*Review Article*

Chicken By-Products as Functional Additives in Sausage Products: A Review on The Nutritional Potential and Physicochemical Quality

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ABSTRACT

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| Chicken sausage is a popular processed meat product, but there is a growing need to improve its nutritional quality and the sustainability of its raw materials. The use of chicken by-products such as belly fat, chicken skin, chicken feet collagen and chicken liver as additives can affect the physical and chemical characteristics of sausages. This review discusses the effect of each ingredient on the physical quality and chemical composition of the final product based on literature analysis. Results showed that belly fat improved sausage brightness and fat content, chicken skin improved water binding capacity and texture at optimal levels, while chicken feet collagen improved emulsion stability and was suitable for low-fat sausages. The addition of chicken liver tends to decrease hardness and protein content, and results in a darker color due to its mineral content. The use of chicken by-products as additives has the potential to improve nutritional value and product quality while supporting the sustainable utilization of industrial resources. However, proper formulation and innovative processing techniques are necessary to address challenges related to emulsion stability and sausage texture. This review provides important insights for the development of healthier and environmentally friendly chicken sausage products. |

*Keywords: Chicken by-products; formulation; sausage quality; functional additives; meat processing*

1. INTRODUCTION

The poultry industry plays an important role in providing animal protein to the global population (Canti et al., 2021). To meet the increasing demand, the poultry sector must enhance production efficiency. However, efforts to scale up production present new challenges, particularly the accumulation of large amounts of organic by-products such as blood, bones, offal, skin, fat, heads, and feet (Toldrá et al., 2016). Although often regarded as waste, these by-products still contain valuable compounds such as proteins, collagen, fats, and minerals, offering considerable economic and nutritional potential (Salim et al., 2024; Alao et al., 2017). This situation presents an opportunity to drive science-based innovation in optimizing the utilization of poultry by-products, both to generate value-added products and to support sustainability principles in the meat processing industry.

Challenges and opportunities in by-product utilization are becoming increasingly crucial, especially in the chicken processing industry, which is one of the sectors with the largest production volume among poultry commodities. As global consumption increases, chicken processing generates a huge amount of by-products each year. It is estimated that the global chicken processing by-products reach more than 45 million tons per year, including parts such as feet, skin, head and fat (Seidavi et al., 2019). Most of these by-products have not been optimally utilized, even though they have great potential as alternative raw materials with high nutritional value and can be processed into functional food products. In the modern food industry, approaches based on sustainability and resource efficiency are increasingly being considered, so the utilization of chicken by-products is considered a strategic step in supporting a resilient and environmentally friendly food system.

One promising form of chicken by-product utilization is in sausage products. As a meat emulsion product, sausage has high flexibility in formulation, allowing the integration of non-conventional ingredients such as collagen from chicken feet, abdominal fat, skin, and chicken liver. Several studies have shown that the addition of chicken feet collagen can improve the texture and stability of sausage emulsions. Araújo et al. (2019) reported that collagen from chicken feet was able to produce product quality equivalent to collagen from other sources. However, the results of Miwada et al. (2025) revealed that the effectiveness of collagen is greatly influenced by the processing method and its proportion in the formulation. Another study by Miwada et al. (2024) also showed that the addition of chicken skin improved moisture content and sensory acceptability, while Fan et al. (2024) warned that the use of excess fat may decrease emulsion stability. The different results from these studies emphasize the need for further studies to understand the mechanism and optimal limit of using chicken by-products in sausage formulations.

Similarly, the development of functional food products is now a major focus in the food industry. Functional foods not only fulfil basic nutritional needs, but also provide additional health benefits without sacrificing sensory aspects that are important to consumers. In this context, chicken by-products have great potential to be developed into functional additives in chicken sausages. Through the application of appropriate technology, components such as collagen, skin and chicken fat can be processed into highly nutritious food while supporting sustainability principles (Elsesy et al., 2015). This paper focuses on a scientific review of the effect of chicken fat, chicken skin, chicken feet collagen and chicken liver in improving the physical and chemical quality of chicken sausage, and considers the implications for sustainable functional food product innovation.

2. NUTRITIONAL POTENTIAL OF CHICKEN BY-PRODUCTS

2.1 Chicken Fat By-Products

Abdominal fat and gizzard fat are often considered as worthless waste, so they are often discarded along with offal, feathers and blood by small producers. In fact, these two types of fat remaining in chicken carcasses can account for around 2-2.5% of the total chicken weight after slaughter. This disposal practice not only ignores their nutritional potential, but also exacerbates environmental problems (Peña-Saldarriaga et al., 2020).

In fact, chicken by-product fats, especially abdominal and gizzard fats, have promising nutritional potential as lipid sources in the development of emulsion-based processed meat products. From each chicken carcass, about 40 grams of fat can be generated as by-products, of which 65% is abdominal fat and 35% is gizzard fat. The lipid extraction rate from these parts reaches about 75%, indicating a high efficiency in their utilization (Peña-Saldarriaga et al., 2020).

