIFIER ALTERNATIVES

There are various emulsifiers applied in the meat food industry, Ghosh et al. (2020) indicate that the use of either soybean or sunflower lecithin improves texture, water retention and product stability. Sinha et al. (2019) suggest that the use of xanthan gum improves texture and viscosity by retaining moisture in the meat product. O'Sullivan et al. (2021) mention that the addition of carrageenan maintains sensory quality, texture and water retention. Guar gum increases viscosity and improves water retention capacity being a good emulsifier alternative as mentioned by Rhim *et al.,* (2018). Fritsch et al. (2021) propose polysorbates as an alternative emulsifier because it improves the stability and homogeneity of the mixture and it is an emulsifier of synthetic origin so it is more economical than emulsifiers of natural origin. Cheng et al. (2022) choose sodium stearoyl lactylate for improving texture and emulsion stability as it is a derivative of fatty acids and lactic acid. Chen et al. (2023) used pectins as gelling and stabilizing agents within the emulsion maintaining the texture and water retention of the product. Dhingra et al. (2021) indicate that modified starches stabilize, improve water retention and contribute to the texture of meat products.

SUBSTITUTES FOR GELLING AGENTS

The most common are starches, which are made up of 20% amylose and 80% amylopectin, in addition to a minority fraction of lipids and minerals, as indicated by Montoya et al. (2015), however, this proportion varies according to the type of starch and its botanical source, since this modifies its shape (regular or irregular) and diameter, which ranges from 1 to 100 microns, thus modifying the amylose and amylopectin content present in the starch as mentioned by Stasiak et al. (2014); the use of starch in its native state has limitations such as low thermal stability, high predisposition to retrogradation, high viscosity and low affinity with some solvents and polymers as expressed by Lefnaoui & Moulai (2015), so that modified starches or resistant starches (RA) were recently used, which have the ability to be prebiotic and symbiotic as suggested by Olayo et al. (2021), by interaction with other prebiotic fibers; however modified starches have specific characteristics such as a granular shape and compact structure which limits the approach of digestive enzymes as addressed by Jaiturong et al. (2020), furthermore, Pizarro et al. (2016) and Villarroel et al. (2018), point out that resistant starches have a mild flavor, fine particle size, white appearance, decrease ingredient agglomeration, improve viscosity, are stable at acidic pH (0 to 4.5) and elevated temperatures (greater than 90°C).

CONCLUSION

The consumption of meat sausages is part of the daily diet of the population, and this is a trigger for the production of foods with better properties and less impact on health without altering their organoleptic and sensory characteristics. It is therefore necessary to continue with research oriented towards the development of ingredients or techniques that improve the industrial processes of meat derivatives, offering healthier foods, contemplating the substitution of fats and chemical agents that have an impact on consumers. However, the minimization of changes in color, water retention capacity, texture, weak emulsions, unpleasant odors and flavors should be foreseen, due to the economic importance of these meat products in Mexico and the world.

REFERENCES

-Álvarez Villagómez, J. D. L. (2016). *Evaluación de la calidad de la salchicha elaborada con carne de cuy (Cavia porcellus) y variuos niveles de harina de haba (Vicia faba)* (Bachelor's thesis, Escuela Superior Politécnica de Chimborazo).

-Atashkar, M., Hojjatoleslamy, M. & Sedaghat Boroujeni, L. (2018). The influence of fat substitution with κ-carrageenan, konjac, and tragacanth on the textural properties of low-fat sausage. Food science & nutrition, 6(4), 1015-1022.

-Bouvard, V., Loomis, D., Guyton, K. Z. & Grosse, Y. (2015). Carcinogenicity of consumption of red and processed meat. The Lancet Oncology, 16(16), 1599-1600. https://doi.org/10.1016/S1470-2045(15)00444-1.

-Britez, M. G., Rolhaiser, F. A., Fernández, C. L., Fogar, R. A. y Romero, M. C. (2021). Emulsiones gelificadas enriquecidas con harina de garbanzo como potencial sustituto de grasa animal. Enfoque UTE, 12(3), 24-35. https://doi.org/10.29019/enfoqueute.744

-Chen, S., Zhang, X. & Li, D. (2023). Utilization of Pectin as a Stabilizer in Meat Products: An Innovative Approach. Food Biophysics, 18, 19-29. https://doi.org/10.1007/s11483-022-09845-1.

