

Review

Not peer-reviewed version

---

# Valorization of By-Products for Functional Ingredients in Meat and Meat Replacers: A Circular Bioeconomy Approach

---

[Ana Leite](#) , [Lia Vasconcelos](#) , [Alfredo Teixeira](#) , [Sandra S.Q. Rodrigues](#) \*

Posted Date: 27 March 2026

doi: 10.20944/preprints202603.2163.v1

Keywords: valorization; by-products; circular economy; sustainability



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a [Creative Commons CC BY 4.0 license](#), which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Review

# Valorization of By-Products for Functional Ingredients in Meat and Meat Replacers: A Circular Bioeconomy Approach

Ana Leite, Lia Vasconcelos, Alfredo Teixeira and Sandra S.Q. Rodrigues \*

CIMO, LASusTEC, Instituto Politécnico de Bragança, Campus de Santa Apolónia, 5300-253 Bragança, Portugal

\* Correspondence: srodrigues@ipb.pt

## Abstract

The food industry faces the dual challenge of meeting a global protein demand projected for 11.2 billion people by 2100 while mitigating environmental impacts. This review explores the valorization of agri-food by-products within a circular bioeconomy, shifting from a linear "take-make-dispose" model to one prioritizing resource efficiency. Processing residues such as fruit peels, pomace, animal blood, and bones is increasingly recognized as an untapped source of functional ingredients. These by-products provide bioactive compounds—such as polyphenols, carotenoids, and peptides—that offer antioxidant and cardioprotective health benefits. Simultaneously, technological compounds such as dietary fibers, collagen, and hydrocolloids serve as structural building blocks. They improve water-holding capacity, texture, and emulsion stability in both traditional meats and plant-based analogues. While upcycling these materials reduces disposal costs and formulation expenses, challenges remain regarding compositional variability, regulatory barriers, and consumer perception of "waste-derived" ingredients. Ultimately, integrating advanced processing technologies such as enzymatic hydrolysis and fermentation is essential to building a resilient, sustainable, and circular global food system.

**Keywords:** valorization; by-products; circular economy; sustainability

---

## 1. Introduction

The global agri-food sector is currently facing the dual challenge of meeting the nutritional demands of a rapidly growing population while mitigating the severe environmental impacts of food production. With the global population projected to reach 8.6 billion in 2030, 9.8 billion by 2050, and approximately 11.2 billion by 2100, according to a new United Nations (UN) report, even accounting for deaths and the continued decline in birth rates. Rising incomes in low- and middle-income countries are expected to accelerate a shift in dietary patterns, increasing consumption of all basic resources (meat, vegetables, and cereals). This transition will require corresponding adjustments in agricultural production and may intensify the pressure placed on natural resources [1,2]. Paradoxically, thousands of tons of food are wasted daily across the supply chain, exacerbating environmental degradation while thousands of people suffer from malnutrition or die of hunger.

To address these inefficiencies, global initiatives such as the United Nations' Zero Hunger goal and the 2030 Agenda for Sustainable Development emphasize responsible food consumption and production [3]. Valorizing agri-food waste containing bioactive compounds has been a trend applicable to most industries. This, in line with the Circular Economy Action Plan approved in Europe, aims to promote the reuse of waste to obtain high-value products [4]. Both the traditional meat industry and the growing meat-replacer sector generate substantial volumes of processing residues, ranging from fruit and vegetable peels and pomaces to animal co-products such as blood plasma and bone-derived fractions [5,6]. Commonly viewed as waste, these materials contribute to

high disposal costs and environmental pollution. The shift towards sustainable food systems has heightened the necessity to rethink food industry by-products, viewing them not as waste but as valuable secondary resources. In the context of the circular bioeconomy, transforming agro-industrial by-products into functional food ingredients offers a strategic approach to lessen environmental impacts while enhancing economic and nutritional value. Producing alternative proteins from waste significantly reduces the environmental footprint by requiring less land, water, and energy. This reduction is reflected in greenhouse gas emissions, which remain high in traditional animal protein production systems [7]. Analyses of food waste recovery show that reuse and conversion to produce functional ingredients support sustainable production strategies that account for food waste and material inefficiencies [8,9].

Recent studies have shown that food processing residues, including those from meat, dairy, and plant-based industries, contain substantial amounts of recoverable proteins, peptides, fibers, and bioactive compounds, some of which exhibit antimicrobial activity, offering both technological and health benefits [8]. Since some of them (tocopherols, ascorbic acid, terpenes, phenolic acids, polyphenols) exhibit antioxidant and antimicrobial activities, they can be used as alternatives to conventional preservatives in these meat matrices [9]. Also, some phytochemicals exhibit prebiotic, anti-inflammatory, antiproliferative, anti-obesity, and antidiabetic effects, among others [10].

On the other hand, this, coupled with improved nutritional and sensory profiles, indicates that consumers are more likely to accept and potentially prefer these enhanced products [4,11]. Another important factor in choosing these products relates to cost, the impact on animal welfare, and familiarity with the taste [12]. This opens avenues for food manufacturers to innovate and differentiate their products in the market [4,11]. However, caution and strategy are necessary when using claims such as "healthy", "natural", "additive-free", "minimally processed", "authentic", and others on product labels, to avoid conveying a sense of trendiness or misleading consumers [9].

A circular bioeconomy approach seeks to close the loop in food systems by upcycling residual biomass into high-value components. This strategy not only reduces waste but also creates new economic streams and improves the overall resource efficiency of the food supply chain [13]. They are increasingly recognized as untapped reservoirs that can enhance food quality, nutrition, and sustainability [6,13]. Valorizing these streams involves extracting or modifying bioactive compounds, such as fibers, proteins, and polyphenols, to serve specific technological roles in food matrices.

The rapid growth of plant-based meat analogues has intensified the search for sustainable, functional ingredient sources. Plant-derived by-products, including berry pomace, citrus peels, oilseed press cakes, fiber-rich residues, and polyphenol compounds (including flavonoids and non-flavonoids), have been investigated for their versatile techno-functional contributions and improving shelf-life stability of meat products and meat substitutes [11,14,15]. They encompass water-holding capacity, gelation, texture modulation, oxidative stability, and coloring agents [16].

Also, these plant-derived fractions provide dietary fiber and natural antioxidants that can extend shelf life and encourage consumption of reformulated products through "clean" labeling [5,9,17]. For instance, pineapple pomace and oilseed cakes (e.g., sunflower and flaxseed) have been shown to modulate the texture and chewiness of extruded meat analogs, creating structures that more closely resemble traditional muscle tissue [5,6]. Although research on valorized animal by-products in plant-based systems remains limited, the broader concept of by-product recovery for functional applications spans both conventional and alternative protein sectors.

In parallel, these ingredients are particularly valuable for addressing common quality issues, such as lipid oxidation, moisture loss, and the lack of dietary fiber, in the meat industry [14,17]. However, it is important to note that although plant-based proteins have proven more efficient in terms of alternative resources, their production is susceptible to climate change and deficiencies in essential amino acids, such as B12, highlighting the need to compensate for these deficiencies with other sources [7]. In the meat industry, significant quantities of trimmings, connective tissues, bones, blood fractions, and organ materials are produced during processing. While some of these components have traditionally been repurposed for animal feed or low-value rendering applications,

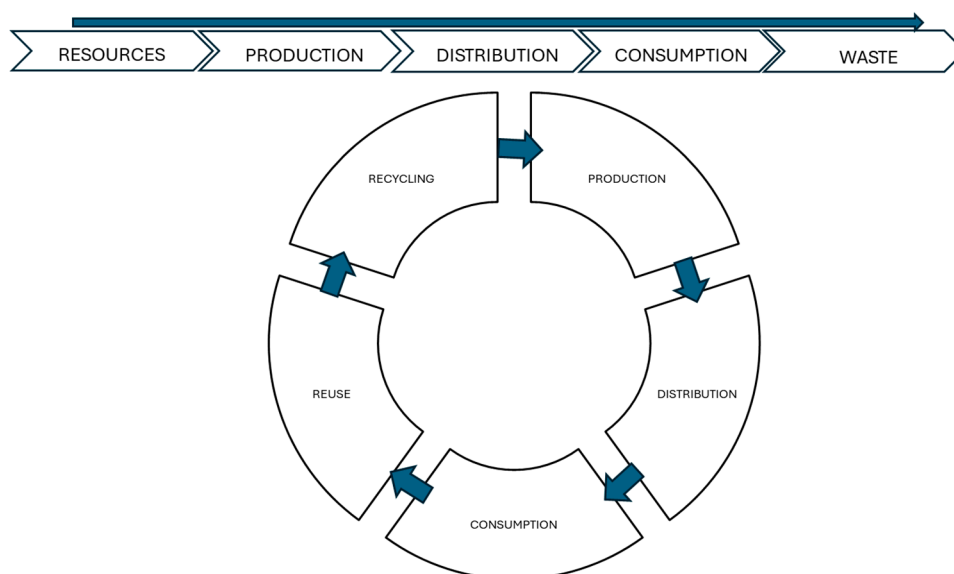
recent biotechnological advancements have facilitated their conversion into high-value functional ingredients. Like vegetable by-products, animal co-products, such as porcine plasma and blood-derived proteins, offer unique gelation and binding properties and a beneficial amino acid profile, which are critical for maintaining juiciness, yield, and functionality in processed meat systems [18,19]. The application of these recycled ingredients enables a comparison between traditional meat and meat substitutes from a functional perspective. While in traditional meat by-products often act as shelf-life extenders and nutritional enhancers, in meat substitutes they function at the level of texture, water retention capacity, and structural integrity [11,15]. Furthermore, they reinforce the viability of these valorization strategies, demonstrating potential to reduce environmental impacts and disposal costs [6,13].

Thus, technologies that transform these waste products into high-value protein products include lignocellulosic biomass processing, single-cell proteins derived from microorganisms, insect protein, and other microbial proteins that grow on low-cost substrates. Enzymatic hydrolysis has been extensively studied as a technique to produce protein hydrolysates with enhanced solubility, emulsifying capacity, antioxidant activity, and potential bioactivity [20]. Similarly, controlled fermentation processes have demonstrated the ability to generate peptides with functional and biological significance from meat and dairy by-products, underscoring the role of microbial biotechnology in waste valorization [21]. These technological advancements align with circular economic principles by preserving material value throughout the food chain. Despite the growing volume of scientific research in specific areas, such as the use of animal by-products and the development of plant-based ingredients, there remains a notable lack of comprehensive reviews that integrate both meat and meat replacer systems within a cohesive circular bioeconomy framework.

