

Review

Development of Functional Fermented Meat Products Using Agro-Food Byproducts

Yavor Ivanov , Milka Atanasova  and Tzonka Godjevargova * 

Department Biotechnology, University “Prof. Dr. Asen Zlatarov”, 8010 Burgas, Bulgaria

* Correspondence: godjevargova@yahoo.com; Tel.: +359-887-861993

Abstract

Fermented foods play an important role in human nutrition due to their probiotic properties, improved nutrient absorption and potential health benefits. The incorporation of various agro-food byproducts into them leads to the production of innovative functional foods with even better nutritional properties. In recent years, the application of industrial byproducts has become a hot spot of research, as they are rich in polyphenols, flavonoids, carotenoids, tocopherols, vitamins and anthocyanins, which provide high antioxidant capacity for foods. Among the most popular groups of fermented foods are meat products. The addition of agro-food byproduct powder or extracts to these traditional food products leads to an increase in their nutritional value and antioxidant capacity, a decrease in lipid oxidation and color change, inhibition of the growth of pathogenic microorganisms and the provision of health benefits. The use of these ingredients in the fermentation of meat products is considered to be a promising strategy in the development of new functional fermented meat products. This review will discuss the development of functional fermented meat products by incorporating agro-food byproducts, determining their optimal concentration, studying their impact on the fermentation of the meat products and on its properties and storage, as well as the health benefits of these functional products.

Keywords: agro-food byproducts; fermented meat products; antioxidant properties; stability; health benefits

1. Functional Fermented Food Products

The recent employment of high-calorie foods leads to the emergence of serious diseases, including obesity, Alzheimer’s, type II diabetes, Parkinson’s, osteoporosis and cardiovascular diseases [1]. These emerging diseases are usually treated by long-term use of drugs that negatively affect the physiological functioning of the body. Functional foods, which have been developed in recent years, are seen as an alternative to solve these problems. There are many definitions of the concept of functional foods, but basically, a food is considered to be “functional” if it has a beneficial effect on specific body functions, which goes beyond nutritional effects and is intended to promote overall health and well-being and reduce the risk of many diseases [2]. Functional foods are becoming increasingly popular worldwide. In 2020, the global market for these foods reached \$161.99 billion, and in 2025, it is expected to reach \$228.79 billion [3]. Often, the terms “natural health products” or “healthy foods” are used instead of functional foods [4]. Foods that offer additional values to the basic nutritional values can be classified as healthy foods, whether natural or processed foods [5]. The richest sources of functional components with potential physiological benefits in addition to their nutritional role are conventionally used cereals,



Academic Editors: Carlos A. Ligarda-Samanez, David Choque Quispe and Betsy S. Ramos-Pacheco

Received: 4 January 2026

Revised: 29 January 2026

Accepted: 5 February 2026

Published: 9 February 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

millet, fruits, vegetables, spices and flavorings. The growing awareness of consumers in the field of healthy nutrition has significantly changed their food preferences. Consumers are actively looking for foods that offer specific health benefits [6]. In addition, there is a growing preference for natural and minimally processed foods. These preferences are leading manufacturers to develop new functional foods, in which they replace synthetic additives with natural sources [6]. Natural sources of antioxidants are most often sought as alternatives to synthetic additives, as they can lead to health problems. Functional foods contain valuable bioactive substances such as terpenes, polyphenols, limonoids, carotenoids and saponins [7] and are increasingly gaining popularity as they are safer to use. These bioactive compounds possess antimicrobial and anti-lipid activity and strong antioxidant potential [8].

Fermented foods are an important part of human diet, health and cultural characteristics. Fermentation is a process known and applied by humanity since ancient times. It is used all over the world, as it is integrated into different regions according to local products and environment features [9]. The definition of fermentation has changed with the development of contemporary microbiological and biotechnological approaches. Today, it is known how important the role of microorganisms in fermentation is, not only for the purpose of preserving food, but also for improving its nutritional and functional properties [10]. Nowadays, fermented foods are an object of interest due to their potential probiotic effects and their role in supporting gut health and immunity [11].

Fermented foods are classified based on the raw material, the main microorganisms that are responsible for fermentation or the resulting primary metabolites. Among the most well-known categories based on the raw material are: dairy-based fermentations, cereal-based fermentations, legume fermentations, vegetable fermentations, fruit fermentations, and meat and fish fermentations [12]. Fermentation of meat and fish products (salami, fish sauce, shrimp paste, etc.) is a more complex process. It includes lactic acid bacteria (LAB), yeast and halophilic bacteria [13]. In this case, the salt concentration plays an important role in the selection of microorganisms and safety management of the product. The process is usually characterized by proteolysis and lipolysis. This microbe enzymatic degradation leads to the formation of peptides, amino acid and volatile compounds which leads to the development of a unique taste profile and texture [14].

