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Review Paper

Meat-derived bioactive peptides: application potential in functional foods

Burcu Ozturk-Kerimoglu[1]

[1] *University, Faculty of Engineering, Department of Food Engineering, 35040 İzmir, Türkiye*

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ABSTRACT

Meat proteins constitute a rich reservoir of encrypted bioactive peptides that may be released during enzymatic or microbial hydrolysis, gastrointestinal digestion, and various food processes, subsequently exerting diverse physiological functions. These peptides show antioxidant, antimicrobial, antihypertensive, and antidiabetic properties, along with additional roles such as immunomodulatory and anti-aging effects. They have demonstrated significant potential as multifunctional ingredients, not only improving human health but also enhancing shelf life as well as techno-functional and sensory attributes of foods. Their incorporation into diverse food systems can improve oxidative stability, microbial quality, and consumer acceptance, while recent advances also point to innovative applications in antimicrobial packaging. Nevertheless, the translation of these peptides from laboratory to industry faces key challenges, including production scalability, bioavailability, and regulatory constraints. Emerging approaches, such as the utilization of nano-encapsulation techniques and protease inhibitors, are under exploration to overcome these limitations. This review aims to provide an updated overview of current findings on meat-derived biopeptides, emphasizing their bioactive properties, utilization opportunities in different food formulations, and the main challenges that must be addressed for broader application.

1. Introduction

Meat is well recognized as a major source of high-quality proteins, providing essential amino acids crucial for human nutrition. Being a major source of high-quality proteins, meat simultaneously serves as a valuable reservoir of functional protein derivatives, particularly bioactive peptides (BPs). BPs can be defined as short amino acid sequences, typically fewer than 20 residues, encrypted within parent proteins and released through hydrolysis, thereby exerting specific physiological activities with health-promoting potential (*Chew et al.*, 2019; *Ozturk-Kerimoglu et al.*, 2025). Conventional methods, such as enzymatic hydrolysis, microbial fermentation, and chemical hydrolysis, have long been employed to obtain BPs from food proteins. Recently, innovative physical techniques, including microwave, ultrasound, pulsed electric fields, and high hydrostatic pressure, have also gained attention for enhancing hydrolysis efficiency, reducing enzyme use, and improving peptide purity and yield (*Zaky et al.*, 2022; *Hamdi et al.*, 2025). The product obtained after hydrolysis, referred to as the "hydrolysate," predominantly consists of di- and tripeptides (*Eckert et al.*, 2019; *Zinina*

***Corresponding author:** Burcu Ozturk-Kerimoglu, *burcu.ozturk@ege.edu.tr*

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et al., 2022). The process of BP production generally involves raw material pretreatments, hydrolysis, protein fractionation and purification, evaluation of bioactivity, peptide identification, *in silico* evaluation for bioactivity assessment, and confirmation of activities following chemical peptide synthesis (*Ozturk-Kerimoglu et al.*, 2025). The purification of the proteins in the resulting protein hydrolysates is carried out by different techniques such as ultrafiltration, reverse osmosis, ion-exchange column chromatography (IEC), and reversed-phase high-performance liquid chromatography (RP-HPLC), while the identification of the peptide sequences is then done by advanced mass spectroscopy, namely liquid chromatography-tandem mass spectrometry (LC-MS/MS), matrix-assisted laser deionization time-of-flight (MALDI-TOF), and electrospray ionization–mass spectrometry (ESI-MS) (*Hamdi et al.*, 2025).

BPs derived from various food sources have been documented to exert a broad spectrum of physiological activities, such as antioxidant, antimicrobial, antithrombotic, antihypertensive, immunomodulatory, anticancer, and lipid- or blood pressure-lowering effects; moreover, they influence not only human health but also the sensory attributes and functional characteristics of food systems (*Chew et al.*, 2019; *Toldrá et al.*, 2020; *Du and Li*, 2022; *Singh et al.*, 2022; *Karami and Akbari-Adergani*, 2019). Beyond single-activity BPs, multifunctional peptides that act on several physiological pathways at once were also documented (*Chai et al.*, 2020). Among these activities, meat-derived BPs show particular promise in antioxidant, antimicrobial, antihypertensive, and antidiabetic effects. These diverse bioactivities, along with their ability to improve functional and sensory properties, have made meat-derived BPs attractive candidates for use as functional ingredients in food processing. In this context, the present review aims to summarize the health-promoting and functional potentials of meat-derived BPs and to evaluate their possible applications in various food formulations, while also discussing the current challenges and future directions in this emerging research field.