This review aims to explore ways of recovering plant by-products and animal co-products as functional ingredients within the framework of a circular bioeconomy. It provides examples of potential applications based on their technological properties and examines their comparative functionality in both traditional meat products and meat substitutes. By highlighting the sustainability and economic benefits of these approaches, this review underscores the critical role of waste valorization in building a more resilient and circular global food system.

## 2. Circular Economy and Valorization of By-Products

The urgency to address environmental and climate challenges continues to intensify. Traditional economic models based on production and disposal are increasingly recognized as unsustainable, highlighting the need for systemic change. Growing pressure to adopt more sustainable approaches is driving the transition from a linear to a circular economy, prioritizing resource efficiency, waste reduction, and long-term value retention. According to the World Health Organization [22], the circular economy is grounded in a structural and systemic shift away from a linear economic paradigm. Whereas the linear approach is characterized by the extraction of natural resources, production, use, and eventual disposal, the circular economy aims to maintain resources in circulation for as long as possible. This is achieved by promoting continuous reuse and by reducing the pressure on natural systems imposed by the traditional linear model. The circular and linear economy models are illustrated in Figure 1.



**Figure 1.** The linear and circular economy.

The concept of the circular economy has also become increasingly relevant in the context of waste management and the utilization of industrial by-products. Unlike traditional waste management approaches, circular strategies intend to convert residues and by-products into valuable resources that can be reintegrated into production systems. This approach reduces environmental impacts and promotes the efficient use of materials and energy across supply chains. Agro-industrial by-products have attracted increasing attention due to their high content of bioactive compounds, fibers, and other valuable constituents that can be recovered and used in the food, pharmaceutical, and cosmetics industries. Converting these materials into value-added products aligns with the principles of the circular bioeconomy and reduces the environmental impact of waste disposal [23]. Despite growing interest and technological progress in this field, challenges remain in the large-scale implementation of circular economic strategies. These challenges include technical limitations related to process scalability, variability in by-product composition, economic feasibility, regulatory barriers, and consumer acceptance of waste-derived products. Overcoming these challenges requires interdisciplinary collaboration among researchers, industry stakeholders, and policymakers to develop efficient valorization pathways and encourage sustainable innovation in circular production systems [24]. According to the Food and Agriculture Organization, approximately one-third of all food produced globally for human consumption is lost or wasted each year, amounting to nearly 1.3 billion tons. This food is lost or wasted throughout the supply chain, including during production, processing, distribution, retail, and final consumption. In addition to the economic losses associated with wasted resources, food waste contributes significantly to environmental degradation, including greenhouse gas emissions, land degradation, and inefficient water use [25].

#### *Animal and Plant By-Products*

The food sector is currently facing a range of structural and conjunctural challenges that significantly affect its economic, environmental, and social sustainability. Among the main challenges are rising production costs, driven by higher energy and raw material prices, as well as the impacts of geopolitical conflicts that disrupt global supply chains and logistics systems. In addition, labor shortages in several regions, combined with changing consumer habits – particularly the growing demand for healthier, more sustainable foods with transparent origins – require continuous adaptation from companies operating in the food sector. At the same time, sustainability and climate change have become central issues in the agri-food sector. Extreme climate events, such as prolonged droughts, floods, and abrupt temperature variations, directly affect agricultural productivity, the

availability of raw materials, and the stability of food production chains. These impacts underscore the urgent need to develop strategies that promote more resilient, resource-efficient food systems [26,27].

In this context, reducing food waste has been widely recognized as a global priority. It is estimated that a significant proportion of food produced worldwide is lost or wasted across different stages of the food supply chain, from agricultural production to final consumption. This phenomenon has a considerable economic impact due to the waste of water, energy, land, and other resources used in food production. Throughout the various stages of the food production chain, numerous by-products and residues are generated. Traditionally, many of these materials have been undervalued or directed toward low-value applications, such as animal feed or disposal. However, recent studies demonstrate that several of these by-products have high valorization potential and can be used as alternative raw materials rich in bioactive compounds, dietary fibers, proteins, and other components with relevant technological and functional properties. The valorization of food by-products is closely aligned with the circular economy, which aims to maximize resource efficiency and minimize waste generation across the entire production system. In this sense, transforming by-products into value-added ingredients or materials of the food sector, while simultaneously contributing to waste reduction and innovation in the development of new food products [28], represents a vital strategy.

Animals and plant by-products are generated in large quantities throughout the food production and processing chain. These materials originate from agricultural activities, food processing operations, and industrial processes, and generally include husks, seeds, pomace, skins, bones, and other residual fractions. Although traditionally considered waste or used in low-value applications such as animal feed or disposal, these by-products have been attracting increasing scientific and industrial interest due to their rich composition of bioactive compounds, dietary fiber, proteins, lipids, and other functional components. The recovery and valorization of these materials represent an important strategy for improving resource efficiency, reducing environmental impact, and promoting more sustainable and circular food systems [9].

Despite growing scientific and industrial interest in valorizing plant and animal by-products, several factors still limit their large-scale implementation. One of the main challenges is the variability in the chemical composition of these materials, which can depend on factors such as species, processing conditions, and seasonal variations. Additionally, technological limitations related to extraction, stabilization, and processing techniques can hinder the efficient recovery of valuable compounds. Additionally, regulatory constraints regarding the incorporation of recovered ingredients into food products represent an important limitation because strict safety and quality standards must be met. Furthermore, consumer perception of foods derived from waste streams may influence market acceptance, underscoring the importance of transparency and communication about the sustainability benefits of these practices.

These challenges require the development of standardized, efficient processing technologies and supportive regulatory frameworks that facilitate the safe use of recovered compounds in food systems. Increasing research efforts and greater consumer awareness are also essential to promoting the transition toward more sustainable, circular food production systems. In this context, valorizing plant and animal by-products is a promising strategy for improving resource efficiency, reducing environmental impacts, and supporting the development of innovative, sustainable food products.

### 3. Functional Compounds Derived from By-Products

A functional compound - often referred to as a bioactive compound or functional ingredient - is defined as a specific chemical substance found in, or extracted from, a biological source that provides a targeted benefit when added to a food matrix [29,30]. Within the context of meat and meat analogues, these compounds generally fall into two distinct categories based on their intended target: those that provide physiological health benefits to the consumer, and those that fulfill technological functions within the food structure.

### 3.1. Bioactive Functional Compounds (Health-Targeted)

Bioactive functional compounds are molecules that confer physiological health benefits beyond basic nutritional requirements. They are primarily utilized in the formulation of functional foods intended to promote optimal health or mitigate the risk of chronic diseases. A diverse array of these compounds, derived from both plant and animal sources [31,32], can be integrated into meat products and their analogues to enhance their nutritional profiles.

#### 3.1.1. Plant-Derived Bioactive Compounds

Plants, fruits, vegetables, and their processing by-products are rich reservoirs of functional compounds that offer significant health benefits, primarily by protecting against cellular oxidative damage. Polyphenols, encompassing a wide array of flavonoids [33] and phenolic acids (e.g., gallic, caffeic, and salicylic acids) [34], act as powerful antioxidants and anti-inflammatory agents. These compounds provide extensive systemic benefits, including cardioprotective and neuroprotective effects, as well as improved endothelial function. Similarly, carotenoids (such as  $\beta$ -carotene, lycopene, and lutein) are highly valued for their strong antioxidant, anti-inflammatory, and anti-carcinogenic properties [35]. Glucosinolates—precursors to active compounds like sulforaphane and isothiocyanates—further contribute to disease prevention by supporting natural detoxification pathways [36]. Finally, essential vitamins found in these plant sources, such as C, A, K, and folate, play a foundational role in general disease prevention, management, and overall health.

In addition to the previously mentioned compounds, plant sterols (which include both sterols and stanols) play a vital role in health management. They are specifically noted for their ability to aid in cholesterol and cancer control, while contributing to a broader One Health approach [37]. Furthermore, dietary fiber, encompassing both soluble and insoluble forms, offers significant functional and technological benefits. These include prebiotic dietary fibers (such as various oligosaccharides, polysaccharides, and resistant starches), which stimulate beneficial gut microbiota [38], as well as dietary fibers that reduce cholesterol levels, blood pressure, and inflammation, and improve vascular and immune function [39]. Beyond basic nutritional fortification, dietary fibers are highly effective tools for replacing fat and reducing calories, making them incredibly useful for creating healthier, lower-fat food formulations without sacrificing texture.

Table 1 shows different plant-derived functional compounds and their bioactive effects.

**Table 1.** Functional compounds found in plants, fruits and vegetables, and their effects.

Category	Examples	Functional effects	Reference
Polyphenols	Flavonoids (flavones, flavonols, isoflavones, flavanones, and anthocyanins)  Phenolic acids (hydroxybenzoic (salicylic acid, protocatechuic acid, vanillic acid, benzoic acid, gallic acid, and ellagic acids) and hydroxycinnamic acids (p-coumaric, caffeic, ferulic, and sinapic acids))	Antioxidant, anti-inflammatory, antidiabetic, cardioprotective, neuroprotective; improve endothelial function; chronic disease risk reduction	[34,39–41]
Carotenoids	$\beta$ -carotene, lycopene, lutein, $\alpha$ -carotene	Antioxidant, anti-cancer, anti-inflammation, and anti-allergenic properties	[35]
Glucosinolates	Sulforaphane precursors, isothiocyanate precursors	Anti-cancer, antioxidant, detoxification supportive	[36,42]

Vitamins	C, A, K, folate	Disease prevention, management, and control	[43]
Minerals	K, Mg, Ca	Maintaining normal health, preventing disease, optimal functioning of the immune system	[44,45]
Plant sterols	Sterols, stanols	Cholesterol control, cancer control, contribution to one health approach	[37,46,47]
Dietary fiber	Soluble & insoluble	Fat replacement, calorie reduction, nutritional fortification	[48,49]

### 3.1.2. Animal-Derived Bioactive Compounds

Animal-derived functional compounds (Table 2) play a dual role in modern food science: they enhance the physiological benefits of traditional meat products and serve as critical fortifying agents to address nutritional gaps in plant-based meat analogues, thereby transforming both into targeted functional foods. Based on their biological applications, they can be grouped into different categories.