One of the most important aspects of fermented foods is their storage stability. Various environmental factors, such as light and temperature, can affect the destruction of available biologically active components. This degradation process deteriorates both the nutritional value and the quality of the product. To make bioactive components in fermented foods more stable, various approaches are applied, such as proper storage and the addition of stabilizers, antioxidants, probiotics and fiber. That is why recently, there has been active work on the development of innovative fermented foods by adding natural antioxidants, stabilizers, fiber, biologically active peptides, etc. This leads to increased interest in obtaining natural antioxidants from various byproducts of fruit, vegetables, cereals and meat processing. There are numerous publications that discuss the extraction and application of natural antioxidants from different sources [15]. Studies convincingly indicate that the antioxidant potential of fermented foods could be increased by the addition of plant extracts (from herbs, fruits, vegetables), thus improving their functional properties [16]. The utilization of byproducts and waste from food processing is a practice with increasing popularity. Recently, gluten-free foods enriched with antioxidant extracts have been increasingly developed and introduced. Commonly used extracts are, for example, those obtained from olive leaves and olive mill wastewater [17]. Very often in the production of different kinds of fermented meat products, antioxidants from byproducts of wine production (grape marc, grape seed and skin extracts), etc., are used. These new products not only meet dietary

restrictions and have a high antioxidant capacity, but also enhance the nutritional value of everyday foods. In addition, in recent years, the incorporation of bioactive peptides from food proteins into functional foods has been very popular. Different studies reported that these peptides possess antioxidant properties and can be used in a variety of applications, from food supplements to food fortification [18]. The use of new antioxidants, such as those derived from seaweed, also shows that functional foods development is constantly seeking innovative solutions and practices [19]. The integration of traditional fermented foods into modern diets is a notable trend, as these foods are rich in probiotics and antioxidants, and by incorporating additional bioactive substances, they become even more attractive to consumers seeking to improve their health [20].

The creation of these complex multicomponent systems requires very detailed studies on their effectiveness. Bioactive compounds are often chemically unstable. This can also be amplified by different conditions, such as high temperature and light, applied during food processing [21]. The fermentation process can also change the structure of these compounds, interfering with different aspects of their bioactivity as well as their stability [22]. Another factor that could hinder their bioactivity is the interaction between the bioactive compounds and other components presented in food. This necessitates research and creation of innovative systems to improve solubilization [21]. Traditionally produced fermented foods may contain both components that enhance and components that inhibit the absorption of bioactive ingredients, greatly complicating their efficacy [23]. Solutions to these challenges include improving extraction techniques from plant sources and ensuring strict control of fermentation processes, monitoring the antioxidant potential of innovative foods during their preparation and storage, investigating the bioavailability of bioactive compounds, and monitoring their health-promoting biological effects on the body [24]. The development of new approaches, such as the use of microencapsulated bioactive components or synergistic food systems and extracts with synergistic effects, could improve the bioavailability of antioxidants and enhance the effectiveness of innovative functional fermented foods.

Naturally, research to prove the therapeutic effect of innovative fermented foods is very important. It is believed that their therapeutic effect extends across a wide spectrum—inflammatory bowel diseases, type 2 diabetes, cardiovascular diseases, obesity, hypertension, etc. [4]. The number of publications investigating the biological action of various plant extracts is significant [4,6,25]. To realize the therapeutic potential of functional fermented foods, future research should focus on identifying specific bioactive compounds and their mechanisms of action. In addition, clinical trials are needed to confirm the efficacy of functional fermented foods in the prevention and treatment of chronic diseases. To ensure the therapeutic efficacy of functional fermented foods, further research should focus on identifying the type of the bioactive components and their mechanisms of action. In addition, it is very important to conduct clinical trials in order to confirm the efficacy of these functional foods and the possibility of their usage in the prevention and treatment of different chronic diseases.

A significant problem with functional fermented products is their labeling and presentation in the trade network. A unified regulatory framework does not exist and there are differences in global food regulations. Global regulation is needed regarding labeling and presentation of health claims. This will prevent unfair competition and misleading advertising in the food industry. This will allow for functional products to be freely distributed in international markets. The growing interest in functional fermented foods requires the establishment of effective guidelines and regulations at national and international levels to ensure their safety and application on a global scale.

2. Agro-Food Byproducts Used as Novel Ingredients in Production of Functional Foods

In recent decades, the agro-food industry has generated great amounts of byproducts and wastes, originating not only from fruit and vegetable processing, but also from the meat, dairy and seafood industries. According to the Directive 2008/98/EC on waste, a byproduct is defined as a substance that is produced as a result of a manufacturing process and has the ability to be used further, following conventional industrial processing, except for any adverse consequences on human health or the environment. For this reason, there is growing interest in the possibilities for utilizing these byproducts. These materials, often rich in bioactive compounds, proteins, polysaccharides and minerals, are increasingly recognized as valuable resources for food ingredient recovery, rather than disposal. Their incorporation into foods aligns with circular economy principles, reduces environmental impact and creates added value through functional and technological benefits [26,27]. Other than the food industry, these byproducts can also be used in a number of other industries: the pharmaceutical industry and medical sector [28,29], food packaging [30], cosmetic sector [31,32], and the production of probiotics and prebiotics (Figure 1).