-Cheng, Y., Li, Z.& Zhang, H. (2022). Effects of Sodium Stearoyl Lactylate on Low-Fat Meat Emulsions. Journal of Food Science, 87(6), 2524-2532. https://doi.org/10.1111/1750-3841.16376.

-De la Hoz, L. & García, A. (2020). "Characterization of traditional Spanish sausages: Physical, chemical, and microbiological properties." *Food Science & Technology*, 39(4), 123-130.

-De Souza Paglarini, C., Vidal, V. A. S., Ribeiro, W., Badan Ribeiro, A. P., Bernardinelli, O. D., Herrero, A. M. & Pollonio, M. A. R. (2020). Using inulin based of emulsion gels as fat substitute in salt reduced Bologna sausage. Journal of the Science of Food and Agriculture. https://doi:10.1002/jsfa.10659.

-Dhingra, D., Nouri, F. & Bansal, N. (2021). Modified Starches as Texture Modifiers in Meat Products. Meat Science, 175, 108496. https://doi.org/10.1016/j.meatsci.2021.108496

-Diario Oficial de la Federación. (2019). *Acuerdo por el que se establece el programa de apoyo a la producción de carne de cerdo*. https://www.dof.gob.mx/nota_detalle.php?codigo=5556645&fecha=03/04/2019#gsc.tab=0.

-Domínguez, R., Pateiro, M. & Barba, F. J. (2022). Use of alginate as a fat replacer in low-fat meat products: Effects on quality and sensory attributes. Food Hydrocolloids, 125, 107443. https://doi.org/10.1016/j.foodhyd.2021.107443.

-Feng, L., Jia, X., Zhu, Q., Liu, Y., Li, J. & Yin, L. (2019). Investigation of the mechanical, rheological and microstructural properties of sugar beet pectin/soy protein isolate-based emulsion-filled gels. *Food Hydrocolloids*, *89*, 813–820.

-Fritsch, C., Müller, L. & Lang, M. (2021). The Impact of Polysorbate 80 on the Quality of Meat Products. Meat Science, 177, 108447. https://doi.org/10.1016/j.meatsci.2021.108447

-Gaivor Gómez, F. P. (2022). Evaluación de la calidad e inocuidad de salchicha elaborada con camarón, corvina y harina de quinua.

-Ghosh, S., Kaur, A. & Singh, N. (2020). Utilization of Lecithin as a Fat Replacer in Meat Products. Meat Science, 164, 108092. https://doi.org/10.1016/j.meatsci.2019.108092.

-Halagarda, M. & Wójciak, K. M. (2022). Health and safety aspects of traditional European meat products. A review. *Meat Science*, *184*, 108623.

-Herrera Corella, M. (2020). Efecto de la sustitución parcial o total de almidón de papa con fibra de soya en las características fisicoquímicas y sensoriales de un salchichón.

-Jaiturong, P., Laosirisathian, N., Sirithunyalug, B., Eitssayeam, S., Sirilun, S., Chaiyana, W. & Sirithunyalug, J. (2020). Physicochemical and prebiotic properties of resistant starch from Musa sapientum Linn., ABB group, cv. Kluai Namwa Luang. Heliyon, 6(12).

-Jiménez-Colmenero, F., Carballo, J. & Cofrades, S. (2001). Healthier meat and meat products: their role as functional foods. *Meat science*, *59*(1), 5-13. https://doi.org/10.1016/j.meatsci.2013.03.030Get rights and content

-Lefnaoui, S. & Moulai-Mostefa, N. (2015). Synthesis and evaluation of the structural and physicochemical properties of carboxymethyl pregelatinized starch as a pharmaceutical excipient. *Saudi Pharmaceutical Journal*, *23*(6), 698-711.

-Micha, R., Peñalvo, J., Cudhea, F. & Imamura, F. (2017). "Association between dietary factors and mortality from heart disease and stroke in the United States." *BMJ*, 357, j2846. https://doi.org/10.1136/bmj.j2846

-Montoya, I. D., Murillo, W., Barbosa, L. & Méndez, J. (2015). Acetilación enzimática de almidones: una opción de valor agregado. *Revista Tumbaga*, *1*(10), 88–107.