Derived from the breakdown of animal proteins, bioactive peptides act as powerful dual-purpose ingredients. Technologically, their natural antioxidant and antimicrobial properties help delay lipid oxidation and inhibit the growth of foodborne pathogens, thereby vastly extending the shelf life of the meat matrix. Physiologically, they provide targeted health benefits, most notably serving as antihypertensive agents and immune system enhancers [50]. Expanding on peptide technology, fermented dairy bioactives (probiotic metabolites, antimicrobial peptides, and immunomodulatory peptides) derived from dairy fermentation [51] provide significant gut health support, immune enhancement, and systemic anti-inflammatory benefits.

Lipid fractions, such as Omega-3 polyunsaturated fatty acids (DHA and EPA) and conjugated linoleic acid (CLA), are increasingly incorporated into meat products to improve their lipid profiles. While Omega-3s are fortified for their cardioprotective, anti-inflammatory, and neuroprotective properties [52], CLA is valued for its ability to regulate immune responses and support lipid metabolism [53]. Due to their susceptibility to oxidation, these highly unsaturated fats often require microencapsulation prior to incorporation [54]. Furthermore, naturally occurring endogenous antioxidants (Coenzyme Q10, Glutathione, Lipoic Acid), provide potent systemic anti-inflammatory properties while serving as critical technological aids by scavenging free radicals and preserving myoglobin color [55–57].

Beyond their vital technological role as emulsifiers (such as lecithin, which stabilizes the fat-water matrix in vegan burgers), choline and betaine act as potent biological regulators. They actively support neurotransmitter synthesis for optimal cognitive function and play a foundational role in liver health [58].

Crucially, modern plant-based meat analogues often require fortification with "carnitrients"—bioactive compounds naturally abundant in animal tissues but absent in the plant kingdom—to achieve true nutritional mimicry [59]. These include creatine, which acts as a vital cellular energy buffer; L-carnitine, which facilitates fatty-acid transport for cellular energy production; and taurine, which provides essential cardioprotective and neurological support.

**Table 2.** Functional compounds found in animals and their effects.

Compound Category	Examples	Functional effects	References
Bioactive Peptides	Antihypertensive peptides, antioxidant peptides,	Antioxidant, antihypertensive, antimicrobial, immune enhancing	[60–63]

			antimicrobial peptides			
Omega 3 Long Chain Fatty Acids			DHA (docosahexaenoic acid), EPA (eicosapentaenoic acid)	Cardioprotective, anti-inflammatory, neuroprotective	[64]	
Conjugated Linoleic Acid (CLA)			c9,t11 CLA, t10,c12 CLA	Supports lipid metabolism, immune regulation, fat oxidation	[53,54]	
Creatine analogues)	(in meat)		Creatine, phosphocreatine	Enhances metabolism, muscle performance, brain function	[59,65]	
Carnitine analogues)	(in meat)		L carnitine	Facilitates fatty-acid transport for energy production, contributes to overall metabolic and muscle function	[66]	
Taurine analogues)	(in meat)		Taurine	Cardioprotective, antioxidant, neurological support	[65]	
Endogenous Antioxidants			Coenzyme glutathione, acid	Q10, lipoic	Antioxidant, anti-inflammatory, supports energy production	[55–57]
Fermented Bioactives		Dairy	Probiotic metabolites, antimicrobial peptides, immunomodulatory peptides	Gut-health support, immune enhancement, anti-inflammatory	[51,67–70]	
Choline & Compounds		Related	Choline, betaine	Supports neurotransmitter synthesis, liver health, cognitive function	[58,71]	

### 3.2. Technological Functional Compounds (Matrix-Targeted)

While bioactive compounds target human health, technological functional compounds are utilized specifically to solve structural and manufacturing challenges: binding moisture, stabilizing emulsions, extending shelf life, and engineering precise textural attributes. Based on their biological origin, these technological tools function in distinct ways across the meat industry.

#### 3.2.1. Plant-Origin Technological Compounds

Because plant-based meat analogues inherently lack the myofibrillar proteins that confer gelling in animal muscle, food scientists must construct the meat matrix using plant-derived ingredients [72]. Functional plant proteins (e.g., highly extruded wheat gluten or soy isolate) provide the fundamental fibrous texture, while plant-based emulsifiers (e.g., soy lecithin) are required to bind the added plant oils and water, preventing fat separation during thermal processing [73,74].

Hydrocolloids, such as carrageenan, xanthan gum, and konjac, are widely used for their exceptional water-binding and gel-forming properties [75]. In traditional meat products, dietary fibers act as moisture-retaining agents, enabling significant reductions in animal fat while

maintaining a juicy mouthfeel [49]. Additionally, natural plant extracts (such as rosemary and oregano) serve as potent antioxidants that inhibit lipid oxidation [76], while nitrate-rich vegetable powders (like celery juice powder) act as clean-label curing agents to stabilize the classic pink pigment of processed meats [77].

Table 3 presents plant-origin technological compounds and their effects on meat products and their analogues.

**Table 3.** Plant-origin technological compounds and their effects.

Compound Category	Examples	Technological Effects	Functional Effects	Reference
Hydrocolloids & Gums	Carrageenan, xanthan gum, konjac root, alginate, agar	Gelation	& Binding: Binds massive amounts of water to create firm, sliceable gels. In vegan meats, konjac and carrageenan are often used to mimic the firm-but-melting texture of animal fat pockets.	[75,78]
Dietary Fibers	Citrus fiber, oat fiber, bamboo fiber, cellulose	Moisture Retention & Fat Replacement:	Acts like a microscopic sponge. It dramatically reduces "drip loss" during cooking, keeping the meat juicy, and provides bulk to replace animal fat in low-fat sausages.	[49,79]
Functional Proteins	Plant Soy protein isolate, wheat gluten (seitan), pea protein	Texturization & Emulsification:	Creates the core structural network. Wheat gluten provides a highly elastic, fibrous chew, while soy and pea proteins act as structural emulsifiers to hold the batter together.	[73,74]
Natural Preservatives & Color Fixers	Rosemary extract, celery juice powder, cherry powder	Shelf Life & Curing:	Rosemary extract prevents lipid oxidation (rancidity). Celery powder provides natural nitrites, which cure the meat, prevent botulism, and lock in the classic pink color of hot dogs and bacon.	[76,77]
Plant Emulsifiers	Soy lecithin, sunflower lecithin	Emulsion Stability:	Prevents fat and water from separating. Ensures that the added plant oils don't simply melt and leak out of a vegan burger when it hits a hot grill.	[74]

### 3.2.2. Animal-Origin Technological Compounds

In the traditional meat sector, animal-derived compounds are highly prized for their unparalleled binding strength and thermo-reversible properties [80,81]. Dairy proteins, specifically sodium caseinate, act as highly effective emulsifiers, rapidly coating fat droplets to create stable oil-in-water emulsions that withstand high cooking temperatures [82,83]. Ingredients like gelatin

provide strong cold-set gels ideal for slicing deli meats, while egg whites form firm heat-set gels upon cooking. Finally, cross-linking enzymes, such as microbial transglutaminase, catalyze covalent bonds between protein molecules, allowing processors to restructure meat trimmings and improve product texture [84,85].

Table 4 shows animal-origin technological compounds and their effects on meat products and their analogues.

**Table 4.** Animal-origin technological compounds and their effects.

Compound Category	Examples	Technological Effects	Functional	References
Connective Tissues & Blood Proteins	Gelatin, collagen powder, blood plasma	Cold-Set Gelation & Yield: Gelatin and collagen melt when heated but form strong, sliceable gels when chilled (crucial for deli meats and pâtés). Blood plasma is an incredibly strong binder used to glue meat particles together.		[86,87]
Dairy Proteins	Sodium caseinate, whey protein concentrate	Superior Emulsification: Caseinates are among the most powerful emulsifiers in food science. They coat fat droplets in finely milled sausages to completely prevent fat rendering (greasing out) during cooking.		[82,83]
Cross-linking Enzymes	Transglutaminase (often called "meat glue")	Structural Restructuring: An enzyme that catalyzes permanent covalent bonds between protein molecules. It is used to bind scrap meat pieces together into uniform steaks or to give sausages a perfectly snappy "bite."		[88,89]
Egg Derivatives	Egg white powder (ovalbumin), egg yolk lecithin	Heat-Set Gelation: Egg whites form irreversible, highly elastic gels when heated, providing a very firm chew to processed meats. Egg yolks are used for their natural emulsifying power.		[90,91]
Fermented Bioactives	Dairy Exopolysaccharides (EPS) from Lactic Acid Bacteria	Biothickening: Long-chain sugars secreted by dairy bacteria that act as natural thickeners and water-binders, improving the mouthfeel and stability of low-fat fermented meats (like salami).		[69,92]

Although these functional ingredients offer significant advantages, their high extraction costs often limit universal commercial application. Consequently, they are typically reserved for premium health markets or necessary fortification in meat analogues. However, embracing the circular bioeconomy presents a sustainable economic solution [93]. By upcycling underutilized animal by-

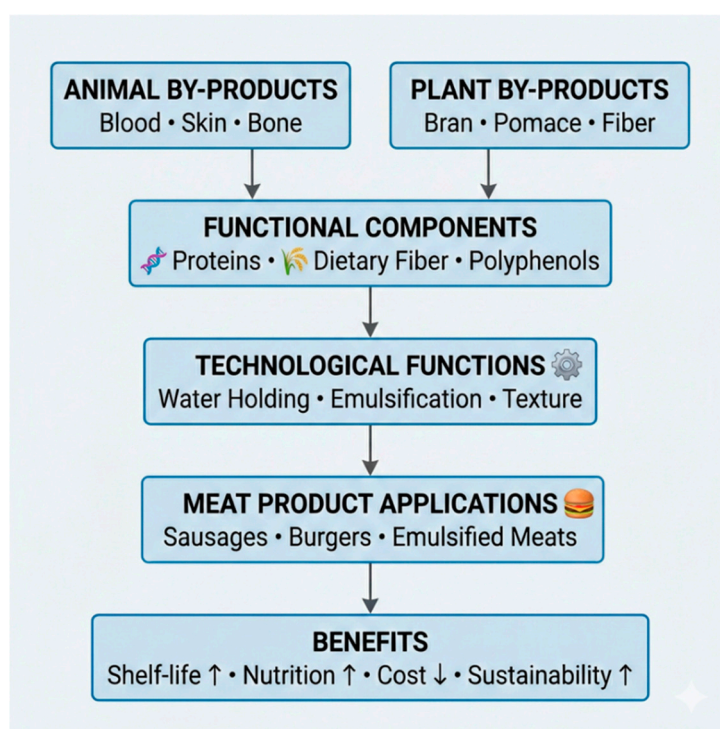
products (such as blood plasma and dairy processing streams) and plant side streams (such as oilseed press cakes and fruit pomace), the food industry can transform low-value raw materials into premium functional ingredients [94,95]. This approach not only minimizes global agricultural waste but drastically lowers formulation costs, creating an economically viable and nutritionally robust supply chain for both traditional and alternative meat sectors. Ultimately, the most valuable functional compounds within this framework are those exhibiting dual functionality—such as apple pomace dietary fiber, which acts technologically to bind water while physiologically lowering glycemic responses [96–99].