The fatty acid profile of chicken by-product fat shows a predominance of unsaturated fatty acids, mainly oleic acid (C18:1) and linoleic acid (C18:2). The unsaturated fat content in chicken by-product fat reached 65.5%, much higher than saturated fat which was only about 30.3%. This composition suggests that chicken by-product fat could be a healthier alternative to conventional animal fats, such as beef or pork fat, which generally have a higher proportion of saturated fat. For comparison, the composition of saturated and unsaturated fat in beef is 58.13%: 37.80%, while in pork it is 43.54% : 47.45% (Lisitsyn et al., 2017). Therefore, the utilization of chicken fatty byproducts not only contributes to waste reduction but also supports the development of more functional and nutritionally valuable product formulations.

**2.2 Chicken Skin**

Henry et al. (2019) reported that hicken skin accounts for approximately 6.68% of the total live weight of chickens, with a chemical composition consisting of 52.80% moisture content, 13.01% protein, 34.48% fat, 0.46% ash, and an energy value of 362.36 Kcal/100g. This energy value is the highest compared to other chicken by-products, such as liver, gizzard, and wings. Despite its high fat content, the fat content of chicken skin is about 45% lower than abdominal fat (Santos et al., 2020), indicating that chicken skin is relatively lower in lipids than other adipose tissues.

In addition to its nutritional value, chicken skin also has other valuable functional potential, particularly as a source of gelatin. According to Jafandeva & Khair (2025), gelatin extracted from chicken skin through a simple method of heating using a water bath shows good physicochemical characteristics. The gelatin produced had a moisture content of 14.15%, ash content of 3.26%, pH 4, and viscosity of 2.74 cP. FTIR analysis also identified the presence of typical functional groups of gelatin, such as O-H, N-H, C-O, C=O, C-N, and NCO. These findings indicate that chicken skin has the potential to be a viable and environmentally friendly source of gelatin, as well as supports the food industry's need for natural additives.

**2.3 Chicken Feet**

Chicken feet have considerable culinary value, especially in the form of appetizers and street food. In addition, its functional potential cannot be ignored. Its high collagen content makes chicken feet a promising raw material for gelatin production (Potti & Fahad, 2017; Santana et al., 2020). Collagen is composed of three polypeptide chains and can be hydrolyzed into gelatin (Hashem et al., 2023). Generally, chicken feet that are utilized come from broiler chickens that are slaughtered at a young age, less than 42 days, so that the collagen tissue is still fresh and has not undergone much degradation. This condition supports the extraction and purification process to be more efficient (Rana et al., 2024).

Studies show that collagen from chicken feet can reach levels of more than 70.90%, much higher than commercial gelatin from cow skin which only contains about 35%. The utilization of collagen from chicken feet not only provides added value to meat industry by-products, but also offers a more socially and culturally acceptable alternative to other collagen sources (Santana et al., 2020). The content of key amino acids such as glycine, proline, alanine, and glutamic acid strengthens the potential of chicken feet as a functional food raw material (Alkahtani et al., 2023). The amino acid profile also produces collagen with multifunctional characteristics, such as the ability to retain oil and water, good emulsion, thermal stability, water solubility, and the ability to form foam (Talha et al., 2024). The utilization of chicken feet as a by-product of the poultry industry reduces significant environmental pollutants and provides an environmentally friendly source of collagen to meet global demand (Zinina et al., 2022).

**2.4 Chicken Liver**

The liver is an accessory organ in the digestive system and the largest gland in the body. It plays an important role in various physiological functions, including the metabolism of fats, carbohydrates, proteins, vitamins, and minerals, as well as detoxification and excretion of waste substances. The liver also serves as the main storage site for fat-soluble vitamins (A, D, E, and K), vitamin B12, glycogen, and certain minerals such as iron (Fe) and copper (Cu) (Zaefarian et al., 2019). Due to its physiological functions, chicken liver contains a variety of macronutrients (protein, carbohydrates, and fat) as well as essential micronutrients such as vitamin A, vitamin B12, iron, zinc, and selenium that play a role in maintaining blood and immune system function (Hadi, 2020).

Chicken liver is also a natural source of folic acid (vitamin B folate), which amounts to 781 µg/100 g fresh weight. Folic acid is recommended to be consumed by groups most vulnerable to folate deficiency, such as pregnant women and the elderly. This is because folic acid has an important role in the prevention of a number of diseases, such as megaloblastic anemia and decreased neurocognitive function in the elderly (Czarnowska-Kujawska et al., 2020).

Chicken liver is known to contain high amounts of iron (Fe), which is around 363.88 mg/kg (Duman et al., 2019), making it one of the potential natural sources of iron that is easily absorbed by the body. This content does not pose a health risk if consumed in food form, because the body has an effective homeostasis mechanism in regulating iron absorption according to physiological needs. Iron from food will be absorbed selectively, while the excess is not stored but safely excreted (Kicinska et al., 2019).