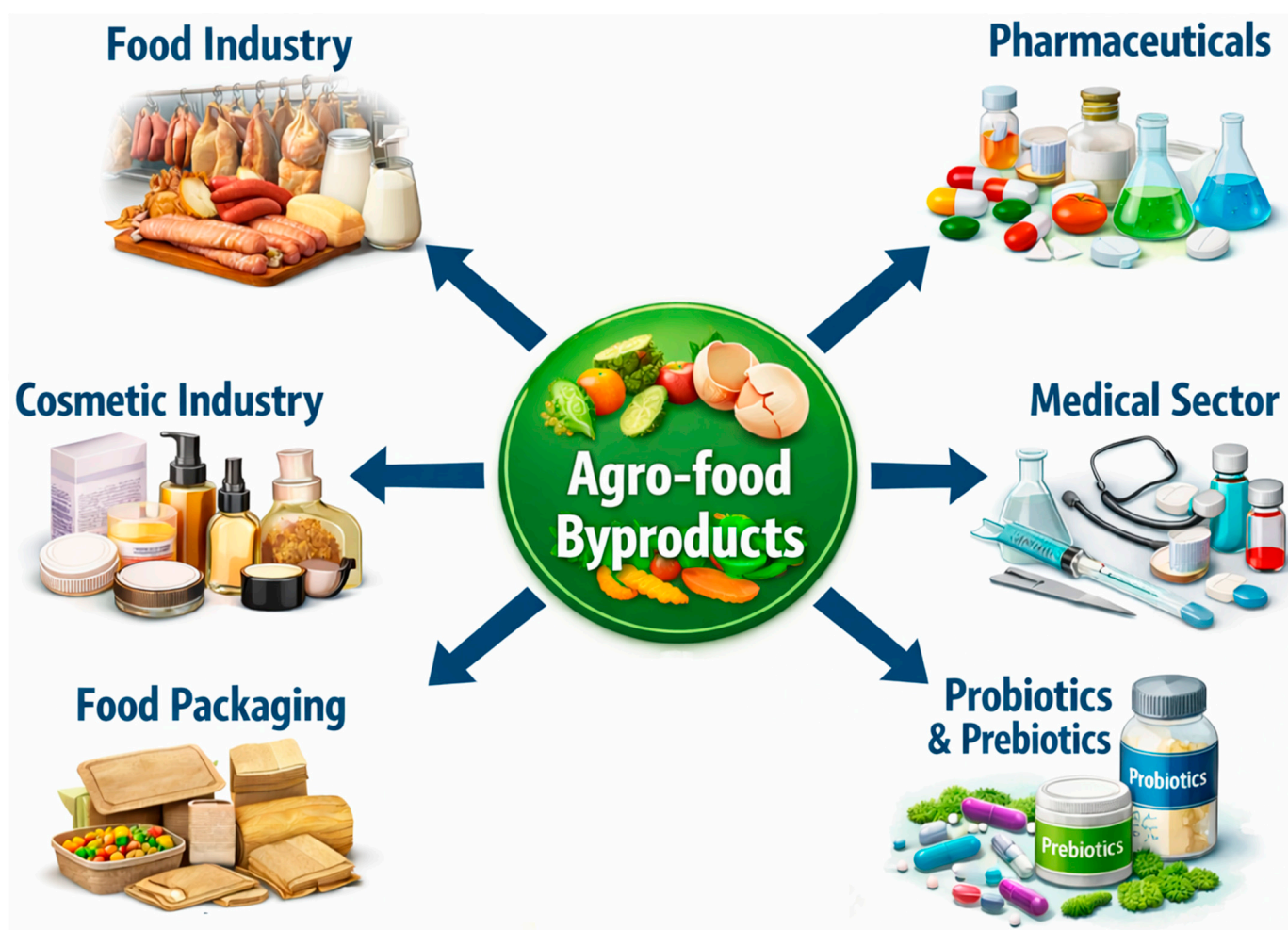


Figure 1. Applications of agro-food byproducts in different sectors.

The wide variety of byproducts that remain from the agri-food industry have many different applications in the food industry: antioxidant additives, anti-lipid additives, antimicrobial agents, preservatives, colorants, and texturizing agents.

2.1. Antioxidant, Anti-Lipid and Anti-Microbial Applications

Oxidative reactions are unavoidable phenomena in biological systems and food matrices that play a critical role in the deterioration of food quality. The progression of oxidation leads to the formation of secondary metabolites that negatively affect sensory characteristics such as flavor, appearance and texture, as well as reducing nutritional value. In some cases, oxidation may also result in the generation of compounds with toxicological relevance [33–35]. To mitigate these effects, the food industry routinely incorporates protective agents designed to limit or delay oxidative processes. Among these, antioxidants represent a key technological strategy, as they inhibit oxidation degradation pathways and contribute to the extension of product shelf life [33–36].

Antioxidant additives function by stabilizing oxidation-sensitive components, particularly lipids, through the interruption of free-radical chain reactions and the suppression of lipid peroxidation [35,37]. In recent years, increased consumer awareness and preference for clean-label products have brought to the forefront, with naturally derived antioxidants being used as alternatives to synthetic compounds. Conventional synthetic antioxidants commonly applied in food systems include butylated hydroxyanisole (BHA), butylated hydroxytoluene, ethoxyquin, tert-butylhydroquinone, and propyl gallate; however, attention should be paid to the possibility of adverse effects, due to the availability of studies investigating their effects on human health [38–41].

Effective control of lipid oxidation is particularly important for ensuring the quality and safety of foods with a high fat content. Natural antioxidants obtained from plant and animal processing byproducts have demonstrated efficacy in delaying lipid peroxidation in meat products, dairy fats, and edible oils. Bioactive compounds such as tocopherols, phenolic compounds, and carotenoids derived from plant residues, together with antioxidant peptides released from animal proteins, act in a complementary manner to enhance oxidative stability in food systems [26].

Plant-based wastes remain the most extensively studied sources of natural antioxidants, particularly fruit pomace, peels and seeds, which are rich in phenolic compounds, flavonoids, carotenoids and vitamins. Grape pomace, citrus peel, apple pomace and olive byproducts exhibit strong antioxidant capacity and are widely applied to delay lipid oxidation in meat products, oils, bakery goods and dairy matrices [42,43]. The byproducts from the treatment of pomegranate, strawberry, kinnow, grapes, blackcurrant, annatto, bearberry, banana and sapodilla contain relatively high concentrations of antioxidants [44–47]. Table 1 presents some of the potential antioxidant and preservative applications of agro-food byproducts.