#### 4. Application

The agri-food industry generates significant quantities of by-products and waste streams that have traditionally been underutilized or discarded, contributing to environmental and economic inefficiencies. In particular, the meat industry produces substantial quantities of by-products during slaughter and processing operations, including blood, bones, skin, fat, and connective tissues, as well as plant-derived residues incorporated during formulation.

Historically considered low-value materials or waste, these by-products are increasingly recognized as valuable sources of functional ingredients with technological, nutritional, and economic benefits. Within the framework of the circular bioeconomy, their valorization enables reintegration into the food chain, reducing waste and improving resource efficiency [100,101], while supporting the transition toward more sustainable and circular food systems [8,102].

By-products of both animal and plant origin contain a wide range of bioactive and functional compounds. Animal-derived by-products are particularly rich in high-quality proteins such as collagen and gelatin, which are widely used in meat processing due to their excellent gelling, emulsifying, and water-binding properties. Blood proteins, for instance, exhibit strong emulsification and foaming capacities, making them suitable for incorporation into emulsified meat products such as sausages and pâtés. Similarly, collagen extracted from skin and connective tissues contributes to improved texture, binding, and structural integrity in processed meats [93,102,103]. The main sources, functional components, and applications of by-products in meat systems are summarized in Figure 2.



**Figure 2.** Valorization of by-products as functional ingredients in meat products.

Plant-based by-products, including fruit pomace, cereal bran, oilseed cakes, and vegetable residues, are increasingly incorporated into meat products due to their high content of dietary fiber, polyphenols, antioxidants, and water-binding capacity. These compounds enhance water-holding capacity, reduce cooking losses, and improve emulsion stability. In addition, the antioxidant activity of plant-derived phenolics plays a crucial role in delaying lipid oxidation, thereby extending the shelf life of meat products and maintaining their sensory quality [9,104,105]. These properties make them suitable for incorporation into food matrices, particularly in meat systems where moisture retention and oxidative stability are critical.

Similarly, animal-based by-products such as blood, bones, skin, and connective tissues provide high-value components including collagen, gelatin, and bioactive peptides. These compounds are widely used to improve texture, nutritional value, and functional performance in meat products [9,102]. In addition, emerging sources such as algae residues, fermentation biomass, and insect-derived materials are gaining relevance due to their high protein content and sustainability potential.

The incorporation of by-products into meat products offers multiple functional benefits. From a technological perspective, these ingredients enhance water-holding capacity, emulsion stability, and fat-binding properties, thereby improving texture and product yield. Dietary fibers and protein extracts derived from by-products can act as structuring agents, reducing formulation costs while maintaining product quality. Moreover, the presence of polyphenols and other antioxidant compounds contributes to oxidative stability by delaying lipid and protein oxidation, which are primary causes of quality deterioration in meat products [9]. In addition to antioxidant effects, certain by-products exhibit antimicrobial properties due to the presence of phenolic compounds and bioactive peptides, thereby extending shelf life and improving food safety.

Nutritionally, the use of by-products enriches meat products with dietary fiber, micronutrients, and bioactive compounds, aligning with current consumer demand for healthier foods. Furthermore, these ingredients support clean-label formulations by replacing synthetic additives such as preservatives and stabilizers with natural alternatives. This is particularly important in the context of increasing consumer awareness and preference for minimally processed foods with recognizable ingredients.

In parallel, by-products are increasingly utilized in the development of meat replacers, particularly plant-based analogues. These products rely on plant proteins and structuring agents to mimic meat's sensory characteristics. By-products such as oilseed meals and legume residues serve as cost-effective protein sources, while dietary fibers contribute to the development of fibrous textures and improved mouthfeel [16]. Additionally, by-products can enhance sensory properties, such as flavor and color, though careful formulation is required to avoid undesirable attributes. The presence of bioactive compounds in plant-derived by-products further contributes to the development of functional meat analogues with potential health benefits, such as antioxidant and anti-inflammatory effects.

Advanced processing technologies play a crucial role in enabling the use of by-products in both meat products and meat replacers. Techniques such as extrusion are widely used to create fibrous structures in plant-based meat analogues, while enzymatic hydrolysis and fermentation improve digestibility, functionality, and flavor. These processes are essential for overcoming some of the limitations associated with raw by-products, including poor sensory properties and limited nutrient bioavailability.

From a circular bioeconomy perspective, the valorization of by-products represents a key strategy for achieving sustainable food systems. By converting waste streams into functional ingredients, the food industry can reduce environmental impacts, lower greenhouse gas emissions, and decrease reliance on primary raw materials [100,102]. Industrial symbiosis further enhances this approach by facilitating the exchange of by-products between sectors, such as the use of brewery residues in food formulations or the transformation of dairy whey into protein ingredients. The biorefinery concept extends this idea by integrating multiple processes to extract high-value compounds from biomass while minimizing waste generation [105].

Despite these advantages, several challenges must be addressed to fully exploit the potential of by-products in food applications. Safety concerns, including the presence of contaminants such as mycotoxins and heavy metals, require careful monitoring and control. Additionally, variability in by-product composition, driven by seasonal and processing differences, poses challenges for standardization and consistent product quality.

Recent studies on the application of animal- and plant-derived by-products as functional ingredients in meat products and meat analogues, highlighting their technological roles and effects on product quality, are summarized in Table 5.

**Table 5.** Applications of by-products as functional ingredients in meat products and meat replacers.

By product	Ingredient type	Application	Functional Role	Key Findings	References
Blood plasma	Animal protein	Sausages	Emulsifier, binder	Improved emulsion stability at 10% replacement	[106]
Animal skin, bones	Collagen / gelatin	Sausages, emulsified meats	Gelation, water-holding, emulsification	Improved texture, stability, and elasticity in meat systems	[107]
Blood (porcine/bovine)	Blood proteins / plasma	Meat emulsions, sausages	Emulsification, binding	Enhanced emulsion stability and protein functionality	[108]
Meat by-products (liver, skin, bones)	Protein hydrolysates / peptides	Functional meat formulations	Antioxidant, antimicrobial	Bioactive peptides improve nutritional and functional properties	[109]
Meat processing streams	Recovered proteins	Sausages	Protein replacement	Maintained quality at ≤10% inclusion	[106]
Collagen (skin/bones)	Gelatin/collagen	Emulsified meats	Gelation, WHC	Improved texture and elasticity	[110]
Wheat bran	Dietary fiber	Functional sausages	WHC, fat replacement	Improved fiber content and shelf-life	[111]
Date fiber	Plant fiber	Meat analogues	Fibrous structure	Improved anisotropy and texture	[111]
Okara	Soy by-product fiber	Pork jerky	Meat extender	Up to 10% improved texture and flavor	[112]
Okara	Protein + fiber	Burgers/ sausages	Fat reduction, WHC	Increased fiber, reduced fat	[113]
Brewers spent grain	Insoluble fiber	Meat analogues	Texture structuring	Enhanced “meaty” texture	[114]
Vegetable residues	Fiber	Meat extenders	WHC, yield	Increased yield and reduced fat	[113]
Cereal ingredients	Plant-based ingredients	Hybrid meat sausages	Reduce meat content	Acceptable sensory properties	[115]

Mixed industrial products	agro-by-	Bioactives	Functional meat	Antioxidant	Improved nutritional quality	[110]
Fruit pomace		Polyphenols + fiber	Meatballs	Antioxidant	Increased fiber and oxidative stability	[116]
Liver/offal		Organ meat	Pâté	Nutritional enrichment	Increased protein and micronutrients	[116]
Edible filamentous fungi		protein bioingredients	Meat analogues	Functional protein source	Alternative protein source	[117]
Animal products (general)	by-	Bioactive peptides	Functional foods	Antioxidant, antimicrobial	Added health functionality	[118]
Olive cake (in animal diet → indirect)		Functional feed	Dry-cured meat	Lipid profile modulation	Improved fatty acid profile and oxidative stability	[119]
Sweet potato residues		Fiber	Meat analogues	Structure	Similar texture to meat	[120]
Soy pulp residues		Fiber/protein	Hybrid sausages	Texture	Acceptable sensory up to 20%	[120]
Bamboo shoot residue		Fiber	Hybrid meat	Texture improvement	Improved emulsion stability	[120]
Olive cake (in animal diet → indirect)		Functional feed	Dry-cured pork meat products	Lipid quality	Lower PUFA n-6/n-3 ratio	[121]
Olive cake (in animal diet indirect)		Functional feed	Pork meat quality	Chemical Compositions Lipid profile	optimizing feeding strategies, better meat quality and sustainability.	[122]

As summarized in Table 5, the current literature demonstrates the multifunctional potential of a wide spectrum of raw materials. These range from animal-derived components such as blood plasma, collagen, and protein hydrolysates to plant-based residues like wheat bran, okara, and fruit pomace—each contributing distinct functional properties, including emulsification, water-holding capacity, antioxidant activity, and textural enhancement. Notably, the recurrence of certain functional roles, particularly water-holding capacity and emulsion stability, underscores their critical importance in meat system reformulation.