Based on the results of research by Henry et al. (2019), chicken liver has the highest essential amino acid content, which is 37.23 grams, when compared to other by-products such as gizzards, wings, and skin. This high amino acid content makes chicken liver a source of high-quality protein that is beneficial for supporting muscle growth and cell regeneration processes in the body (Siddiqui et al., 2024).

**3. PHYSICAL QUALITY OF SAUSAGE BY USING VARIOUS TYPES OF CHICKEN BY-PRODUCT**

The utilization of various types of chicken byproducts as additives in sausage making is not only an economically valuable alternative for the meat processing industry, but also contributes to reducing environmental impacts. The use of by-products such as fatty byproducts, chicken skin, chicken feet and chicken liver are known to affect the physical characteristics of the final product. Therefore, it is important to review how each of these by-products contributes to the physical parameters of sausages, as summarized in Table 1.

Belly fat from chicken slaughter is one of the by-products that acts as a lipid source and is commonly used in the processing industry (Lima et al., 2020). It has potential application as an additional component in sausage making (Lima et al., 2021). Peña-Saldarriaga et al. (2020) reported that using fatty byproducts as a partial replacement for chicken skin increases the L\* value of sausages. This is because higher fat content in meat formulations tends to increase brightness (L\* value), resulting in sausages with a lighter appearance. The fat content of chicken skin was recorded as 34.48%, while that of fatty byproduct reached 74.36% (Henry et al., 2019; Marx et al., 2016).

Chicken skin contains valuable components such as protein, fat, and collagen (Fallah-Delavar & Farmani, 2018) which play an important role in improving the water binding capacity and texture of processed meat products (Juhui & Hack-Youn, 2019; Nath et al., 2016). The addition of chicken skin to chicken sausage has a significant effect on the physical quality of the product. Data from research by Miwada et al. (2024) showed that cooking loss increased from 3.35% in the control to 3.83% at 5% addition, then decreased at 10% (3.78%) and continued to decrease at 15% (3.54%) and 20% (3.59%). The initial increase in cooking loss is due to the release of water and fat from the sausage during cooking, while the decrease at higher levels is due to the formation of a more stable emulsion structure (Pathare & Roskilly, 2016; Kumar et al., 2016). WHC (Water Holding Capacity) increased up to 16.14% at 10% addition, then decreased at higher additions (14.40-14.80%) as excess fat not only disrupts water bonding in the emulsion, but also causes dilution of protein concentration required for gel network formation. This results in disruption of the emulsion structure and decreased ability of the meat to retain water during cooking (Fan et al., 2024). Sausage texture improved at 5-10% (12.75-12.52 N) due to the role of collagen in strengthening the protein network, which works by chemically binding water through the protein matrix and providing cohesion to the dough structure. However, at higher additions, the emulsion structure is disrupted, leading to a decrease in texture (Sousa et al., 2017). In addition, increasing chicken skin content also affected the color of the sausage, where brightness (L\*) increased with the addition of chicken skin.

Chicken feet gelatin is an alternative to produce healthier low-fat sausages. Based on the results of research by Araújo et al. (2019), the addition of chicken feet gelatin significantly increased the WHC of sausage and improved emulsion stability compared to other treatments. Chicken feet gelatin was able to reduce liquid loss during cooking through the formation of strong chemical bonds, although the collagen extraction method slightly affected emulsion stability. This finding is consistent with previous studies that showed increasing fat content to the optimal amount would strengthen the emulsion structure and increase WHC (Santhi et al., 2015). In addition, sausages with added chicken feet gelatin showed significantly higher brightness (L\*) values than the other treatments.

Replacing chicken meat with chicken liver up to 50% did not show significant changes in water binding capacity (WHC) and emulsion stability. However, at 75% substitution level, there was a decrease in WHC to 74.43%, an increase in liquid (6.41%) and fat (5.22%) release, and an increase in cooking loss to 7.03%. Although the pH in the 75% formula was higher, the low protein content and high water content led to a reduced ability of the emulsion to retain water and fat, because these proteins are capable of increasing water- and fat-binding capacity and forming stable gels and emulsions (Toldra et al., 2020). Visually, the addition of chicken liver resulted in a darker sausage color due to the high content of minerals such as iron and zinc. In addition, the texture of the sausages became softer as the amount of chicken liver increased, as liver does not have muscle fibers like chicken meat. This led to a significant decrease in hardness and textural quality compared to the control sausage (Nacak et al., 2023).