In parallel, animal-derived byproducts also demonstrate antioxidant potential. Protein hydrolysates obtained from meat trimmings, poultry byproducts, fish skin and bones contain bioactive peptides with radical-scavenging and metal-chelating activities. These peptides can inhibit oxidative processes in food systems and may also exert physiological antioxidant effects after ingestion [48,49]. Dairy-derived peptides released during whey or casein hydrolysis similarly show antioxidant activity, particularly in emulsified and lipid-rich foods [50].

The dairy industry generates substantial byproducts, particularly whey, whey permeates and buttermilk. Whey proteins (β -lactoglobulin, α -lactalbumin) are extensively valorized as emulsifiers, foaming agents, antioxidants and antimicrobial ingredients. Lactose- and mineral-rich permeates can be used as fermentation substrates or functional fillers, while buttermilk phospholipids enhance emulsification and nutritional value [50].

Byproducts from meat processing (blood, bones, meat trimmings and viscera) can be used to extract protein hydrolysates with relevant bioactivity. These isolates are often called antioxidant bioactive peptides [51,52].

Table 1. Potential antioxidant and preservative applications of agro-food byproducts.

Origin	Byproduct	Bioactive Compounds	Bioactive Properties/Application	References
Figs (<i>Ficus carica</i> L.)	Skin, seed, leaf of figs	Flavonoids (flavonoid glycosides and prenylated), coumarins, phenolic acids, terpenoids, alkaloids.	Antioxidant, antidiabetic, anticancer activity, neuroprotective effect, anti-inflammatory, anti-insecticidal activity, and antimicrobial activity	[53,54]
Blackcurrant (<i>Ribes nigrum</i> L.)	Pomace of blackcurrant	Vitamin C, carotenoids, and phytosterols, antocyanids (cyanidin and delphinidin derivatives), phenolic acids (protocatechuic, vanillic, ellagic, gallic, and syringic acid)	Antioxidant, anti-inflammatory activities, prevention of cardiovascular disease, reduced systolic blood pressure	[55]
Blueberry (<i>Vaccinium</i> sp.)	Pomace of blueberry	Phenolic acids, flavonoids (anthocyanidins, tannins, anthocyanins, proanthocyanidins), vitamin C.	Antioxidant, anti-inflammation, neuro-protection, anti-metastatic, cardio-protective, antimicrobial, reno-protective, ophthalmoprotective, anti-diabetic, hepato-protective, gastro-protective, anti-osteoporotic, anti-aging	[56]
Strawberry (<i>Arbutus unedo</i> L.)	Pomace of strawberry	Phenolic acids (ellagic acid, chlorogenic acid); flavanols (catechin, procyanidin); anthocyanins (cyanidin-3-glucoside); fatty acids (α -linolenic, linoleic acid (ω -6)); vitamin E, vitamin C	Antiallergic, antibacterial, hepatoprotective, antithrombotic, antiviral, urinary antiseptic, anti-inflammatory, anti-diarrheal, anti-hypertension, anti-diabetic, anticarcinogenic, neurodegenerative, and vasodilator effects	[57]
Pineapple (<i>Ananas sativus</i> L.)	Peel, core, pomace, and crown	Phenolic acids; vitamin C, vitamin D, vitamin E	Antioxidant, anti-inflammatory, antibacterial, antifungal, and anticancer activities	[58]
Lemon (<i>Citrus limon</i> L.)	Peel of lemon	Flavanones (eriodictyol, hesperidin, hesperetin, naringin); flavones (apigenin, diosmin); flavanols (quercetin, lymphocitrin); essential oils (limonene, β -pinene, γ -terpinene, α -pinene, myrcene, sabinene, geranial); ascorbic acid, organic acids, phenolic acids	Antimicrobial, anti-inflammatory, anticancer, antidiabetic, anti-obesogenic, anti-urolithic, and anti-cardiovascular disease effects	[59]

Table 1. Cont.

Origin	Byproduct	Bioactive Compounds	Bioactive Properties/Application	References
Pomegranate (<i>Punica granatum</i> L.)	Peel of pomegranate	Phenolic acids, flavonols (quercetin, kaempferol, catechin), tannins (ellagic acid, 1,2,4-tri-O-galloyl- β -glucopyranose), anthocyanins	Antioxidant, antimicrobial, anti-inflammatory, antidiabetic, cytotoxic, anticancer activities	[60]
Apple (<i>Malus domestica</i>)	Peel, pomace, seed of apple	Phenolic acids, flavonoids, anthocyanins	Antioxidant	[61]
Tomato (<i>Solanum lycopersicum</i>)	Peel and seed of tomato	Carotenoids, phenolic acids and flavonoids, lycopene, dietary fiber	Antioxidant and radical scavenger	[62]
Grape (<i>Vitis vinifera</i>)	Pomace, seed, skin of grape	Anthocyanins, resveratrol, quercetin, kaempferol, catechins, phenolic acids and procyanidins	Antioxidant, anti-inflammatory, gut microbiota modulation, anti-obesity, cardioprotective, antidiabetic, hepatoprotective, anticancer, neuro-protective, antiproliferative anti-aging and antiaging activities	[63]
Eggs	Egg shells	Antioxidant peptides	Antioxidant activity, anti-inflammatory activity	[64,65]
Bovine	Buffalo horn	Peptides	Antioxidant	[66]
Bovine	Bovine hemoglobin hydrolysate	Peptides	Antibacterial, antihypertensive	[67]
Tomato	Tomato byproducts	Dietary fibers, proteins, carotenoids, tocopherols, polyphenols, lycopene	Anti-inflammatory, antiallergenic, antimicrobial, vasodilatory, antithrombotic, cardioprotective, antioxidant	[68,69]

At present, lysozyme (E1105) is the only animal-derived antimicrobial additive authorized for use in both the European Union and the United States. Sourced from eggs, lysozyme is primarily applied in cheese preservation, although research has also examined its use in eggs, milk, and beef. Nevertheless, it shows no inhibitory effect on yeasts or fungi [70,71].