Despite these promising technological applications, several gaps in the literature remain. First, studies are predominantly focused on technological performance, while fewer address sensory acceptance, scalability, and long-term consumer perception, which are crucial for industrial implementation. Second, although multiple by-products show promising results at specific inclusion levels (e.g., ≤10–20%), the lack of standardized experimental conditions across studies limits direct comparability and generalization. Additionally, some redundancy in entries (e.g., repeated references to similar by-products such as collagen or olive cake) suggests the need for better categorization or grouping to improve clarity. The inclusion of emerging sources such as filamentous

fungi and indirect applications via animal feed is particularly valuable, as it broadens the perspective beyond conventional uses and reflects evolving research trends. Nevertheless, the table would benefit from a more explicit distinction between direct and indirect valorization pathways, as well as the inclusion of quantitative performance indicators (e.g., percentage improvements, sensory scores). Overall, Table 5 effectively illustrates the multifunctional potential of by-products and highlights critical research gaps in standardization, sensory validation, and industrial feasibility that must be addressed to fully support their integration into circular bioeconomy-driven food systems. Sensory limitations, such as off-flavors, undesirable colors, and textural issues, may also restrict their use at high inclusion levels. Furthermore, regulatory barriers and consumer perceptions of by-products as “waste-derived” ingredients can hinder market acceptance.

## 5. Future Perspectives

The valorization of agri-food by-products as functional ingredients represents a transformative strategy for the food industry, aligning product innovation with the core principles of the circular bioeconomy. By recovering high-value bioactive compounds—such as collagen, dietary fibers, and polyphenols—from both animal and plant waste streams, industry can enhance the technological, nutritional, and shelf-life attributes of traditional meat products and emerging plant-based analogues. However, fully exploiting these materials at an industrial scale requires addressing several challenges, including compositional variability, safety concerns related to contaminants, and inherent sensory limitations.

Moving forward, the successful widespread application of these ingredients depends on several key future directives. First, extraction and processing technologies must be optimized to maximize the safety and functionality of by-product-derived ingredients. Furthermore, integrating advanced approaches, such as precision fermentation and artificial intelligence-driven formulation, offers significant potential to expand their applications. At the same time, overcoming the consumer perception of by-products as “waste-derived” materials is essential; increasing awareness of their sustainability benefits will be key to market acceptance. To fully unlock the potential of these ingredients, progress in food technology, regulatory frameworks, and consumer education must occur simultaneously. Future research efforts should focus on optimizing protein sources, developing scalable production methods, conducting comprehensive environmental and economic assessments, and leveraging artificial intelligence to drive innovation. Ultimately, incorporating by-products into food matrices not only improves product performance but also supports the global transition toward more sustainable, efficient, and resilient food systems.

**Author Contributions:** Conceptualization, S.S.Q.R.; writing—original draft preparation, S.S.Q.R., A.L., L.V. and A.T.; writing—review and editing, S.S.Q.R., A.L., L.V. and A.T. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

**Acknowledgments:** Authors are grateful to the Foundation for Science and Technology (FCT, Portugal) for financial support by national funds FCT/MCTES to CIMO (UIDB/00690/2020); Laboratory of Carcass and Meat Quality, Agriculture School of Polytechnic Institute of Bragança. The authors A. Teixeira and S.S.Q. Rodrigues are members of the SISPEC network, funded by CYTED (ref. 12RT0167).

## References

1. United Nations. World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. United Nations. Accessed 10 March 2026.
2. FAO, The Future of Food and Agriculture– Trends and Challenges, Food and Agriculture Organization of the United Nations, Rome, 2017.
3. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. General Assembly Resolution A/RES/70/1; Division for Sustainable Development, United Nations Department of Economic and Social Affairs; United Nations: New York, NY, USA, 2015; Available online: [https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A\\_RES\\_70\\_1\\_E.pdf](https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf) (accessed on 10 march 2026).
4. Pinna, N.; Ianni, F.; Codini, M.; Cenci-Goga, B. T.; Misuraca, M.; Costanzi, E.; Cossignani, L.; & Blasi, F. Development of Value-Added Chicken Burgers by Adding Pumpkin Peel Powder as a Sustainable Ingredient. *Antioxidants*, **2025**, *14*(6), 648. <https://doi.org/10.3390/antiox14060648>
5. Lu, V.L.; Gavahian, M.; Lin, J. Textural properties of plant-based meat analogue Extrudates enriched with pineapple processing by-product powder. *Int. J. Food Sci. Technol.* **2025**, *60*, Issue 1, vvae080. <https://doi.org/10.1093/ijfood/vvae080>
6. Luise, L.; Torres Gomez, A. M.; Maria, A.; Jonas, N.; & Cornelia, R. Valorizing Press Cakes as Ingredients in Textured Vegetable Proteins: Processing, Structure, and Texture. *J. Food Sci.* **2025**, *90*(8), e70471. <https://doi.org/10.1111/1750-3841.70471>
7. Dhiman, S.; Mukherjee, G.; & Kumar, A. Alternative proteins from waste streams: a circular economy roadmap for sustainable food systems. *RSC.* **2026**. <https://pubs.rsc.org/en/content/articlehtml/2026/fb/d5fb00829h>
8. Mia, M.S.; Ahmed, M.M.; & Zaman, W. Valorization of food waste into functional ingredients supports a sustainable strategy for the food industry. *Discover Food*, **2025**, *5*, 275. <https://doi.org/10.1007/s44187-025-00584-3>
9. Grasso, S.; Estévez, M.; Lorenzo, J. M.; Pateiro, M.; & Ponnampalam, E. N. The utilization of agricultural by-products in processed meat products: Effects on physicochemical, nutritional and sensory quality - Invited Review. *Meat Sci.* **2024**, *211*, 109451. <https://doi.org/10.1016/j.meatsci.2024.109451>
10. Aguilera, Y.; Benítez, V. Phytochemicals: Dietary Sources, Innovative Extraction, and Health Benefits. *Foods*. **2022**, *11*, 72. <https://doi.org/10.3390/foods11010072>
11. Smarzyński, K.; Kowalczewski, P.Ł.; Tomczak, A.; Zembrzaska, J.; Ślachciński, M.; Neunert, G.; Ruskowska, M.; Świątek, M.; Nowicki, M.; Baranowska, H.M. Upcycling Potato Juice Protein for Sustainable Plant-Based Gyros: A Multidimensional Quality Assessment. *Sustainability*. **2025**, *17*(17), 7626. <https://doi.org/10.3390/su17177626>
12. Boachie, R. T.; & Aluko, R. E. Plant-Based Meat Analogues: Processing, Product Safety, Protein Quality, and Contributions to Environmental Sustainability. *Sustain. Food Proteins*, **2025**, *3*:e70018. <https://doi.org/10.1002/sfp2.70018>
13. Boruah, B.; & Ray, S. Current progress in the valorization of food industry by-products for the development of functional food products. *Food Sci. Appl. Biotechnol.* **2024**, *7*(2), 289. <https://doi.org/10.30721/fsab2024.v7.i2.349>
14. Zhang, J.; & Li, Y. Berry pomace as a potential ingredient for plant-based meat analogs. *Food biotecnol.* **2024**, *1*, 2, 127-139. <https://doi.org/10.1002/fob2.12010>
15. Kurchaeva, E.; Vostroilov, A.; Derkanosova, N.; Artemov, E.; Svetlana, K. Use of Bio-Modified Raw Materials of Plant And Animal Origin in Technology of Functional Foods. *Advances in Engineering Research*, **2018**, *151*. <https://doi.org/10.2991/agrosmart-18.2018.79>
16. da Silva, V.T.; Mateus, N.; de Freitas, V.; Fernandes, A. Plant-Based Meat Analogues: Exploring Proteins, Fibers and Polyphenolic Compounds as Functional Ingredients for Future Food Solutions. *Foods*, **2024**, *13*, 2303. <https://doi.org/10.3390/foods13142303>
17. Haque, A., Ahmad, S., Azad, Z. R. A. A., Adnan, M., & Ashraf, S. A. (2023). Incorporating dietary fiber from fruit and vegetable waste in meat products: a systematic approach for sustainable meat processing

- and improving the functional, nutritional and health attributes. *PeerJ*. **2023**, *11*, e14977. <https://doi.org/10.7717/peerj.14977>
18. Fort, N. F. (2010). Improvement of heat-induced gel properties of porcine plasma. *Food Chemistry*. **2007**, *101*, 49-56. <https://doi.org/10.1016/j.foodchem.2005.11.050>
  19. Álvarez, C., Drummond, L., & Mullen, A. M. (2018). Protein recovered from meat co-products and processing streams as pork meat replacers in Irish breakfast sausages formulations. *LWT*. **2018**, *96*, 679–685. <https://doi.org/10.1016/j.lwt.2018.06.020>
  20. Terzioğlu, E. E.; Oz, E.; Oz, F. Valorization of meat trimming waste via protein hydrolysate production: influence of extraction pH on physicochemical and functional properties. *Int. J. Food Sci. Technol.* **2026**, *61*, vvaf281. <https://doi.org/10.1093/ijfood/vvaf281>
  21. Kuo.; Chen, D.; Jiménez-Flores, R.; Wick, M.; Campanella, O. Valorization of byproducts from meat and dairy industries through fermentation to produce peptides. *Sustain. Food Technol.* **2024**, *2*, 1469-1475. <https://doi.org/10.1039/d4fb00058g>
  22. World Health Organization (WHO). Circular Economy and Health: Opportunities and Risks; WHO: Copenhagen, Denmark, **2018**; Available online: accessed on 4 March 2026.
  23. Dordevic, T. R.; Vujetic, J. C.; Sarac, D. D. P. Current circular economy aspect in valorization of agro-industrial waste as value-added products. *Food Feed Res.* **2024**, *51*, 57-67. <https://doi.org/10.5937/ffr0-48782>
  24. Ligarda-Samanez, C.A.; Huamán-Carrión, M.L.; CalsinaPonce, W.C.; Cruz, G.D.I.; Calderón Huamán, D.F.; Cabel -Moscoso, D.J.; Garcia-Espinoza, A.J.; Sucari-León, R.; Aroquipa-Durán, Y.; Muñoz-Saenz, J.C.; et al. Technological Innovations and Circular Economy in the Valorization of Agri-Food By-Products: Advances, Challenges and Perspectives. *Foods*. **2025**, *14*, 1950. <https://doi.org/10.3390/foods14111950>
  25. Food and Agriculture Organization of the United Nations (FAO). The state of Food and Agriculture 2019: Moving Forward on Food Loss and Waste Reduction; FAO: Rome, Italy, 2019. Available online: accessed on 4 March 2026.
  26. Wang, G.; Wang, Y.; Li, S.; Yi, Y.; Li, C.; Shin, C. Sustainability in Global Agri-Food Supply Chains: Insights from a Comprehensive Literature Review and the ABCDE Framework. *Foods*. **2024**, *13*, 2914. <https://doi.org/10.3390/foods13182914>
  27. Skalkos, D. Prospects, challenges and sustainability of the Agri-Food Supply Chain in the new global economy II. *Sustainability*. **2023**, *15*, 12558. <https://doi.org/10.3390/su151612558>
  28. Chamorro, F.; Carpena, M.; Fraga-Corral, M.; Echave, J.; Rajoka, M, S, R.; Barba, F. J.; Cao, H.; Xiao, J.; Prieto, M. A.; Simal-Gandara, J. Valorization of kiwi agricultural waste and industry by-products by recovering bioactive compounds and applications as food additives: A circular economy model. *Food Chem.* **2022**, *370*, 131315. <https://doi.org/10.1016/j.foodchem.2021.131315>
  29. Rana, A.; Samtiya, M.; Dhewa, T.; Mishra, V.; Aluko, R. E. Health benefits of polyphenols: A concise review. *J. Food Biochem.* **2022**, *46*, 10, e14264. <https://doi.org/10.1111/jfbc.14264>
  30. Doolam, B., Mishra, B., Surabhi, D.; Mandal, S. K.; Sada, S.; Reddy, N. R.; Panda, J.; Rustagi, S.; Mishra, a. k.; Mohanta, Y, K. A systematic review of potential bioactive compounds from *Saccharomyces cerevisiae*: exploring their applications in health promotion and food development. *Environ Dev Sustain.* **2025**, *27*, 2945–2982. <https://doi.org/10.1007/s10668-024-04969-9>
  31. Kausar, T.; Hanan, E.; Ayob, O.; Praween, B.; Azad, Z. A review on functional ingredients in red meat products. *Bioinformation.* **2019**, *15*(5), 358-363. <https://doi.org/10.6026/97320630015358>
  32. Marcía-Fuentes, J.A.; Santos Aleman, R.; Ore Areche, F.; Corilla Flores, D.; Ventura Roman, A.; Martín-Vertedor, D.; Montero-Fernández, I. Functional Foods: A Review of Foods Ingredient and Their Health Benefits. *Food Human*, **2026**, *6*, 100953. <https://doi.org/10.1016/j.foohum.2025.100953>
  33. Iqbal, I.; Wilairatana, P.; Saqib, F.; Nasir, B.; Wahid, M.; Latif, M.F.; Iqbal, A.; Naz, R.; Mubarak, M.S. Plant Polyphenols and Their Potential Benefits on Cardiovascular Health: A Review. *Molecules*, **2023**, *28*, 6403. <https://doi.org/10.3390/molecules28176403>
  34. Gerogianni, V.-E.; Karathanos, V.T.; Chiou, A. Phenolic Acids and Flavonoid Profiles of *Vitis vinifera* L. var. Apyrena Grapes across Four Consecutive Harvest Years. *J. Food Compos. Anal.* **2026**, *152*, 109022. <https://doi.org/10.1016/j.jfca.2026.109022>