2. Major bioactive functions of meat-derived BPs

Meat and meat products are excellent sources of BPs. Numerous BPs with diverse functional effects have been identified in various meat parts/further processed meat products, as well as in meat-derived by-products. The most frequently reported bioactive properties across various meat sources include antioxidant, antimicrobial, antihypertensive, and antidiabetic activities. In particular, antioxidant peptide sequences were identified in protein hydrolysates obtained from Spanish dry-cured ham (*Li et al.*, 2021), fermented pork sausage (*Kong et al.*, 2023), fermented chicken meat (*Babu et al.*, 2025), and traditional Yunnan dry-cured beef (*Wang et al.*, 2025), as well as from different meat by-products such as porcine liver (*López-Pedrouso et al.*, 2021), porcine plasma (*Zhan et al.*, 2022), chicken feet (*Ozturk-Kerimoglu et al.*, 2023), and bovine bone extract (*Begum et al.*, 2024). Potential antimicrobial peptides were identified in different meat-derived by-products such as bovine and porcine blood proteins (*Sanchez-Reinoso et al.*, 2021), chicken feathers (*Qin et al.*, 2022), and traditional ham broth (*Yang et al.*, 2025). Angiotensin converting enzyme (ACE) inhibitory activity, also known as antihypertensive activity, is another critical bioactivity of the peptides derived from meat sources, which was formerly detected in different meat types/products/by-products like fish and beef skeletal muscles (*Maky and Zendo*, 2021), Indonesian traditional fermented beef (*Cangkuk*) (*Mirdhayati et al.*, 2024), and beef liver hydrolysates (*Gallego et al.*, 2024). Furthermore, Dipeptidyl Peptidase-IV (DPP-IV) inhibitory activity, in other words, antidiabetic activity of peptides derived from various sources such as dry-cured pork loins (*Kęska and Stadnik*, 2021), sheep skin (*Wang et al.*, 2021), beef liver (*Gallego et al.*, 2024), and rabbit meat (*Hu et al.*, 2024) was reported. Beyond these described functions, BPs obtained from meat by-products are also mentioned to exert further effects, including opioid, anti-inflammatory, anti-tyrosinase, calcium-binding, and anti-aging activities (*Ozturk-Kerimoglu et al.*, 2025).

3. Meat-derived BPs as novel ingredients in food formulations

Food protein-origin BPs are regarded as valuable candidates for the design of functional food components and the advancement of nutraceutical products. The market for BPs from food proteins is experiencing remarkable growth, expanding from USD 48.6 billion in 2020 to a forecasted USD 95.7 billion in 2028 (*Du and Li*, 2022). Besides, thanks to their minimal toxicity, efficient metabolism in the human body, and biocompatible origin, BPs have emerged as versatile compounds with broad potential not only in the food sector but also in the feed, medical, pharmaceutical, and cosmetic industries (*Akbarian et al*., 2022; *Singh et al*., 2022; *Zaky et al*., 2022). *Chew et al.* (2019) emphasized that BPs have attracted growing interest as natural alternatives to pharmaceuticals due to their health-promoting properties. Recognized as nutraceuticals, they hold promise in preventing noncommunicable diseases (NCDs) and addressing nutritional deficiencies. Their role in preventive healthcare highlights their potential as key functional ingredients in future diets.

Table 1. Applications of meat-derived protein hydrolysates/BPs in different food products