-Muratore, G., Parvez, S. & Goli, G. (2021). "Effects of replacing animal fat with sunflower oil in fermented sausages". *LWT - Food Science and Technology*, 139, 110586. DOI:10.1016/j.lwt.2020.110586.

-Nasir, M., Zhang, Z. & Zhou, G. (2023). "Incorporation of oat bran in reduced-fat sausages: Effects on quality and sensory characteristics". *Meat Science*, 195, 109060. DOI:10.1016/j.meatsci.2022.109060

-Nollet, L., & Toldrá, F. (2015). *Handbook of food analysis: Two-volume set*. CRC Press, 289-299 https://doi.org/10.1201/b18668

-Olayo-Contreras, V. M., Alemán-Castillo, S. J., Rodríguez-Castillejos, G. y Castillo-Ruiz, O. (2021). Almidón resistente como prebiótico y sus beneficios en el organismo humano. Tip Revista Especializada en Ciencias Químico-Biológicas, 24(), . https://doi.org/10.22201/fesz.23958723e.2021.406

-Olmedilla-Alonso, B., Jiménez-Colmenero, F. & Sánchez-Muniz, F. J. (2013). Development and assessment of healthy properties of meat and meat products designed as functional foods. *Meat science*, *95*(4), 919-930. https://doi.org/10.1016/j.meatsci.2013.03.030

-Ortega, A. G. y Pino, J. A. (2018). Revisión de publicaciones relacionadas con el aroma del café durante 1960-2016. Ciencia y Tecnología de Alimentos, 27(3).

-O'Sullivan, M., McDonnell, C. K. & Kerry, J. P. (2021). The Role of Carrageenan in the Stability of Low-Fat Meat Products. Food Hydrocolloids, 113, 106513. https://doi.org/10.1016/j.foodhyd.2020.106513.

-Pan, A., Sun, Q., Caballero, B. & Hu, F. (2021). "Red meat consumption and risk of cardiovascular disease, cancer, and all-cause mortality: a meta-analysis." American Journal of Clinical Nutrition, 113(5), 1218-1230. https://doi.org/10.1093/ajcn/nqaa349

-Pehlivanoğlu, H., Demirci, M., Toker, O. S., Konar, N., Karasu, S. & Sagdic, O. (2017). Oleogels, a promising structured oil for decreasing saturated fatty acid concentrations: Production and food-based applications. Critical Reviews in Food Science and Nutrition, 58(8), 1330–1341. https://doi:10.1080/10408398.2016.1256866

-Perez, K. F. Y. y Negreiros, V. R. L. (2021). Retos actuales y tendencias futuras en la fortificación nutricional y reducción de sustancias dañinas en alimentos de consumo masivo: pastas, embutidos y quesos. *Manglar*, *18*(3), 329-341.

-Pinho, O., Carvalho, F. & Ferreira, I. (2023). "Impact of different emulsifiers on the properties of low-fat meat emulsions". *Food Research International*, 162, 112086. DOI:10.1016/j.foodres.2022.112086.

-Pizarro, M., Sánchez, T., Ceballos, H., Morante, N. & Dufour, D. (2016). Diversificación de los Almidones de Yuca y sus Posibles Usos en la Industria Alimentaria. Revista Politécnica, 37(2).

-Regina, A., Berbezy, P., Kosar-Hashemi, B., Li, S., Cmiel, M., Larroque, O. & Morell, M. (2015). A genetic strategy generating wheat with very high amylose content. Plant Biotechnology Jornal, 13(9), 1276–1286. https://doi:10.1111/pbi.12345

-Rhim, J., Lee, J. & Hong, S. (2018). "Effects of Guar Gum on the Physicochemical Properties of Low-Fat Sausage". *Food Science and Biotechnology*, 27(4), 1045-1051. DOI:10.1007/s10068-018-0371-5

-Rodríguez Tarrag, H. L., Angulo Palma, H. J. y Falcón Hernández, J. (2015). Comportamiento reológico de las emulsiones empleando productos de la pirólisis. Tecnología Química, XXXV(3), 412-423.