35. Gebregziabher, B.S.; Gebremeskel, H.; Debesa, B.; Ayalneh, D.; Mitiku, T.; Wendwessen, T.; Habtemariam, E.; Nur, S.; Getachew, T. Carotenoids: Dietary Sources, Health Functions, Biofortification, Marketing Trend and Affecting Factors – A Review. *J. Agric. Food Res.* **2023**, *14*, 100834. <https://doi.org/10.1016/j.jafr.2023.100834>
36. Baldelli, S.; Lombardo, M.; D'Amato, A.; Karav, S.; Tripodi, G.; Aiello, G. Glucosinolates in Human Health: Metabolic Pathways, Bioavailability, and Potential in Chronic Disease Prevention. *Foods*. **2025**, *14*(6), 912. <https://doi.org/10.3390/foods14060912>
37. Zio, S.; Tarnagda, B.; Tapsoba, F.; Zongo, C.; Savadogo, A. Health Interest of Cholesterol and Phytosterols and Their Contribution to One Health Approach: Review. *Heliyon*. **2024**, *10*(21), e40132. <https://doi.org/10.1016/j.heliyon.2024.e40132>
38. Gopal, R.K.; Ganesh, P.S.; Pathoor, N.N. Prebiotic dietary fibre from marine seaweed: A potential treatment strategy for type 2 diabetes. *Algal Research*, **2025**, *92*, 104368. <https://doi.org/10.1016/j.algal.2025.104368>
39. Aune, D.; Giovannucci, E.; Boffetta, P.; Fadnes, L.T.; Keum, N.; Norat, T.; Greenwood, D.C.; Riboli, E.; Vatten, L.J.; Tonstad, S. Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality—A systematic review and dose-response meta-analysis of prospective studies. *Int. J. Epidemiol.* **2017**, *46*, 1029–1056. <https://doi.org/10.1093/ije/dyw319>
40. Gonçalves, A.C.; Nunes, A.R.; Falcão, A.; Alves, G.; Silva, L.R. Dietary Effects of Anthocyanins in Human Health: A Comprehensive Review. *Pharmaceuticals*. **2021**, *14*, 690. <https://doi.org/10.3390/ph14070690>
41. da Silva, A.P.G.; Sganzerla, W.G.; John, O.D. et al. A comprehensive review of the classification, sources, biosynthesis, and biological properties of hydroxybenzoic and hydroxycinnamic acids. *Phytochem.* **2025**, *24*, 1061–1090. <https://doi.org/10.1007/s11101-023-09891-y>
42. Ayuso, P.; Quizhpe, J.; Marín-Sánchez, J.; Zhang, L.; García-Pérez, P.; Lucini, L.; Nieto, G. Inclusion of Pulsed Electric Fields-Treated Broccoli By-Products to Improve Pork Frankfurters: Evidence at the Nutritional, Metabolomic and Functional Levels. *Food Res. Int.* **2026**, *224*, 117951. <https://doi.org/10.1016/j.foodres.2024.117951>
43. Handu, S.; Prakash, B.; Jan, S.; Habib, M.; Jan, K. Vitamins as Functional Foods and Nutraceuticals. In: Bashir, K., Jan, K., Ahmad, F.J. (eds) *Functional Foods and Nutraceuticals: Chemistry, Health Benefits and the Way Forward*. Springer, Cham. **2024**. [https://doi.org/10.1007/978-3-031-59365-9\\_6](https://doi.org/10.1007/978-3-031-59365-9_6)
44. Razzaque, M.S.; Wimalawansa, S. J. Minerals and Human Health: From Deficiency to Toxicity. *Nutrients*. **2025**, *17*(3), 454. <https://doi.org/10.3390/nu17030454>
45. Weyh, C.; Krüger, K.; Peeling, P.; Castell, L. The Role of Minerals in the Optimal Functioning of the Immune System. *Nutrients*. **2022**, *14*(3), 644. <https://doi.org/10.3390/nu14030644>
46. Chen, J.; Li, D.; Tang, G.; Zhou, J.; Liu, W.; Bi, Y. Thermal-Oxidation Stability of Soybean Germ Phytosterols in Different Lipid Matrixes. *Molecules*. **2020**, *25*, 4079. <https://doi.org/10.3390/molecules25184079>
47. Evtuyugin, D. D.; Evtuguin, D. V.; Casal, S.; Domingues, M.R. Advances and Challenges in Plant Sterol Research: Fundamentals, Analysis, Applications and Production. *Molecules*. **2023**, *28*, 6526. <https://doi.org/10.3390/molecules28186526>
48. Ciobanu, M. M.; Manoliu, D.R.; Ciobotaru, M. C.; Flocea, E. I.; Boișteanu, P. C. Dietary Fibres in Processed Meat: A Review on Nutritional Enhancement, Technological Effects, Sensory Implications and Consumer Perception. *Foods*. **2025**, *14*(9), 14. <https://doi.org/10.3390/foods14091459>
49. Mishra, B. P.; Mishra, J.; Paital, B.; Bath, P. K.; Jena, M. K.; Reddy, B. V. V.; Pati, P. K.; Panda, S. K.; Sahoo, D. K. Properties and physiological effects of dietary fiber-enriched meat products: a review. *Front Nutr.* **2023**, *10*, 1275341. <https://doi.org/10.3389/fnut.2023.1275341>
50. Arguello-Hernández, P.; Samaniego, I.; Leguizamo, A.; Bernalte-García, M.J.; Ayuso-Yuste, M.C. Nutritional and Functional Properties of Quinoa (*Chenopodium quinoa* Willd.) Chimborazo Ecotype: Insights into Chemical Composition. *Agriculture*. **2024**, *14*, 396. <https://doi.org/10.3390/agriculture14030396>
51. Peres-Fabbri, L.; Cavallero, A.; Vidotto, F.; Gabriele, M. Bioactive Peptides from Fermented Foods: Production Approaches, Sources, and Potential Health Benefits. *Foods*. **2024**, *13*, 3369. <https://doi.org/10.3390/foods13213369>

