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Review Paper

Cooked-emulsified rabbit meat sausages: a technological challenge or sustainable solution?

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ABSTRACT

Rabbit meat is characterized by a high content of biologically valuable proteins, low levels of fat, cholesterol, and sodium, appreciable quantities of n-6 and n-3 polyunsaturated fatty acids (PUFAs), and substantial amounts of B-complex vitamins, particularly vitamin B12. Given its favorable nutritional profile, rabbit meat is well-suited for the formulation of cooked-emulsified sausages, particularly those with added value aimed at health-conscious consumers. From a technological standpoint, rabbit meat possesses specific characteristics that can be an advantage or challenge in the production of cooked-emulsion sausages. Therefore, this paper highlights the technological characteristics of rabbit meat and considers its suitability for the production of cooked-emulsified sausages.

1. Introduction

Rabbit meat is a nutritionally valuable source of protein (18.6–22.4%) (*Dalle Zotte & Szendrő*, 2011), characterized by excellent digestibility and a notable content of essential amino acids, including lysine, threonine, leucine, valine, isoleucine, and phenylalanine (*Honrado et al.,* 2022; *Siudak & Palka*, 2022; *Deng et al*., 2024). It is classified as a lean meat, exhibiting a fat content that varies between 1.8% and 8.8%, depending on the anatomical part of the carcass (*Dalle Zotte & Cullere*, 2019). Importantly, rabbit meat contains appreciable quantities of both n-6 and n-3 polyunsaturated fatty acids (PUFAs), which are essential for human health. Among these PUFAs, linoleic acid (an n-6 fatty acid) and α-linolenic acid (an n-3 fatty acid) are predominant, besides long-chain n-3 fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are known for their cardioprotective and anti-inflammatory properties (*Dalle Zotte & Szendrő*, 2011). In comparison to other meats, rabbit meat also has lower cholesterol content, averaging about 47 mg/100 g, with levels influenced by the animal's diet (*Hernàndez & Dalle Zotte*, 2010). As a white meat, it contains less iron (1.1–1.3 mg/100 g) and zinc (0.55 mg/100 g) than red meats like beef, lamb, or pork (*Lombardi-Boccia et al*., 2005). Another notable nutritional advantage of rabbit meat is its low sodium

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content (37–47 mg/100 g), which makes it suitable for inclusion in diets for individuals with hypertension (*Dalle Zotte & Szendrő*, 2011; *Dalle Zotte & Cullere*, 2019). Simultaneously, rabbit meat serves as a valuable source of essential minerals, including potassium (428–431 mg/100 g), phosphorus (222–234 mg/100 g), and selenium (9.3–15 µg/100 g), which are integral to numerous physiological processes (*Dalle Zotte & Szendrő*, 2011; *Dalle Zotte & Cullere*, 2019). In addition, rabbit meat is particularly rich in B-complex vitamins, which play a crucial role in metabolism, nervous system function, and the synthesis of red blood cells (*Dalle Zotte & Szendrő*, 2011).

Due to its high digestibility, nutritional profile, and low allergenic potential, rabbit meat is frequently recommended for nutritionally sensitive populations, such as children, pregnant women, the elderly, and individuals with health conditions including allergies, diabetes, obesity, and hypertension (*Składanowska-Baryza & Stanisz*, 2019; *Suvajdžić et al*., 2023). Despite its nutritional advantages, rabbit meat consumption remains low (*Cullere & Dalle Zotte*, 2018; *Szendrő et al*., 2020; *Siddiqui et al*., 2023). This limited acceptance is influenced by several factors, including socio-demographic characteristics, cultural background, the perception of rabbits as companion animals, concerns regarding animal welfare, as well as the meat's sensory characteristics and price (*Siddiqui et al*., 2023). Therefore, innovative strategies are required to increase the consumption of rabbit meat. One promising approach involves developing novel, health-oriented products that align with contemporary dietary preferences (*Suvajdžić et al*., 2023). Cooked-emulsified rabbit meat sausages are a viable option, as this type of product offer convenience and ease of preparation. Accordingly, this paper highlights the technological characteristics of rabbit meat and considers its suitability for the production of cooked-emulsified sausages.

2. Rabbit meat in the production of cooked-emulsified sausages

Cooked sausages are primarily composed of a meat batter or meat emulsion, which is subjected to heat treatment after being stuffed into casings (*Vuković*, 2020; *Vasilev et al*., 2023). The production of emulsion-type cooked sausages is a complex technological process in which the composition and interaction of the main filling components – meat, fat tissue, salt, and water – play a crucial role (*Vuković*, 2020). In the production of cooked sausages, meat with high water-binding capacity is preferred (*Vuković*, 2020). The water-binding capacity of meat depends on salt-soluble myofibrillar proteins, particularly myosin and actin (*Santhi et al*., 2017). During meat batter preparation, myofibrillar proteins are released through mincing and interact with added salts, becoming well hydrated and capable of binding added water (*Vuković,* 2020). In the presence of salt, approximately one-fifth of myofibrillar proteins become solubilized, and up to one-third do so when salt is combined with phosphates. The remaining myofibrillar proteins swell, retaining a significant portion of the water naturally present in the meat as well as the added water (ice) during batter preparation (*Puolanne*, 2010). On the other hand, the water-binding capacity of meat is positively correlated with the pH and is most pronounced before the onset of postmortem rigor, when the pH is the highest (*Vuković*, 2020). The production of cooked-emulsified sausages requires meat with pH between 5.8 and 6.2. Within this range, the protein structure is favorable for maximum water-binding capacity and exhibits good emulsifying and gel-forming properties, resulting in improved emulsion stability and a firmer product texture (*Santhi et al*., 2017). According to literature data, the ultimate pH of rabbit meat ranges from 5.7 to 6.0 (*Kozioł et al*., 2015; *Sampels & Skoglund*, 2021; *Frunză et al*., 2023), which is considered optimal for the preparation of cooked sausage batters. However, the ultimate pH of rabbit meat is influenced by a range of factors, including genetics, environmental conditions, diet, rearing system, as well as pre- and post-slaughter conditions (*Kumar et al*., 2023). A low ultimate pH leads to decreased water-binding capacity, resulting in both technological and economic losses (*de Oliveira Paula et al*., 2020). Conversely, rabbit meat with a high ultimate pH is generally avoided due to its negative impact on product shelf life (*Suvajdžić et al*., 2023).