Hydrolysate/BP	Food product	Highlighted findings	Reference
Bovine α- and β-globulin hydrolysates	Bread	•The addition of 4% (w/w) globulin papain hydrolysate (GPH) did not alter the physical quality or acceptance of bread. • *In vivo* tests in spontaneously hypertensive rats showed a significant systolic blood pressure reduction. • Antihypertensive activity of GPH remained stable after baking, supporting its potential use in functional foods.	Lafarga et al. (2016)
Microencapsulated stripped weakfish hydrolysate (*Cynoscion guatucupa*)	Yogurt	• Hydrolysate addition reduced syneresis and improved yogurt stability, especially in the microencapsulated form. • Both free and encapsulated hydrolysates provided stable antioxidant and ACE-inhibitory activities after 7 days. • Microencapsulation masked fishy flavor, resulting in sensorily acceptable functional yogurts.	Lima et al. (2021)
Yellow fin tuna (*Thunnus albacares*)	Functional beverage	• A malted grain-based health beverage was successfully fortified with tuna protein hydrolysate (TPH) derived from yellowfin tuna red meat. • 2.5% TPH was identified as the most sensorially acceptable formulation. • The enriched beverage exhibited improved nutritional, functional, antioxidant, and digestibility properties, along with good storage stability at 28 °C. • The potential of utilizing tuna cannery red meat by-products for value-added, health-promoting functional beverages was underlined.	Unnikrishnan et al. (2021)
Fish collagen-derived BPs (GPLGAAGP, GRDGEP, MTGTQGEAGR)	Yogurt	• Yogurt fortified with fish collagen-derived peptides (P1, P2, P3) showed no adverse effects on composition or sensory quality. • Protein content, water-holding capacity, and viscosity increased with peptide concentration. • At 1 mg/mL, the strongest antioxidant, ACE inhibition, and DPP-IV inhibition were observed. • Peptides P1 and P2 retained bioactivity after digestion, supporting their potential in functional yogurt formulations.	Ayati et al. (2022)
Rainbow trout roe	Mutton meat	• Alcalase-produced hydrolysate showed a higher degree of hydrolysis, stronger antioxidant activity, and higher essential amino acid content compared to pepsin. • Hydrolysate addition enhanced antioxidant and antimicrobial properties of alginate–chia seed composite coating (CC). • CC plus 1.5% hydrolysate significantly delayed microbial spoilage and lipid oxidation. • The incorporation of hydrolysate into CC effectively extended meat shelf life, meeting consumer demand for clean-label products free from synthetic preservatives.	Golpaigani et al. (2023)
Thawed drip hydrolysates from pork ham	Pork patty	• Thawed drip hydrolysates reduced thawing and cooking losses and delayed color deterioration during freeze-thaw cycles. • Protein denaturation and oxidation were inhibited, as evidenced by lower carbonyls and surface hydrophobicity, higher free sulfhydryl, and α-helix content. • 1.4% hydrolysate concentration showed the strongest protective effect, comparable to the positive control (sorbitol + sucrose).	Han et al. (2025)

BPs serve as sweetening agents, color stabilizers, texturizers, anti-caking agents, emulsifiers, flavor enhancers, and acidity regulators in food processing. In addition, BPs can enhance product quality by influencing water- and oil-holding capacity, colloidal stability, viscosity, and foaming properties (*Zaky et al*., 2022). Furthermore, growing consumer concerns regarding food safety have driven the industry to explore natural substitutes for synthetic antioxidants. In this context, antioxidant proteins and peptides are considered promising alternatives, as they exhibit equal or even superior capacity to inhibit lipid oxidation (*Aguilar-Toalá et al*., 2022; *Zaky et al*., 2022).

Table 1 presents applications of meat-derived protein hydrolysates and BPs in different food products, along with their highlighted findings. As seen in the related table, the key findings demonstrate that protein hydrolysates and BPs, mostly those derived from fish, have been successfully incorporated into diverse food systems such as meat, dairy, bakery products, and beverages. These components exhibited health-promoting bioactivities, including antioxidant, antihypertensive, antimicrobial, and enzyme-inhibitory effects. Moreover, they contributed to improved oxidative stability, microbial safety, sensory acceptance, and techno-functional properties of the products. Overall, their multifunctional potential highlights an important role in preserving food quality and developing functional foods. Specifically, umami and koku-inducing peptides from meat origin are increasingly recognized as promising functional compounds for enhancing flavor perception and sensory quality in food systems (*Mora and Toldrá*, 2025).

Although BPs can be directly incorporated into formulations, one of their most notable applications is in food packaging, where they are embedded as antimicrobial agents to enhance food safety and prolong shelf life (*Alzaydi et al*., 2023). *Notably, Si et al.* (2024) reported that utilization of composite hydrogels with antimicrobial peptides was effective in inhibiting *Staphylococcus aureus* and *Escherichia coli*, and prolonged the storage time of frozen chicken breast. Taken together, these findings underscore the growing importance of meat-derived BPs as multifunctional ingredients with significant contributions to food quality, safety, and functionality across a broad range of applications.