52. Ahmad, M. F.; Alsayegh, A. A.; Khanam, A.; Ahmed, A.; Raposo, A.; Bantun, F.; Zeyaulah, M.; Babalghith, A. O.; Aldairi, A. F.; Mozaffar, B.; Bajahzer, M. F.; Abdelrahman, M. H.; Alam, M. I. Efficacy of omega-3 fatty acids as a functional food: a multifaceted approach to health reinforcement. *J Sci Food Agric*. **2025**, *22*. <https://doi.org/10.1002/jsfa.70346>
53. Benjamin, S.; Spener, F. Conjugated linoleic acids as functional food: an insight into their health benefits. *Nutr Metab (Lond)*. **2009**, *6*, 36. <https://doi.org/10.1186/1743-7075-6-36>
54. Cittadini, A.; Munekata, P.E.S.; Pateiro, M.; Sarriés, M.V.; Domínguez, R.; Lorenzo, J.M. Microencapsulated Healthy Oil Mixtures to Enhance the Quality of Foal Pâtés. *Foods*. **2022**, *11*, 3342. <https://doi.org/10.3390/foods11213342>
55. Parveen, R.; Asghar, A.; Anjum, F. M.; Khan, M. I.; Arshad, M. S.; Yasmeen, A. Selective deposition of dietary  $\alpha$ -lipoic acid in mitochondrial fraction and its synergistic effect with  $\alpha$ -tocopherol acetate on broiler meat oxidative stability. *Lipids Health Dis*. **2013**, *12*, 52. <https://doi.org/10.1186/1476-511X-12-52>
56. Tobin, B.D.; O'Sullivan, M.G.; Hamill, R.; Kerry, J.P. Effect of Cooking and In Vitro Digestion on the Stability of Co-Enzyme Q10 in Processed Meat Products. *Food Chem*. **2014**, *150*, 187–192. <https://doi.org/10.1016/j.foodchem.2013.10.104>
57. Amaral, A.B.; Silva, M.V.; Lannes, S.C.S. Lipid Oxidation in Meat: Mechanisms and Protective Factors—A Review. *Food Sci. Technol*. **2018**, *38*(Suppl. 1), 1–15. <https://doi.org/10.1590/fst.32518>
58. Kulczyński, B.; Sidor, A.; Gramza-Michałowska, A. Characteristics of Selected Antioxidative and Bioactive Compounds in Meat and Animal Origin Products. *Antioxidants*. **2019**, *8*, 335. <https://doi.org/10.3390/antiox8090335>
59. Demarquoy, J. Nutrient Equivalence of Plant-Based and Cultured Meat: Gaps, Bioavailability, and Health Perspectives. *Nutrients*. **2025**, *17*(24):3860. <https://doi.org/10.3390/nu17243860>.
60. Albenzio, M.; Santillo, A.; Caroprese, M.; Della Malva, A.; Marino, R. Bioactive Peptides in Animal Food Products. *Foods*. **2017**, *6*, 35. <https://doi.org/10.3390/foods605005>
61. Maky, M.A.; Zendo, T. Generation and Characterization of Novel Bioactive Peptides from Fish and Beef Hydrolysates. *Appl. Sci*. **2021**, *11*, 10452. <https://doi.org/10.3390/app112110452>
62. Madhu, M.; Kumar, D.; Sirohi, R.; Tarafdar, A.; Dhewa, T.; Aluko, R.E.; Badgajar, P.C.; Awasthi, M.K. Bioactive Peptides from Meat: Current Status on Production, Biological Activity, Safety, and Regulatory Framework. *Chemosphere*. **2022**, *307*, 135650. <https://doi.org/10.1016/j.chemosphere.2022.135650>
63. González-Osuna, M.F.; Bernal-Mercado, A.T.; Wong-Corral, F.J.; Ezquerro-Brauer, J.M.; Soto-Valdez, H.; Castillo, A.; Rodríguez-Figueroa, J.C.; Del-Toro-Sánchez, C.L. Bioactive Peptides and Protein Hydrolysates Used in Meat and Meat Products® Preservation—A Review. *Food Sci. Technol*. **2024**, *4*, (5). <https://doi.org/10.1021/acsfoodscitech> .
64. Pateiro, M.; Domínguez, R.; Varzakas, T.; Munekata, P. E. S.; Movilla-Fierro, E.; Lorenzo, J. M. Omega-3-Rich Oils from Marine Side Streams and Their Potential Application in Food. *Mar Drugs*. **2021**, *19*(5), 233. <https://doi.org/10.3390/md19050233>.
65. Wu, G. Important roles of dietary taurine, creatine, carnosine, anserine and 4-hydroxyproline in human nutrition and health. *Amino Acids*. **2020**, *52*(3), 329–360. <https://doi.org/10.1007/s00726-020-02823-6>
66. Jairath, G.; Biswas, A. K.; Mal, G.; & Suman, S. P. “Bioactive Compounds in Meat: Their Roles in Modulating Palatability and Nutritional Value”. *Meat and Muscle Biology*. **2024**, *8*(1), 16992, 1–15. <https://doi.org/10.22175/mmb.16992>
67. Werning, M.L.; Hernández-Alcántara, A.M.; Ruiz, M.J.; Soto, L.P.; Dueñas, M.T.; López, P.; Frizzo, L.S. Biological Functions of Exopolysaccharides from Lactic Acid Bacteria and Their Potential Benefits for Humans and Farmed Animals. *Foods*. **2022**, *11*, 1284. <https://doi.org/10.3390/foods11091284>
68. Elhalis, H.; See, X.Y.; Osen, R.; Chin, X.H.; Chow, Y. Significance of Fermentation in Plant-Based Meat Analogs: A Critical Review of Nutrition, and Safety-Related Aspects. *Foods*. **2023**, *12*, 3222. <https://doi.org/10.3390/foods12173222>
69. Carneiro, K.O.; Campos, G.Z.; Scafuro Lima, J.M.; Rocha, R.d.S.; Vaz-Velho, M.; Todorov, S.D. The Role of Lactic Acid Bacteria in Meat Products, Not Just as Starter Cultures. *Foods*. **2024**, *13*, 3170. <https://doi.org/10.3390/foods13193170>

70. Boukid, F.; Hassoun, A.; Zouari, A.; Tülbek, M.Ç.; Mefleh, M.; Ait-Kaddour, A.; Castellari, M. Fermentation for Designing Innovative Plant-Based Meat and Dairy Alternatives. *Foods*. **2023**, *12*, 1005. <https://doi.org/10.3390/foods12051005>
71. Arias, N.; Arboleya, S.; Allison, J.; Kaliszewska, A.; Higarza, S.G.; Gueimonde, M.; Arias, J.L. The Relationship between Choline Bioavailability from Diet, Intestinal Microbiota Composition, and Its Modulation of Human Diseases. *Nutrients*. **2020**, *12*, 2340. <https://doi.org/10.3390/nu12082340>
72. Bohrer, B. M. An investigation of the formulation and nutritional composition of modern meat analogue products. *Food Sci. Hum. Wellness*. **2019**, *8(4)*, 320-329. <https://doi.org/10.1016/j.fshw.2019.11.006>
73. McClements, D.J.; Grossmann, L. The science of plant-based foods: Constructing next-generation meat, fish, milk, and egg analogs. *Compr. Rev. Food Sci. Food Saf.* **2021**, *20*, 4049–4100. <https://doi.org/10.1111/1541-4337.12771>
74. Benković, M.; Jurinjak Tušek, A.; Sokač Cvetnić, T.; Jurina, T.; Valinger, D.; Gajdoš Kljusurić, J. An Overview of Ingredients Used for Plant-Based Meat Analogue Production and Their Influence on Structural and Textural Properties of the Final Product. *Gels*. **2023**, *9*, 921. <https://doi.org/10.3390/gels9120921>
75. Bao, H.; Wang, Y.; Huang, Y.; Zhang, Y.; Dai, H. The Beneficial Role of Polysaccharide Hydrocolloids in Meat Products: A Review. *Gels*. **2025**, *11*, 55. <https://doi.org/10.3390/gels11010055>
76. Yu, H. H., Chin, Y. W.; Paik, H. D. Application of Natural Preservatives for Meat and Meat Products against Food-Borne Pathogens and Spoilage Bacteria: A Review. *Foods*. **2021**, *10(10)*, 2418. <https://doi.org/10.3390/foods10102418>
77. Ferysiuk, K.; Wójciak, K.M. Reduction of Nitrite in Meat Products through the Application of Various Plant-Based Ingredients. *Antioxidants*. **2020**, *9*, 711. <https://doi.org/10.3390/antiox9080711>
78. Alam, A.N.; Samad, A.; Muazzam, A.; Kim, S.-H.; Kim, C.-J.; Hwang, Y.-H.; Joo, S.-T. A Comprehensive Review on Innovative Food Gelling Strategies for Sustainable Production of Meat Analogs and Restructured Meat. *Gels*. **2026**, *12*, 147. <https://doi.org/10.3390/gels12020147>
79. Marczak, A.; Mendes, A.C. Dietary Fibers: Shaping Textural and Functional Properties of Processed Meats and Plant-Based Meat Alternatives. *Foods*. **2024**, *13*, 1952. <https://doi.org/10.3390/foods13121952>
80. Tarté, R. Meat-Derived Protein Ingredients. In *Ingredients in Meat Products: Properties, Functionality and Applications*; Tarté, R., Ed.; Springer: New York, NY, USA, **2009**; pp. 145–171.
81. Xiong, Y.L. Dairy Proteins. In *Ingredients in Meat Products: Properties, Functionality and Applications*; Tarté, R., Ed.; Springer: New York, NY, USA, **2009**; pp. 131–144.
82. Utama, D.T.; Pratama, A.; Gumilar, J.; Wulandari, E.; Putranto, W.S.; Suryaningsih, L. Sodium Caseinate Improves Emulsion Stability of Meat Model System Formulated with Pre-neutralized Red Palm Olein-canola Oil Emulsion Gel. *J. Ilmu Teknol. Has. Ternak*. **2023**, *18*, 212–219. <https://doi.org/10.21776/ub.jitek.2023.018.03.6>
83. Dickinson, E. Emulsion gels: The structuring of soft solids with protein-stabilized oil droplets. *Food Hydrocoll.* **2012**, *28*, 224–241. <https://doi.org/10.1016/j.foodhyd.2011.12.017>
84. Muhammad, A.; Abdulqader, A.; Al-Ansi, W.; Sajid, B.M.; Al-Jaberi, H.; Ejaz, S.; Habimana, I.; Hameed, T.; Xia, L. Current Industrial Applications of Microbial Transglutaminase: A Review. *Int. J. Adv. Eng. Manag. Sci.* **2021**, *7*, 81–92. <https://doi.org/10.22161/ijaems.73.11>
85. Kieliszek M. Microbial transglutaminase in food biotechnology: from biochemical mechanisms to industrial applications. *Appl Microbiol Biotechnol.* **2026**; *110(1)*, 38. <https://doi.org/10.1007/s00253-025-13697-7>
86. Goemaere, O.; Glorieux, S.; Govaert, M.; Steen, L.; Fraeye, I. Phosphate Elimination in Emulsified Meat Products: Impact of Protein-Based Ingredients on Quality Characteristics. *Foods*. **2021**, *10*, 882. <https://doi.org/10.3390/foods10040882>
87. Elgadir, M.A.; Mariod, A.A. Gelatin and Chitosan as Meat By-Products and Their Recent Applications. *Foods*. **2023**, *12*, 60. <https://doi.org/10.3390/foods12010060>
88. Vasić, K.; Knez, Ž.; Leitgeb, M. Transglutaminase in Foods and Biotechnology. *Int. J. Mol. Sci.* **2023**, *24*, 12402. <https://doi.org/10.3390/ijms241512402>