-Rodríguez-Espinosa, H., Restrepo-Betancur, L. F. & Urango, L. A. (2015). Preferencias y frecuencia de consumo de derivados cárnicos por parte de estudiantes universitarios de Medellín, Colombia. Revista Española de Nutrición Humana y Dietética, 19(4), 204-211. https://scielo.isciii.es/scielo.php?pid=S2174-51452015000400004&script=sci_arttext&tlng=en

-Ruíz, C., Herrero, A. & Jiménez, F. (2016). Determination of nitrates and nitrites. En Flow injection analysis of food additives (pp. 135-152). Taylor & Francis Group.

-Santamaría-Ulloa, C. & Bekelman, T. (2021). Consumo de embutidos en mujeres costarricenses: efecto del nivel socioeconómico. Revista de Biología Tropical, 69(2), 665-677. https://doi.org/10.15517/rbt.v69i2.45428

-Secretaría de Economía. (2003). *NOM-158-SCFI-2003: Especificaciones de etiquetado para la carne y productos cárnicos*. https://comecarne.org/wp-content/uploads/2013/07/NOM-158-SCFI-20031.pdf

-Selbes, M. (2014). *The effects of amine structure, chloramine species and oxidation strategies on the formation of N-nitrosodimethylamine* Clemson University.

-Shariati-Ievari, S., Ryland, D., Edel, A., Nicholson, T., Suh, M. & Aliani, M. (2016). *Sensory and Physicochemical Studies of Thermally Micronized Chickpea (Cicer arietinum) and Green Lentil (Lens culinaris) Flours as Binders in Low-Fat Beef Burgers. Journal of Food Science, 81(5), S1230–S1242.* doi:10.1111/1750-3841.13273

-Sinha, R., Sharma, H. & Rani, R. (2019). "Use of Xanthan Gum as a Stabilizer in Low-Fat Sausages". *Journal of Food Science and Technology*, 56(5), 2330-2336. DOI:10.1007/s11483-019-01728-4

-Stasiak, M., Molenda, M., Horabik, J., Mueller, P. & Opaliński, I. (2014). Mechanical properties of potato starch modified by moisture content and addition of lubricant. *International Agrophysics*, *28*(4), 501-509.

-Tahmasebi, M., Labbafi, M., Emam-Djomeh, Z. & Yarmand, M. S. (2016). Manufacturing the novel sausages with reduced quantity of meat and fat: The product development, formulation optimization, emulsion stability and textural characterization. *LWT-Food Science and Technology*, *68*, 76-84.

-Tavernier, I., Patel, A. R., Van Der Meeren, P. & Dewettinck, K. (2017). Emulsion-templated liquid oil structuring with soy protein and soy protein: k-carrageenan complexes. *Food Hydrocolloids*, *65*, 107–120.

-Villarroel, P., Gómez, C., Vera, C. & Torres, J. (2018). Almidón resistente: Características tecnológicas e intereses fisiológicos. Revista chilena de nutrición, 45(3), 271-278.

-Wang, X., Nag, R., Brunton, N. P., Siddique, M. A. B., Harrison, S. M., Monahan, F. J. & Cummins, E. (2022). Human health risk assessment of bisphenol A (BPA) through meat products. *Environmental Research*, *213*, 113734.

-Wang, X., Xie, Y., Li, X., Liu, Y. & Yan, W. (2018). Effects of partial replacement of pork back fat by a camellia oil gel on certain quality characteristics of a cooked style Harbin sausage. Meat Science. https://doi:10.1016/j.meatsci.2018.08.01.

-Xu, X., Zhang, X. & Li, D. (2022). "The role of pea fiber in improving the quality of reduced-fat sausage". *Journal of Food Science*, 87(5), 2252-2260. DOI:10.1111/1750-3841.16449.

-Yang, Y., Li, S., Han, M., Zhang, Y. & Li, D.(2021). "Effect of soy protein isolate on the quality characteristics of low-fat sausage". *Meat Science*, 172, 108324. DOI:10.1016/j.meatsci.2020.108324