**Table 1. Physical quality of sausages with the use of various types of chicken by-products**

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| **Type of Chicken By-product** | **By-product Formulation** | **Physical Quality of Chicken By-product** | **Effect of Addition** | **References** |
| Chicken fatty by-product | Substitution of 40% and 50% chicken skin with fatty by-products | L\*: 66.41-69.42 | Brighter color | Peña-Saldarriaga et al. (2020) |
| Chicken skin | Addition of 0%, 5%, 10%, 15%, and 20% chicken skin | Cooking loss: 3.35-3.83%  WHC: 14.40-16.14%  Texture: 10.60-12.75%  L\*: 40.48-42.74 | Increased cooking loss, WHC, texture, pH, and lightness | Miwada et al. (2024) |
| Chicken feet | Control (100% backfat), 50% substitution of backfat with collagen powder, and 50% substitution with chicken feet gelatin | WHC: 75.19-76.82%  Emulsion stability: 87.33-95.86%  L\*: 74.25-76.45 | Improved WHC, affected emulsion stability, and increased lightness | Araújo et al. (2019) |
| Chicken Liver | Control (100% chicken meat) and substitution with 25%, 50%, and 75% chicken liver | WHC: 74.43-83.19%  TEF: 1.13-6.41%  TFAT: 0.23-5.22%  Cooking loss: 3.89-7.03%  Hardness: 557.77 – 4605.00 g  L\*: 56.78-73.79 | Substitution up to 50% maintained WHC and stabilized TEF, TFAT, and cooking loss. A 75% substitution significantly reduced WHC and increased TEF, TFAT, and cooking loss. Higher liver substitution decreased hardness and lightness (L\*) significantly. | Nacak (2023) |

**4. CHEMICAL QUALITY OF SAUSAGE BY USING DIFFERENT TYPES OF CHICKEN BY-PRODUCT**

Chemical quality is one of the important indicators in assessing the quality and stability of processed meat products such as sausages. Chemical parameters provide an overview of the nutritional value and potential shelf life of sausage products. The utilization of different types of chicken by-products, such as skin, fat tissue, liver and chicken feet, can affect the chemical profile of sausages due to differences in the nutrient composition of each ingredient. Table 2 presents data on the chemical quality of sausages formulated with the addition of different types of chicken by-products.

The fat content of fatty byproduct (38.92%) is higher than chicken skin (34.48%), so its use as a substitute ingredient in sausage making tends to increase the fat content and decrease the moisture content of the final product (Farmani & Rostammiri, 2015; Henry et al., 2019; Peña-Saldarriaga et al., 2020). In contrast, ash content is less affected by the proportion of meat and more dependent on the addition of mineral-rich ingredients such as salt (Mohammed et al., 2024). In addition, the fat profile of chicken tissue is generally healthy as it is dominated by unsaturated fatty acids (65.5%), so its use still supports the nutritional value of the final product (Peña-Saldarriaga et al., 2020).

Chicken skin contains collagen, which is known to retain moisture in the product, provide a fresher appearance, and enable its function as a fat substitute (Araújo et al., 2019). The addition of chicken skin in chicken sausage formulations tends to decrease the moisture content as the proportion used increases. This decrease can be attributed to the role of collagen from chicken skin that dissolves during the heating process, thus increasing the water-binding ability in the product matrix (Juhui & Hack-Youn, 2019). In addition, the higher the level of chicken skin addition, the protein and fat content in the sausage also increased. This finding is in line with the reported findings of Kim et al. (2017) who stated that chicken skin naturally has a high fat content, thus contributing to the increase in fat content in processed meat products. The high collagen content in chicken skin not only acts as a water-binding agent, but also serves as an alternative protein source to replace fat (Araújo et al., 2019). The addition of chicken skin was also shown to increase the pH value of chicken sausage. However, the resulting pH range, 6.86 to 6.93, is still within the normal range for chicken sausage products according to USDA standards, which is between 6.1 to 7.0 (United States Department of Agriculture, 2022). The pH value within this range reflects the neutral and stable condition of the product, and does not indicate any extreme chemical changes that could affect the quality or safety of the product (Balbinot-Alfaro et al., 2019)

The use of collagen gel from chicken feet as a substitute for 50% fat in sausage making (SG treatment) affected the chemical composition of the product. The ash content of SG sausages was higher than standard sausages (SS) and sausages with hydrolysed collagen powder (SC), which may be due to the peptides extracted from collagen that have mineral binding ability (Guo et al., 2015). Although the fat content of SG decreased by approximately 29.02% compared to SS, it was still higher than that of SC due to the higher water content in SG sausages, which affected the calculation of dry-based fat. The protein content of SG also increased as a consequence of replacing fat with collagen as a protein source (Araújo et al., 2019). The pH value of SG sausages was recorded to be the lowest, close to the isoelectric point of myosin (pH 5.5) (Li et al., 2018).