Natural preservation is one of the most promising applications of agri-food wastes. Plant extracts that are rich in polyphenols, organic acids and essential oils often show high antimicrobial activity, especially against foodborne pathogens and spoilage microorganisms. Grape seed, citrus peel and olive leaf extracts have been successfully applied in meat, fish and dairy products to extend their shelf life [72].

Phenolic compounds, besides their antimicrobial activity, are considered to be strong antioxidants. These compounds are typically present in different plants, along with vitamins, minerals, polysaccharides and enzymes. Any byproduct with a high content of any of these compounds can be considered as a possible source of new antioxidant food

additives, e.g., overripe fruits or citric acid and exotic fruits, peels and seeds [34,73–75]. Byproducts from the meat processing industry (like blood, bones, meat trimmings and offal) can yield protein hydrolysates with relevant bioactivity [51,52]. Onion byproducts (like onion stems and skins) can be applied as food additives due to their antioxidant and anti-browning properties [76]. Larrosa et al. [77] reported that the addition of an artichoke byproduct extract (the blanching water) to tomato juice resulted in higher antioxidant activity (measured by DPPH and ABTS+ methods) and therefore a longer shelf life for this product.

From animal-origin wastes, antimicrobial peptides (AMPs) obtained from meat, fish and dairy proteins show strong inhibitory effects against bacteria and fungi. Whey-derived peptides, lactoferrin and lysozyme from dairy byproducts are well-known natural antimicrobials that are already approved for food use in several regions [50]. Fish skin and shrimp shell hydrolysates also exhibit antimicrobial properties, especially when incorporated into edible films or coatings [49].

2.2. Thickeners, Gelling Agents, Texturizers and Colorants

Agro-industrial wastes are key sources of food hydrocolloids. From plant residues, pectin (citrus peel, apple pomace), cellulose and hemicelluloses are already industrially exploited as thickeners, stabilizers and gelling agents in jams, sauces, dairy desserts and plant-based foods [78]. From animal-origin wastes, collagen and gelatin derived from skins, bones and connective tissues of cattle, pigs, poultry and fish play a major role as texturizers. Gelatin is widely used in confectionery, desserts, dairy products and meat formulations, due to its gelling, foaming and water-binding properties. Advances in extraction from fish-processing byproducts respond to religious, cultural and sustainability demands [79,80]. In the dairy sector, whey proteins recovered from cheese-making waste streams act as functional thickeners and emulsifiers, improving the viscosity, gel strength and mouthfeel in beverages, yogurts and bakery products [81].

Gbogouri et al. [82] reported that salmon head hydrolysates treated with the commercial enzyme Alcalase® 2.4 L could potentially be a new source of compounds with great emulsifying capacity and stability. Using the same enzyme mix, Sathivel et al. [83] analyzed the potential of herring (*Clupea harengus*) byproducts hydrolysates. Although the emulsifying capacity was lower than that of egg albumin and soy protein, the hydrolysates could still be used as emulsifiers and stabilizers. Such an effect was also observed for the protein extracts before hydrolysis [84].

Plant-derived wastes are dominant sources of natural pigments: anthocyanins (berry and grape pomace), betalains (beet pulp), carotenoids (tomato and carrot peels) and chlorophylls (leafy vegetable residues). These pigments serve as alternatives to synthetic dyes, though their stability often requires encapsulation or matrix protection [85,86]. Animal-derived colorants are more limited but still relevant. Heme-proteins, such as hemoglobin and myoglobin recovered from slaughterhouse blood, have been explored as natural red colorants and functional ingredients in meat analogs and processed meats. Blood plasma proteins are also used to improve color stability and water-holding capacity in meat products, although consumer acceptance and regulatory issues must be carefully addressed [87]. Some of the potential applications of agro-food byproducts as texturizing agents and colorants are presented in Table 2.

Table 2. Potential applications of agro-food byproducts as texturizing agents and colorants.

Product	Byproduct	Function	References
Fish	Fish bones, fish scales	Smooth and creamy texture, alternative of pork gelatin	[88,89]
Dairy	Whey protein and buttermilk	Texturizing agents	[90–92]
Onion	Onion hulls		[93]
Spinach	Spinach stalks		[94]
Tomato	Lycopene from tomato byproducts, carotenoids from tomato peels	Colorant	[95,96]
Grape	Wine pomace extract and flour	Colorant	[97]
Eggplant	Phenolic compounds from eggplant	Colorant	[98]
Potato	Phenolic compounds from potato peels	Colorant	[99]
Citrus fruits	Citrus peels	Colorant	[100–102]

Recently, increasing attention has been paid to organic farming and the benefits of organic products on human health. Organic farming relies on both traditional practices and innovative clean technologies. When talking about organic farming, it is often also called biological or ecological. The main characteristics of organic farming are that the use or application of any artificial synthetic materials such as pesticides, fertilizers, growth regulators and additives or genetically modified products is unacceptable. The FAO defines organic agriculture as a production system based on the maximum use of available resources, protection of soil fertility and biological activity, minimal use of non-renewable resources, and restricted use of synthetic substances that are harmful to the ecosystem and living beings [103].