4. From potential to practice: challenges in BP applications in food systems

Although BPs exhibit remarkable health-promoting effects and can enhance the functional quality of foods, their widespread application still faces substantial challenges, requiring more detailed investigations and advanced trials to ensure successful adaptation into industry. The large-scale production of BPs requires effective process scale-up and strong collaborations between research laboratories and industry. For successful use in food applications, BPs must also demonstrate stability against gastrointestinal digestion and proteolytic degradation, along with sufficient absorption across intestinal cells (*Chew et al*., 2019; *Hamdi et al*., 2025).

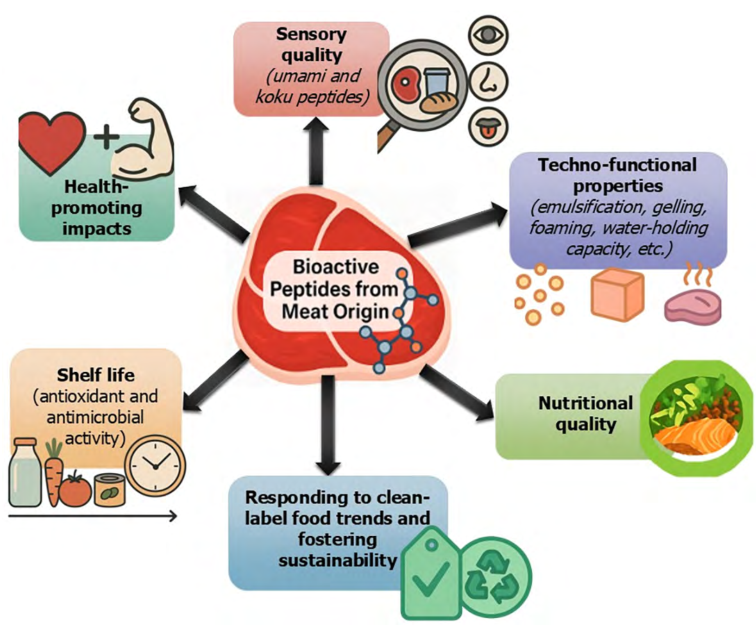

Figure 1. Potential effects of meat-derived BPs on food quality

Zaky et al. (2022) reported that despite advances in understanding peptide structure and function, their interrelationship, stability, and regulatory mechanisms remain insufficiently explored. Therefore, further pre-clinical and clinical studies are crucial to determine effective doses, bioavailability, pharmacokinetics, and the feasibility of integrating BPs into food systems. Due to certain limitations of BPs in the formulation of food and nutraceutical products, further investigations into their interactions within the food matrix, poor water solubility, hygroscopic behavior, and flavor-masking effects are also required. In this context, micro- and nano-encapsulation techniques were mentioned to enhance their compatibility and biological activity upon consumption (*Aguilar-Toalá et al*., 2022). Apart from encapsulation, the use of enzyme inhibitors such as protease blockers, as well as the application of permeation enhancers in epithelial cells, may facilitate the absorption of intact BPs (*Alzaydi et al*., 2023). Moreover, *Hamdi et al.* (2025) highlighted the considerable potential of BPs in the development of functional foods and, in particular, in anticancer research. Their ease of synthesis, structural modifiability, and low immunogenicity also make them attractive candidates for pharmaceutical applications. Nevertheless, their therapeutic use remains constrained by instability within biological systems. This limitation underscores the pressing need for comprehensive clinical studies to establish quality requirements before their full potential in healthcare and food sectors can be realized.

5. Conclusion

Meat-derived BPs are promising compounds with diverse physiological functions and wide application potential in food systems. In addition to their bioactive properties, they can enhance shelf life as well as technological and sensory properties. Their incorporation into functional food formulations is supported by scientific evidence and growing consumer demand for natural health-promoting ingredients. Yet, challenges remain in large-scale production, gastrointestinal stability, bioavailability, and regulatory approval. Advances in processing and encapsulation techniques will be key to overcoming these barriers. Overall, meat BPs hold strong promise as multifunctional ingredients, with further research needed for their full integration into food products.

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Authors info

Burcu Ozturk-Kerimoglu, https://orcid.org/0000-0001-9777-8510