The use of chicken liver as a meat substitute can cause variations in the moisture content, fat, protein, ash, and pH value of the product, both before and after cooking. The moisture content of the sausages ranged from 58.97-61.15%, with the highest values found in formulations that used larger amounts of chicken liver. Fat content was in the range of 19.82-20.80%, and was relatively consistent between treatments. Protein levels varied between 16.48-17.29%, with a decreasing trend as the proportion of chicken liver increased. This finding is consistent with the report of Wibisono et al. (2023) who stated that the addition of chicken liver can reduce protein content in chicken nuggets. Ash content ranged from 2.61-2.80% and was relatively stable in all treatments. The pH value of the raw emulsion was in the range of 6.16-6.57, while after cooking it was 6.24-6.61. Increasing the ratio of chicken liver tends to increase the pH of the emulsion, both in raw and cooked conditions, which is related to the natural pH characteristics of chicken liver (±6.5) which is higher than chicken meat (±6.07) (Dourou et al., 2021; Hertanto et al., 2018).

**Table 2. Chemical quality of sausages with the use of various types of chicken by-products**

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| **Type of Chicken By-product** | **By-product Formulation** | **Chemical Quality of Chicken By-product** | **Effect of Addition** | **References** |
| Chicken fatty by-product | Substitution of 40% and 50% chicken skin with fatty by-products | Moisture: 62.17–61.40% Fat: 10.14–14.67% Protein: 13.04–12.43% Ash: 3.42–3.52% | Decreased moisture content, increased fat content, stable protein and ash levels | Peña-Saldarriaga et al. (2020) |
| Chicken skin | Addition of 0%, 5%, 10%, 15%, and 20% chicken skin | Moisture: 58.80–68.55% Protein: 16.57–18.44% Fat: 12.14–15.89% pH: 6.66–6.93 | Decreased moisture, gradual increase in protein and fat, increased pH value | Miwada et al. (2024) |
| Chicken feet | Control (100% backfat), 50% substitution of backfat with collagen powder, and 50% substitution with chicken feet gelatin | Moisture: 62.81–68.39 g/100g Ash: 5.40–6.11 g/100g Lipid: 25.32–41.11 g/100g Protein: 59.41–70.60 g/100g pH: 5.36–6.62 | Increased ash and protein contents, decreased fat and pH levels; moisture content comparable to control | Araújo et al. (2019) |
| Chicken Liver | Control (100% chicken meat) and substitution with 25%, 50%, and 75% chicken liver | Moisture: 58.97–61.15% Fat: 19.82–20.80% Protein: 16.48–17.29% Ash: 2.61–2.80% Raw pH: 6.16–6.57 Cooked pH: 6.24–6.61 | Higher substitution increased moisture and pH, decreased protein, while fat and ash levels remained stable | Nacak (2023) |

**5. CONCLUSION**

**The utilization of chicken by-products in sausage formulations offers substantial potential for developing functional meat products with high nutritional value, while simultaneously reducing production waste.** However, different types of by-products, such as abdominal fat, chicken skin, chicken feet collagen, and chicken liver, have varying impacts on the physical and chemical properties of sausages, which can affect the overall product quality. These variations present specific challenges related to formulation balance, emulsion stability, and texture optimization. To maximize the benefits of chicken by-products, innovations in processing techniques, ingredient combinations, and functional modifications are necessary to produce high-quality, sustainable sausages.

**Disclaimer (Artificial Intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**REFERENCES**

**Canti, M., Murdiati, A., Naruki, S., & Supriyatno. (2021). Quality Characteristics of Chicken Sausages Using a Combination of Jack (*Canavalia ensiformis* L.) and Soy Protein Isolate as a Binder. *Food Research,* 5(3), 249-261. https://doi.org/10.26656/fr.2017.5(3).544**

Toldrá, F., Mora, L., & Reig, M. (2016). New Insights Into Meat By-Product Utilization. *Meat Science*, 120, 54-59. <https://doi.org/10.1016/j.meatsci.2016.04.021>

Salim, N. V., Madhan, B., Glattauer, V., & Ramshaw, J. A. M. (2024). Comprehensive Review on Collagen Extraction From Food By-Products and Waste as a Value-Added Material. *International Journal of Biological Macromolecules,* 278(1), 1-31. https://doi.org/10.1016/j.ijbiomac.2024.134374

Alao, B. O., Falowo, A. B., Chulayo, A., & Muchenje, V. (2017). The Potential of Animal By-Products in Food Systems: Production, Prospects and Challenges. *Sustainability,* 9(7), 1-18. <https://doi.org/10.3390/su9071089>

Seidavi, A. R., Zaker-Esteghamati, H., & Scanes, C. G. (2019). Chicken Processing: Impact, Co-Products and Potential. *World’s Poultry Science Association*, 75(1), 55-68. <https://doi.org/10.1017/S0043933918000764>

Araújo, I. B. S., Lima, D. A. S., Pereira, F. S., & Madruga, M. S. (2019). Quality of Low-Fat Chicken Sausages with Added Chicken Feet Collagen. *Poultry Science,* 98(2), 1-19. <https://doi.org/10.3382/ps/pey397>