89. Zimoch-Korzycka, A.; Krawczyk, A.; Król-Kilińska, Ż.; Kulig, D.; Bobak, Ł.; Jarmoluk, A. Influence of Microbial Transglutaminase on the Formation of Physico-Chemical Properties of Meat Analogs. *Foods*. **2024**, *13*, 4085. <https://doi.org/10.3390/foods13244085>
90. Li, J.; Wang, X.; Chang, C.; Gu, L.; Su, Y.; Yang, Y.; Agyei, D.; Han, Q. Chicken Egg White Gels: Fabrication, Modification, and Applications in Foods and Oral Nutraceutical Delivery. *Foods* **2024**, *13*, 1834. <https://doi.org/10.3390/foods13121834>
91. Suhag, R. Egg Yolk, a Multifunctional Emulsifier: New Insights on Factors Influencing and Mechanistic Pathways in Egg Yolk Emulsification. *Appl. Sci.* **2024**, *14*, 9692. <https://doi.org/10.3390/app14219692>
92. Juraskova, D.; Ribeiro, S. C.; Silva, C. C. G. Exopolysaccharides produced by lactic acid bacteria: from biosynthesis to Health-Promoting properties. *Foods*. **2022**, *11*(2), 156. <https://doi.org/10.3390/foods11020156>
93. Toldrá, F.; Reig, M.; Mora, L. Management of meat by- and co-products for an improved meat processing sustainability. *Meat Sci.* **2021**, *181*, 108608. <https://doi.org/10.1016/j.meatsci.2021.108608>
94. Mora, L.; Reig, M.; & Toldrá, F. Bioactive peptides generated from meat industry by-products. *Food Res. Int.* **2014**, *65*, 344-349. <https://doi.org/10.1016/j.foodres.2014.09.014>
95. Aspevik, T.; Oterhals, Å.; Rønning, S.B.; Altintzoglou, T.; Wubshet, S.G.; Gildberg, A.; Afseth, N.K.; Whitaker, R.D.; Lindberg, D. Valorization of Proteins from Co- and By-Products from the Fish and Meat Industry. *Top. Curr. Chem.* **2017**, *375*, 53. <https://doi.org/10.1007/s41061-017-0143-6>
96. Haque, A.; Ahmad, S.; Azad, Z. R. A. A.; Adnan, M.; Ashraf, S. A. Incorporating Dietary Fiber From Fruit and Vegetable Waste in Meat Products: A Systematic Approach for Sustainable Meat Processing and Improving the Functional, Nutritional and Health Attributes. *PeerJ.* **2023**, *11*. <https://doi.org/10.7717/peerj.14977>
97. Grisoldi, L.; Ianni, F.; Blasi, F.; Pollini, L.; Crotti, S.; Cruciani, D.; Cenci-Goga, B.T.; Cossignani, L. Apple Pomace as Valuable Food Ingredient for Enhancing Nutritional and Antioxidant Properties of Italian Salami. *Antioxidants*. **2022**, *11*, 1221. <https://doi.org/10.3390/antiox11071221>
98. Delgado-Pando, G.; Ekonomou, S.I.; Stratakos, A.C.; Pintado, T. Clean Label Alternatives in Meat Products. *Foods*. **2021**, *10*, 1615. <https://doi.org/10.3390/foods10071615>
99. Fasolin, L. H.; Pereira, R. N.; Pinheiro, A. C.; Martins, J. T.; Andrade, C. C. P.; Ramos, O. L.; Vicente, A. A. Emergent food proteins – Towards sustainability, health and innovation. *Food Res. Int.* **2019**, *125*, 108586. <https://doi.org/10.1016/j.foodres.2019.108586>
100. European Commission. (2020). A new circular economy action plan for a cleaner and more competitive Europe
101. FAO. (2019). The State of Food and Agriculture: Moving forward on food loss and waste reduction.
102. Mirabella, N.; Castellani, V.; Sala, S. Current options for the valorization of food manufacturing waste. *J. Clean. Prod.* **2014**, *65*, 28-41. <https://doi.org/10.1016/j.jclepro.2013.10.051>
103. Toldrá, F.; Mora, L.; Reig, M. New insights into meat by-product utilization. *Meat Sci.* **2012**, *92*(3), 290-296. <https://doi.org/10.1016/j.meatsci.2016.04.021>
104. Schieber, A.; Stintzing, F. C.; Carle, R. By-products of plant food processing as a source of functional compounds recent developments. *Trends Food Sci. Technol.* **2001**, *12*, 401-413. [https://doi.org/10.1016/S0924-2244\(02\)00012-2](https://doi.org/10.1016/S0924-2244(02)00012-2)
105. Galanakis, C. Food waste valorization opportunities for different food industries. In *The Interaction of Food Industry and Environment*. Academic Press . <https://doi.org/10.1016/B978-0-12-816449-5.00011-4>
106. Alvarez, C.; Drummond, L.; Anne-Maria Mullen, L. A. M. Protein recovered from meat co-products and processing streams as pork meat replacers in Irish breakfast sausages formulations. *LWT.* **2018**, *96*, 679-685. <https://doi.org/10.1016/j.lwt.2018.06.020>
107. Ahmad, M. I.; Li, Y.; Pan, J.; Liu, F.; Dai, H.; Fu, Y.; Huang, T.; Farooq, S.; Zhang, H. Collagen and gelatin: Structure, properties, and applications in food industry. *Int. J. Biol. Macromol.* **2024**, *254*, 128037. <https://doi.org/10.1016/j.ijbiomac.2023.128037>
108. Lopez-Pedrouso, M.; Zaky, A. A.; Lorenzo, J. M.; Camila, M.; Franco, D. A review on bioactive peptides derived from meat and by-products: Extraction methods, biological activities, applications and limitations. *Meat Sci.* **2023**, *204*, 109278. <https://doi.org/10.1016/j.meatsci.2023.109278>

109. Ozturk-Kerimoglu, B. Meat-derived bioactive peptides: application potential in functional foods. *Meat Technol.* **2025**, *66*(3), 54-60. <https://doi.org/10.18485/meattech.2025.66.3.8>
110. Darko, H. S. O.; Ismaiel, L.; Fanesi, B.; Pacetti, D.; Lucci, P. Current Trends in Food Processing By-Products as Sources of High Value-Added Compounds in Food Fortification. *Foods.* **2024**, *13*(17), 2658. <https://doi.org/10.3390/foods13172658>
111. Serikkyzy, M.; Kapysheva, U.; Kenenbay, S. Development of functional meat products based on the food safety system. *Sci. Rep.* **2025**, *16*(1), 601. <https://doi.org/10.1038/s41598-025-30088-0>
112. Keong, L.; Ya E.; Toh, M.; Lu, Y.; Liu, S-Q. Effects of biotransformed okara as a meat extender on the physicochemical properties and baking characteristics of pork jerkies. *Food Biosci.* **2024**, *60*, 104409. <https://doi.org/10.1016/j.fbio.2024.104409>
113. Pintado, T.; Delgado-Pando, G. Towards More Sustainable Meat Products: Extenders as a Way of Reducing Meat Content. *Foods.* **2020**, *9*(8), 1044. <https://doi.org/10.3390/foods9081044>
114. Nyhan, L.; Sahin, A. W.; Schmitz, H. H.; Siegel, J. B.; Arendt, E. K. Brewers' Spent Grain: An Unprecedented Opportunity to Develop Sustainable Plant-Based Nutrition Ingredients Addressing Global Malnutrition Challenges. *J. Agric. Food Chem.* **2023**, *71*(28), 1054310564. <https://doi.org/10.1021/acs.jafc.3c02489>
115. Olewnik-Mikolajewska, A.; Guzek, D.; Gbska, D.; Gutkowska, K. Hybrid Meat Sausages with Cereal Ingredients: A Systematic Review and Development Trial with the Assessment of Physicochemical and Sensory Attributes. *Foods.* **2024**, *13*(21), 3436. <https://doi.org/10.3390/foods13213436>
116. Ospina-Maldonado, S.; Martin-Gómez H.; Cardoso-Ugarte, G.A. From waste to wellness: a review on the harness of food industry by-products for sustainable functional food production. *Int. J. Food Sci. Technol.* **2024**, *59* (11) 8680-8692. <https://doi.org/10.1111/ijfs.17571>
117. Hoxha, L.; Sucic, I.; Taherzadeh, M.J.; Matteo Marangon, M. Development of new meat analogues from filamentous fungi cultivated on oenological by-products: A quality perspective. *Innov. Food Sci. Emerg. Technol.* **2026**, *108*, 104409. <https://doi.org/10.1016/j.ifset.2025.104409>
118. Lee, J.; Lee, D. Y.; Mariano, E. Utilization of animal by-products as sources of bioactive compounds and FBS alternatives for cultured meat: a comprehensive review. *Food Sci Anim Resour.* **2026**, *46*, 32. <https://doi.org/10.1007/s44463-025-00035-8>
119. Leite, A.; Vasconcelos, L.; Rodrigues, S.; Pereira, E.; Domínguez-Valencia, R.; Lorenzo, J. M.; Teixeira, A. Effect of Olive Cake in Bísaro Pig Feed on Physicochemical Composition and Fatty Acid Profile of Three Different Muscles of Dry-Cured Shoulder. *Animals.* **2024**, *14*(11), 1697. <https://doi.org/10.3390/ani14111697>
120. Rasul, S.; Asiz, A. T. A.; Rahmadewi, Y.M.; Tan, M. F. M.; Tarique, M.; Alam, M.Z.; Chiang, J.H.C.; Yuliarti, O. Unveiling the potential of insoluble dietary fiber from by-products in structural advancements of plant-based meat analogues. *Future Foods.* **2025**, *12*, 100839. <https://doi.org/10.1016/j.fufo.2025.100839>
121. Leite, A.; Vasconcelos, L.; Lopez, S.; Outor-Monteiro, D.; Pinheiro, V.; Rodrigues, S.; Teixeira, A. Incorporating Olive By-Products in Bísaro Pig Diets: Effect on Dry-Cured Product Quality. *Foods.* **2024**, *13*(16), 2579. <https://doi.org/10.3390/foods13162579>
122. Paié-Ribeiro, J.; Pinheiro, V.; Guedes, C.; Gomes, M. J.; Teixeira, J.; Leite, A.; Vasconcelos, L.; Teixeira, A.; Outor-Monteiro, D. Exploring the Potential of Olive By-Products in Bísaro Pig Feed: Effects on the Chemical Compositions and Fatty Acid Profiles of Three Different Muscles. *Foods.* **2025**, *14*(5), 836. <https://doi.org/10.3390/foods14050836>

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.