Considering this, the valorization of organic agro-food byproducts is very important and significant for the environment and economics. Furthermore, when talking about utilizing these byproducts, their improved nutritional profile compared to conventionally grown ones must be taken into account. Given the diverse applications of agro-industrial byproducts in the production of functional foods, the improved nutritional profile of organic products is of great importance.

Many authors have reported significant differences in the nutritional and sensory quality of organic and conventional products. A trend in which organically grown crops have a higher dry matter content and a higher concentration of nutrients is observed. The probable reason is the lack of nitrogen sources available in organic systems, which is believed to lead to an increase in the amount of dry matter [104]. The dry matter content (and respectively lower water content) of most organic crops is up to 20% higher than that of conventional ones [105,106]. Dry matter can be a reference point for measuring the accumulation of organic matter and nutritional composition, as well as for the evaluation of the product in terms of its consumption [107]. Some authors reported that organic fruits and vegetables contain a higher dry matter content than conventional ones [108–110]. Gastol et al. noted that compared to conventional products, the dry matter content was higher in organic pears, currants, beets and celery, but lower in organic carrots and apples [111]. Other authors also reported higher dry matter in organic crops (potatoes) [112,113].

Differences were also found in the protein content and amino acid profile of organically grown crops. Organic crops generally have a similar or slightly lower protein content compared to conventionally grown crops, as organic farming often results in slower nitrogen release, which can affect protein accumulation. Long-term studies on organic versus conventional fertilization have shown that conventional fertilization with a high nitrogen content increases the nitrogen content and total protein in plants, but tends to reduce the quality of the protein. As the protein content is not the only indicator reflecting crop quality, the content of amino acids that are digestible and essential for the human body should be considered important. Vrček et al. compared protein content and digestibility between organic and conventional wheat flour and found that organic wheat flour had a lower protein content, but higher protein digestibility than conventional flour [114]. Other authors reported a slightly higher protein content in organic cultivars, and a richer total amino acid profile (higher content of alanine, arginine, asparagine, aspartic acid and glutamic acid) [115]. A recent analytical study comparing organic and conventional legumes (e.g., peas, soybeans) found that the total essential amino acid percentage was higher in organically grown legumes. This was correlated with lower overall protein and nitrogen accumulation in some organic systems, which changed the relative amino acid composition toward essential types [116]. A systematic compilation of comparative studies shows that the content of essential amino acids is higher in organically grown cereals, rye and lupins, compared to their conventional counterparts. Almost the same results were reported by Maggio et al., which compared organic potatoes with conventional ones [117].

Significant differences in mineral and vitamin composition have also been observed in organic farming. Studies have found that organic legumes and vegetables have higher levels of Cu, Mg, Mo, Se, Na, and Zn [118]. Organic broccoli, kale, green peppers and lettuce contained higher levels of K, Ca, Mg, P, Mn and Cr [119–121]. Organic tomatoes had higher levels of K, Ca and Zn [122]. Reddy et al. studied several different fruits, vegetables and tubers (tomato, sweet potato, carrot, sweet orange, papaya) and compared their mineral composition. Higher levels of Cu, Zn, Fe, Ca, Mg, Mn, K, and Na were found in all organically grown fruits and vegetables, compared to conventionally grown ones [123]. There is a limited amount of studies that compare the content of different vitamins in conventional and organic products. A 2010 review on the nutritional quality of organic food reported higher vitamin C contents in organic potatoes, tomatoes, kale and celeriac, as well as a higher vitamin E content in organic olive oil [108]. Worthington's experiment also revealed 27% higher vitamin C levels in organically grown lettuce, spinach, potatoes and cabbage [124].

Another great advantage of organic harvesting is the reduced content of nitrates and heavy metals. Different studies showed that organic fruits and vegetables have significantly lower nitrate values compared to the conventional ones [125,126]. In various experiments, especially with leafy vegetables, nitrate values were found to be two times lower than those that were organically grown [127]. Another study reported that the nitrate content in organic carrot and celery was obviously lower than that in the conventional ones [128]. Similar results were reported for potatoes, lettuce, leek, beet, spinach and tomatoes [121,129]. A similar trend is observed regarding the presence of heavy metals. Different studies reported that heavy metal content in organic wheat, lettuce, pepper and tomato were significantly lower than that in the conventional ones [114,121].

Apart from all the differences mentioned so far, organic cultivation often leads to a higher polyphenol content and antioxidant activity in fruits and vegetables, though results vary significantly by crop, plant part, variety, and environment. Numerous studies showed that organic fruits and vegetables contained a wide variety of phenolic compounds and antioxidants [130–133]. Organic produce can contain 10–50% more phytonutrients, particu-

larly in fruit peels (like oranges and papayas) and some vegetables (onions, lettuce) [134]. Organic cultivation is considered to increase the polyphenol content of peaches and pears compared with conventional cultivation [135]. Overall, various studies on organic crops have observed between 18% and 69% increased antioxidant activity in these products [136].

The listed differences in organic and conventional agricultural products show that the use of organic byproducts in food production has great potential to improve the nutritional profile, vitamin and mineral composition, and antioxidant capacity of the functional food. In addition, the use of organic byproducts in food can minimize the presence of nitrates and heavy metals, which are detrimental to human health. Also, the utilization of these byproducts helps to implement and strengthen the principles of organic farming, such as maximum use of available resources, protection of soil fertility and biological activity, and minimal use of non-renewable resources.