Miwada, I. N. S., Sutama, I. N. S., Wijana, I. W., Susilo, A., & Suardana, I. W. (2025). Evaluation of the Quality of Chicken Sausages Resulting from the Addition of Chicken Feet Skin. *International Journal of Veterinary Science*¸ 14(3), 605-612. <https://doi.org/10.47278/journal.ijvs/2025.006>

Miwada, I. N. S., Susilo, A., Ariana, I. N. T., Sriyani, N. L. P., & Sumarmono, J. (2024). Evaluation of the Physicochemical and Sensory Characteristics of Chicken Sausages Containing Different Types of Chicken Skin. *Indonesian Journal of Animal Science,* 34(2), 214-221. <https://doi.org/10.21776/ub.jiip.2024.034.02.8>

Fan, X., Geng, W., Zhang, X., Li, M., Chang, K., Ma, Y. et al. (2024). Rice Bran Oil-in-Water Emulsion Stabilized by Amur Catfish Myofibrillar Protein: Characteristics and its Application in Surimi Gels. *International Journal of Biological Macromolecules,* 283(2), 1-10. <https://doi.org/10.1016/j.ijbiomac.2024.137417>

Elsesy, T. A., Sakr, D. M., Kdous, M. F. S. A., & Elhae, R. A. A. (2015). Utilization of the Chicken Feet and Skeleton Meat for the Production of Dried Chicken Soup. *Middle East Journal of Agriculture Research,* 4(4), 938-948.

Peña-Saldarriaga, L. M., Fernández-López, J., & Pérez-Alvarez, J. A. (2020). Quality of Chicken Fat by-Products: Lipid Profile and Colour Properties. *Foods,* 9(8), 1-10. <https://doi.org/10.3390/foods9081046>

Lisitsyin, A. B., Chernukha, I. M., & Lunina, O. I. (2017). Fatty Acid Composition of Meat From Various Animal Species and the Role of Technological Factors in Trans-Isomerization of Fatty Acids. *Foods and Raw Materials,* 5(2), 54-61. 10.21603/2308-4057-2017-2-54-61

Henry, S. G. M., Darwish, S. M. I., Saleh, A. S. M., Khalifa, A. H. A. (2019). Carcass Characteristics and Nutritional Composition of Some Edible Chicken By-products. *Egyptian Journal of Food Science,* 47(1), 81-90. 10.21608/EJFS.2019.16364.1018

Santos, M. M. F., Lima, D. A. S., Madruga, M. S., & Silva, F. A. P. (2020). Lipid and Protein Oxidation of Emulsified Chicken Patties Prepared Using Abdominal Fat and Skin. *Poultry Science,* 99(3), 1777-1787. <https://doi.org/10.1016/j.psj.2019.11.027>

Jafandeva, S. d., & Khair, M. (2025). Gelatin Extraction from Chicken Skin: A Preliminary Study. *Brazillian Journal of Development,* 11(2), 1-8. <https://doi.org/10.34117/bjdv11n2-056>

Potti, R. B., & Fahad, M. O. (2017). Extraction and Characterization of Collagen from Broiler Chicken Feet (*Gallus gallus domesticus*)-Biomolecules from Poultry Waste. *Journal of Pure and Applied Microbiology*, 11(1), 315-322. <https://doi.org/10.22207/JPAM.11.1.39>

Santana, J. C. C., Gardim, R. B., Almeida, P. F., Borini, G. B., Quispe, A. P. B., Lianos, S. A. V., Heredia, J. A. et al. (2020). Valorization of Chicken Feet By-Product of the Poultry Industry: High Qualities of Gelatin and Biofilm From Extraction of Collagen. *Polymers,* 12(3), 1-21. <https://doi.org/10.3390/polym12030529>

Hashem, M. S., Magar, H. S., Fahim, A. M., & Sobh, R. A. (2023). Antimicrobial, Antioxidant, Mechanistic, Docking Simulation, and Electrochemical Studies for Grafting Polymerization of Novel Sulphonated Gelatin Derived from Chicken Feet. *Materials Chemistry and Physics,* 310, <https://doi.org/10.1016/j.matchemphys.2023.128474>

Rana, J., Keshri, O., Rahman, C. K. F., Kumar, V., Patel, S. K., & Das, B. C. (2024). Extraction and Evaluation of Collagen as Biomaterial from Chicken Shank. *Indian Journal of Animal Research,* 1-8. <http://dx.doi.org/10.18805/IJAR.B-5502>

Alkahtani, S. A., Mahmoud, A. M., Alqahtani, Y. S., Ali, A. B. H., & El-Welki, M. M. (2023). Selective Detection of Rutin at Novel Pyridinic-Nitrogen-Rich Carbon Dots Derived from Chicken Feet Biowaste: The Role of Bovine Serum Albumin During the Assay. *Spectrochimica Acta Part A: Molecular and Biomolecular* Spectroscopy, 303, 1-7. <https://doi.org/10.1016/j.saa.2023.123252>