The formation of an interfacial protein film around fat globules plays a crucial role in stabilizing the fat phase during the production of cooked-emulsified sausages (*Glorieux et al*., 2019). Primarily composed of myofibrillar proteins, interfacial protein film prevents fat coalescence and the release of liquefied fat as the temperature rises during heat treatment, such as pasteurization (*Barbut & Youssef*, 2016). Concurrently, heating induces the formation of a three-dimensional gel network by myofibrillar proteins, which physically entraps both fat and water fat (*Vuković*, 2020). After that, cooling promotes additional stabilization of the protein network and initiates partial crystallization of the fat phase (*Glorieux et al*., 2019). Fat globules, coated with interfacial protein film and integrated within the protein matrix, enhance the gel rigidity and its structural integrity (*Glorieux et al*., 2019). In a comparison of rabbit, beef, and chicken meats for frankfurter production, *Whiting & Jenkins* (1981) concluded that protein solubility, water-holding capacity, emulsifying capacity, and binding strength were approximately equal among these meat types. Moreover, the low collagen content in rabbit meat (5.71 to 7.97 mg/g) enhances the stabilization of fat globules and promotes greater water retention (*Bueno et al*., 2023).

On the other hand, the production of cooked-emulsified rabbit meat sausages could be a technological challenge due to the low quantity of rabbit fatty tissue as a source of essential fats. Fatty tissue in rabbits is primarily located in the submandibular, scapular, and perirenal regions of the carcass. Obtaining sufficient quantities of rabbit fatty tissue can be particularly difficult, especially in the context of industrial-scale sausage production (*Dalle Zotte & Cullere*, 2019). As the most commonly used raw material in the production of cooked-emulsified sausages, pork back fat is a suitable solution since it contributes to stable emulsion formation, reduces losses during heat treatment, and enhances juiciness and texture (*Polak et al*., 2023). Nevertheless, replacing rabbit fatty tissue with pork back fat compromises both the concept of an authentic rabbit meat product and the expectations of modern health-conscious consumers. To replace animal fat, various hydrocolloid systems, such as alginate, carrageenan, xanthan gum, cellulose derivatives, starches, and pectins, have been investigated (*Petracci & Cavani*, 2013). Nevertheless, the use of other functional ingredients, such as vegetable fiber has shown greater advantages from both technological and nutritional aspects, owing to their favorable rheological properties and dietary benefits (*Petracci & Cavani*, 2013). Vegetable fiber can be used either alone or in combination with plant oils, which increase the content of polyunsaturated fatty acid in the product and make it prone to the oxidation process (*Vasilev et al*., 2023). Therefore, the replacement/reduction of fatty tissue in cooked-emulsified sausages presents a significant technological challenge, as it influences the aroma, color, and texture of these products (*Vasilev et al*., 2023). However, cooked-emulsified sausages with reduced fat content and with functional ingredients are labeled as added-value products, which are more appreciated by consumers, particularly health-conscious individuals.

The color of cooked-emulsified sausages is a very important sensory property, as it creates the consumer's first impression. Due to its low myoglobin content, rabbit meat is relatively light in color (high L^*), with low contributions to redness (a*) and yellowness (b*) (*Suvajdžić et al*., 2023). Therefore, the incorporation of rabbit meat into meat products significantly increases lightness and reduces redness (*Ignacio et al*., 2019). The low myoglobin content limits the development of nitrosyl-myoglobin after the addition of nitrites into meat batter, and consequently, limits the formation of product color (*Suvajdžić et al*., 2023). However, the addition of specific spices, such as paprika, can solve the problem and make a product color more acceptable for consumers (*Polak et al*., 2023). According to *Mićović et al*. (2021), paprika increases the redness and yellowness in frankfurter-type sausages, since it contains red and yellow pigments. Additionally, paprika decreased L^* in frankfurter-type sausages, making them darker than control samples (*Mićović et al*., 2021).

3. Conclusion

Given its nutritional profile, as well as its dietetic and technological properties, rabbit meat is a suitable raw material for the production of cooked-emulsified sausages. The protein solubility, water-holding capacity, emulsifying capacity, and binding strength in rabbit meat is optimal and approximately equal to that of beef and chicken meat. However, the limited amount of rabbit fatty tissue presents a challenge, which can be addressed by incorporating pork back fat, hydrocolloids, or vegetable fiber as functional ingredients. While the use of pork back fat in the production of cooked-emulsified rabbit meat sausages compromises the dietetic properties and authenticity of rabbit meat products, replacing rabbit fatty tissue with other functional ingredients offers a promising alternative.

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