3. Extracts from Agro-Food Byproducts

Usually, agro-food byproducts are from larger-scale food and beverage production (wine production, tomato paste production, juices and canned goods, citrus drinks, etc.). In this way, companies can transform the byproducts into a valuable bioactive product with added value. This allows them to become more competitive in the market. The most commonly used byproducts are seeds, skins and grape pomace, apple peels, orange peels, tomato residues, olive skins, walnut and rapeseed meal or pomace, etc. Agro-food byproducts can be used directly, be dried and ground into powder, or used in the form of an extract containing the isolated biologically active substances. In both cases, it is important to apply appropriate drying conditions for the byproducts, as well as appropriate storage conditions for the dried powder or extract, in order to preserve the activities of the biological components. Despite the growing interest in incorporating agro-food byproducts into functional foods, there are some problems in their acceptance by the public. Attention needs to be paid to their standardization as an additive in order to achieve quality and safety. This can be achieved by continuous quality control of the powder or extracts. This control is more precisely performed on the byproduct extract than on the powder. Extracts from agro-byproducts are widely used, since the isolated bioactive substances have a stronger biological effect. There are several key points in obtaining the extracts: 1. To achieve a high yield of isolated bioactive compounds and for the extract to still be stable. 2. The extract should have high analytical parameters—total phenolic content, flavonoid content, procyanidins, antioxidant capacity, etc. 3. The extract should have strong antimicrobial, anti-lipid and antioxidant properties. 4. To identify the bioactive substances in the extract. 5. To investigate the biological health effects of the extract onto the human body. 6. To preserve the antioxidant activity of the extract after its inclusion in functional foods.

The advantages of agro-food extracts over the direct use of an agro-food byproduct are: extended shelf life, as they are less susceptible to degradation; the percentage of active ingredients is standardized, which guarantees the same activity of the extract every time; and the concentration of active ingredients provides increased efficiency and health benefits from a smaller amount of additive. Conventional and unconventional methods are used to extract bioactive substances from byproducts. Depending on the nature of the bioactive compounds, appropriate solvents are also selected. When choosing a solvent, the application of the extract is also essential. Extraction is performed with various organic solvents (ethanol, methanol, acetone, etc.) and their mixtures with water. If the extract is to be used for inclusion in food or for medicinal purposes, it is preferable to use a mixture of ethanol and water or ethanol alone, as it is harmless for health. One of the most common conventional methods is solid–liquid extraction, but it consumes a significant amount of solvent [62]. In recent years, several unconventional technologies have been developed,

such as ultrasound-assisted extraction, supercritical fluid extraction, microwave extraction, pulsed electric fields and pressurized liquid extraction [63,137]. They achieve an increase in extract yield, a reduction in the amount of organic solvent and a more environmentally friendly extraction of functional compounds from agro-food byproducts. In order to evaluate the qualities of the extract and to standardize it, some studies are needed. First of all, the analytical parameters of the extract, such as total phenolic value, flavonoid content, procyanidins, antioxidant capacity, terpenes, and polysaccharides, should be determined by precise spectrophotometric methods [138]. It is important to determine the antimicrobial and anti-lipid properties of the extract. The antimicrobial properties of the extract are studied by two methods: the agar-diffusion method and determination of the minimum inhibitory capacity of the extract against various pathogenic microorganisms [138]. Anti-lipid activity is assessed by determining the released malondialdehyde as a result of the oxidation of fats and proteins in food [138]. A very important characteristic of the extract is its antioxidant capacity. There are various methods for the measurement of antioxidant capacity [139], but the most commonly used assays are 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS), oxygen radical absorbance capacity (ORAC), iron-reducing antioxidant power (FRAP) and copper-reducing antioxidant capacity (CUPRAC). The individual compositions of the extracts were determined by the HPLC method [140], but it is very important to evaluate the biological properties (in vitro and in vivo) of the agro-food byproduct extracts. The study of the biological properties of the extracts shows the relationship between functional food and health. It is important to determine the mechanisms of action by which the bioactive compound provides health benefits. The inclusion of extracts in functional foods requires a preliminary toxicological assessment. The aforementioned studies need to be performed for each agro-food byproduct extract, due to their specificity. Standardization of extracts is mandatory, as their qualities depend on many factors—agro-plant growing conditions, the treatment process in the food industry, applied extraction methods, drying, storage, etc. In recent years, effective methodologies for encapsulation, lyophilization and spray drying have been developed to improve the stability of bioactive compounds and preserve their characteristics. Today, the search for and identification of new agro-nutritional plant sources; the development of effective methods for extracting bioactive compounds from them, increasing their stability; and the study of new applications of the obtained extracts in foods, especially in fermented meat products, is constantly increasing.