Talha, M., Tanveer, M., Abid, A., Maan, A. A., Khan, M. K. I., Shair, H. et al. (2024). Valorization of Poultry Slaughter Wastes Via Extraction of Three Structural Proteins (Gelatin, Collagen and Keratin). A Sustainable Approach for Circular Economy. *Trends in Food Science & Technology,* 152, 1-18. <https://doi.org/10.1016/j.tifs.2024.104667>

Zinina, O., Merenkova, S., & Rebezov, M. (2022). Analysis of Modern Approaches to the Processing of Poultry Waste and By-Products: Prospects for Use in Industrial Sectors. *Food Science and Technology,* 42(2), 1-10. <http://dx.doi.org/10.1590/fst.03222>

Zaefarian, F., Abdollahi, M. R., Cowieson, A., & Ravindran, V. (2019). Avian Liver: The Forgotten Organ. *Animals,* 9(2), 1-23. <https://doi.org/10.3390/ani9020063>

Hadi, E. A., (2020). Study of The Effect of Cooking Methods on The Sensory and Chemical Properties of Fresh and Frozen Chicken Liver. *Plant Archives,* 20(2), 1034-1037. e-ISSN:2581-6063

Czarnowska-Kujawska, M., Draszanowska, A., & Gujska, E. (2020). Effect of Different Cooking Method on Folate Content in Chicken Liver. *Foods,* 9(10), 1-10. https://doi.org/10.3390/foods9101431

Duman, E., Özcan, M. M., Hamurcu, M., & Özcan, M. M. (2019). Mineral and Heavy Metal Contents of Some Animal Livers. *European Journal of Science and Technology,* (15), 302-307. <https://doi.org/10.31590/ejosat.506340>

Kicinska, A., Glichowska, P., & Mamak, M. (2019). Micro- and Macroelement Contents in the Liver of Farm and Wild Animals and the Health Risks Involved in Liver Consumption. *Environmental Monitoring and Assessment,* 191(132), 1-18. <https://doi.org/10.1007/s10661-019-7274-x>

Siddiqui, S. A., Bhowmilk, S., Afreen, M., Ucak, I., Ikram, A., Gerini, F. et al. (2024). Bodybuilders and High-Level Meat Consumers’ Behavior Towards Rabbit, Beef, Chicken, Turkey, and Lamb Meat: A Comparative Review. *Nutrition*, 119, 1-23. <https://doi.org/10.1016/j.nut.2023.112305>

Lima, J. L., Assis, B. B. T., Arcanjo, N. M. O., Galvao, M. S., Olegario, L. S., Bezerra, T. K. A. et al. (2020). Impact of Use Byproducts (Chicken Skin and Abdominal Fat) on the Oxidation of Chicken Sausage Stored Under Freezing. *Journal of Food Science,* 85(4), 1-11. https://doi.org/10.1111/1750-3841.15068

Lima, J. L., Assis, B. B. T., Olegario, L. S., Galvao, M. D. S., Soares, A. J., Arcanjo, N. M. O. et al. (2021). Effect Adding Byproducts of Chicken Slaughter on the Quality of Sausage Over Storage. *Poultry Science,* 100(8), 1-9. <https://doi.org/10.1016/j.psj.2021.101178>

Marx, S. D., Soares, J. M., Prestes, R. C., Schnitzler, E., Oliveira, C. S., Demiate, I. M. et al. (2016). Influence of Sex on the Physical-Chemical Characteristics of Abdominal Chicken Fat. *Brazilian Journal of Poultry Science,* 18(02), 269-275. <https://doi.org/10.1590/1806-9061-2015-0072>

Fallah-Delavar, M., & Farmani, J. (2018). Recovery and Characterization of Enzymatic Protein Hydrolyzates and Fat from Chicken Skin. *Journal of the American Oil Chemists’ Society,* 95(9), 1151-1161. <https://doi.org/10.1002/aocs.12131>

Juhui, C., & Hack-Youn, K. (2019). Quality Characteristics of Reduced Fat Emulsion-Type Chicken Sausages Using Chicken Skin and Wheat Fiber Mixture as Fat Replacer. *Poultry Science,* 98(6), 2662-2669. <https://doi.org/10.3382/ps/pez016>

Nath, P. M., Kumar, V., Praveen, P. K., & Ganguly S. (2016). Effect of Chicken Skin, Soy Protein and Olive Oil on Quality Characteristics of Chicken Nuggets. *International Journal of Science, Environment*, 5(3), 1574-1585.

Pathare, P. B., & Roskilly, A. P. (2016). Quality and Energy Evaluation in Meat Cooking. *Food Engineering Reviews,* 8, 435-447. https://doi.org/10.1007/s12393-016-9143-5

Kumar, Y., Kairam, N., Ahmad, T., & Yadav D. N. (2016). Physico Chemical, Microstructural and Sensory Characteristics of Low-Fat Meat Emulsion Containing Aloe Gel as Potential Fat Replacer. *International Journal of Food Science Technology*, 51(2), 309-316. <https://doi.org/10.1111/ijfs.12957>

Sousa, S. C., Fragoso, S. P., Penna, C. R. A., Arcanjo, N. M. O., Silva, F. A. P., Ferreira, V. C. S. et al. (2017). Quality Parameters of Frankfurter-Type Sausages with Partial Replacement of Fat by Hydrolyzed Collagen. *LWT-Food Science and Technology*, 76(B), 320-325. <https://doi.org/10.1016/j.lwt.2016.06.034>

Santhi, D., Kalaikannan, A., & Sureshkumar, S. (2015). Factors Influencing Meat Emulsion Properties and Product Texture: A Review. *Critical Reviews in Food Science and Nutrition,* 57(10), 1-30. <https://doi.org/10.1080/10408398.2013.858027>

Toldra, M., Pares, D., Saguer, E., & Carretero, C. (2020). Utilisation of Protein Fractions From Porcine Spleen as Technofunctional Ingredients in Emulsified Cooked Meat Sausages. *International Journal of Food Science and Technology*, 55(2), 871-877. https://doi.org/10.1111/ijfs.14298

Nacak, B. (2023). Effects of Replacing Chicken Meat with Chicken Liver on Some Quality Characteristics of Model System Chicken Meat Emulsion. *Meat Technology*, (64), 438-442. https://doi.org/10.18485/meattech.2023.64.2.84

Farmani, J., & Rostammiri, L. (2015). Characterization of Chicken Waste Fat for Application in Food Technology. *Journal of Food Measure and Characterization,* 9, 143–150. https://doi.org/10.1007/s11694-014-9219-y

Mohammed, H. O., O’Grady, M. N., O’Sullivan, M. G., & Kerry, J. P. (2024). The Effect of Reducing Fat and Salt on the Quality and Shelf Life of Pork Sausages Containing Brown Seaweeds (Sea Spaghetti and Irish Wakame). *Applied Science,* 14(17), 1-17. <https://doi.org/10.3390/app14177811>

Kim, H., Lee, J., Kim, J., Kim, G. (2016). Quality Properties of Chicken Nugget with Various Levels of Chicken Skin. *Korean Journal of Poultry Science,* 43(2), 105-109. <http://dx.doi.org/10.5536/KJPS.2016.43.2.105>

United States Department of Agriculture. (2022). Microbiology Laboratory Guidebook (MLG) 10 Appendix 5.00: Normal pH values for canned meat and poultry products. USDA Food Safety and Inspection Service. https://www.fsis.usda.gov/sites/default/files/media\_file/2021-12/MLG-10-Appendix-5.00.pdf

Balbinot-Alfaro, E., Craveiro, D. V., Lima, K. O., Costa, H. L. G., Lopes, D. R., Prentice, C. (2019). Intelligent Packaging with pH Indicator Potential. *Food Engineering Reviews,* 11, 235-244. https://doi.org/10.1007/s12393-019-09198-9

Guo, L., Harnedy, P. A., O’Keeffe, M. B., Zhang, L., Li, B., Hou, H., & FitzGerald, R. J. (2015). Fractionation and Identification of Alaska Pollock Skin Collagen-Derived Mineral Chelating Peptides. *Food Chemistry,* 173, 536-542. <https://doi.org/10.1016/j.foodchem.2014.10.055>

Li, L., Bai, Y., Cai, R., Wu, C., Wang, P., Xu, X. et al. (2016). Alkaline pH-Dependent Thermal Aggregation of Chicken Breast Myosin: Formation of Soluble Aggregates. *CYTA-Journal of Food,* 16(1), 765-775. <https://doi.org/10.1080/19476337.2018.1470576>

Wibisono, H. H., Aries, M., & Nasution, Z. (2023). Formulation of Chicken Nuggets with the Addition of Chicken Liver as a Product Rich in Iron and Vitamin A for Adolescent Females. *Indonesian Journal of Nutrition and Food,* 18(1), 52-54. https://doi.org/10.25182/jgp.2023.18.Supp.1.52-54

Dourou, D., Grounta, A., Argyri, A. A., Froutis, G., Tsakanikas, P., Nychas et al. (2021). Rapid Microbial Quality Assessment of Chicken Liver Inoculated or Not With *Salmonella* Using FTIR Spectroscopy and Machine Learning. *Frontiers in Microbiology*, 11, 1-17. https://doi.org/10.3389/fmicb.2020.623788

Hertanto, B. S., Nurmalasari, C. D. A., Nuhriawangsa, A. M. P., Cahyadi, M., Kartikasari, L. R. (2017). The Physical And Microbiological Quality Of Chicken Meat In The Different Type Of Enterprise Poultry Slaughterhouse: A Case Study In Karanganyar District. *IOP Conf Ser Earth Environ Sci,* 102, 1-8. 10.1088/1755-1315/102/1/012051