4. Functional Fermented Meat Products

The fermented meat products (dry fermented sausage, salami, chorizo) are of particular importance to the modern consumer in terms of their nutritional properties. Fermented sausages are obtained through three important stages: fermentation, maturation and drying. Fermentation can be carried out by their own microflora or by special starter cultures. These stages modify carbohydrates, proteins and lipids and generate specific physicochemical and sensory parameters [141]. Fermented meat products (FMPs) are among the most researched food categories aimed at reformulating to obtain healthier foods [142]. Innovations in the field of fermented meat products have been aimed at improving their quality and health-related characteristics [143,144]. It is known that FMPs provide important elements for human health, such as proteins with a high biological value, B-complex vitamins (such as B₆ and B₁₂) and minerals [141]. However, fermented meat foods have a high content of fat, saturated fatty acids, salt, sodium, nitrite, synthetic antioxidants and some additives, the consumption of which leads to the development of some chronic non-communicable diseases [145]. The fats and proteins contained in meat products are very susceptible to oxidation. Oxidation processes negatively affect the

shelf life and the sensory and taste qualities of fermented meat products. Furthermore, as a result of these oxidation processes, there is a potential possibility of generating toxic compounds that are considered carcinogenic and harmful to health [146]. A particularly large increase in lipid oxidation can be caused by the production of dry fermented meat products during the fermentation, dehydration and storage of the finished product before consumption [147,148]. A significant problem is also the microbiological contamination of meat products. All these negative phenomena lead to poor sensory and taste qualities and repel the consumer from the finished product. In addition, to inhibit oxidative processes and reduce pathogenic contamination in meat products, synthetic antioxidants are traditionally used at the industrial level. A number of scientific studies showed that these synthetic antioxidants have toxicological properties [149] and as a result, in many countries, they are banned for use in the production meat lines. Thus, the antioxidants octyl gallate and dodecyl gallate are banned in the EU for use as food additives [150]. The synthetic primary antioxidants butylated hydroxyanisole (BHA, E-320), butylated hydroxytoluene (BHT, E-321), tertiary butylhydroquinone (TBHQ, E-319) and propyl gallate (PG, E-310) are permitted for use in products of animal origin, but have a limit value of 200 mg/kg in lard and other animal fats and dehydrated meats, according to European regulations [146]. The following synthetic secondary antioxidants are also permitted: ethylenediaminetetraacetic acid (EDTA, E-385), phosphoric acid (E-338), ascorbyl palmitate (E-304 (i)), sodium erythorbate (E-316), etc. Other additives used in the meat industry, especially in dry fermented products, are nitrites and nitrates. These additives have effective antioxidant and antimicrobial effects, preserve the freshness and color of the meat product and extend its shelf life [151]. However, the latter are very dangerous for human health, as toxic nitroso- and nitrosyl compounds are formed. Nitrates and nitrites are permitted as additives in meat products in the European Union, according to Regulation (EU) No. 1129/2011, at a maximum amount of 150 mg/kg [152]. The use of antioxidants in meat products is regulated by the legislation of each country.

All these problems require new solutions to obtain healthier fermented meat products. The problems with microbiology contaminations of fermented meat product, like lipid oxidation, can be solved by using natural antioxidants. They can be isolated from fruits, vegetables and different plants. In recent years, agro-food byproducts have increasingly been used [153]. They are rich in antioxidants, which can be used for effective control of lipid oxidation and microbial contamination and also to increase the antioxidant capacity of fermented meat products (Figure 2).

In addition, they can replace certain food additives (synthetic antioxidants, nitrites, salt), which have raised concerns about their potential harmfulness in consumers, despite being approved for use under food regulations [150]. This practice is in line with the strategies aimed at producing “clean label” foods. Food manufacturers and consumers often use this term to refer to food products in which the number of additives has been reduced.

Nitrites or nitrates, along with other additives such as salt, are traditionally added to cured meats to extend their shelf life, preserve their color, and improve flavor. Synthetic sodium erythorbate is also added to speed up the curing process. However, acerola extract can serve as a natural curing accelerator, replacing sodium erythorbate. Green acerola cherries are considered to be one of the most concentrated natural sources of L-ascorbic acid [154]. It is believed that the effectiveness of ascorbic acid in this natural matrix is much greater than that of synthetic ascorbic acid. In recent years, acerola has found increasing use in the production of cured meat products. The acerola ascorbic acid added to meat products performs several functions: stabilizing the red color, avoiding rancidity, preventing browning of the meat, and minimizing the formation of carcinogenic nitrosamines. The

nitrite from the curing salt reacts in the presence of water and forms nitric acid. Ascorbic acid oxidizes this nitric acid to produce nitric oxide, which forms a red complex with myoglobin (nitrosomyoglobin), which transformed to a pink color (nitrosylhemochrome) in a cooked cured product. This reduces the risk of brown metmyoglobin formation in the presence of oxygen and preserves the red color of the meat. In turn, brown metmyoglobin reacts with nitric oxide and forms red nitrosomyoglobin. The formation of the highly carcinogenic nitrosamine is also minimized, since ascorbic acid reduces the content of nitric acid. Acerola has been found to have a comparable sensory appeal to synthetic accelerators like sodium erythorbate [154]. Moreover, acerola contains, in addition to vitamin C, other valuable biologically active substances, such as anthocyanins, phenolic acids, flavonoids, etc. The advantages listed above lead to an increase in acerola application in the production of meat products and as supplements. The industrial processing of acerola fruit into pulps and juices produces a dark red residue, constituting about 40% of the fruit volume [155]. This byproduct can be used to produce food supplements and as an additive in meat products [156]. However, ascorbic acid is highly unstable. Moreira et al. reported a 6–15% loss of ascorbic acid during spray drying of acerola peel extract. In order to stabilize acerola extracts, various methods are used, such as encapsulation, immobilization on a carrier, incorporation into an edible film, etc. [157]. Acerola helps to meet consumer demand for “clean label” ingredients, offering benefits like improved pigment formation, antioxidant protection, and comparable sensory appeal to synthetic accelerators like sodium erythorbate.

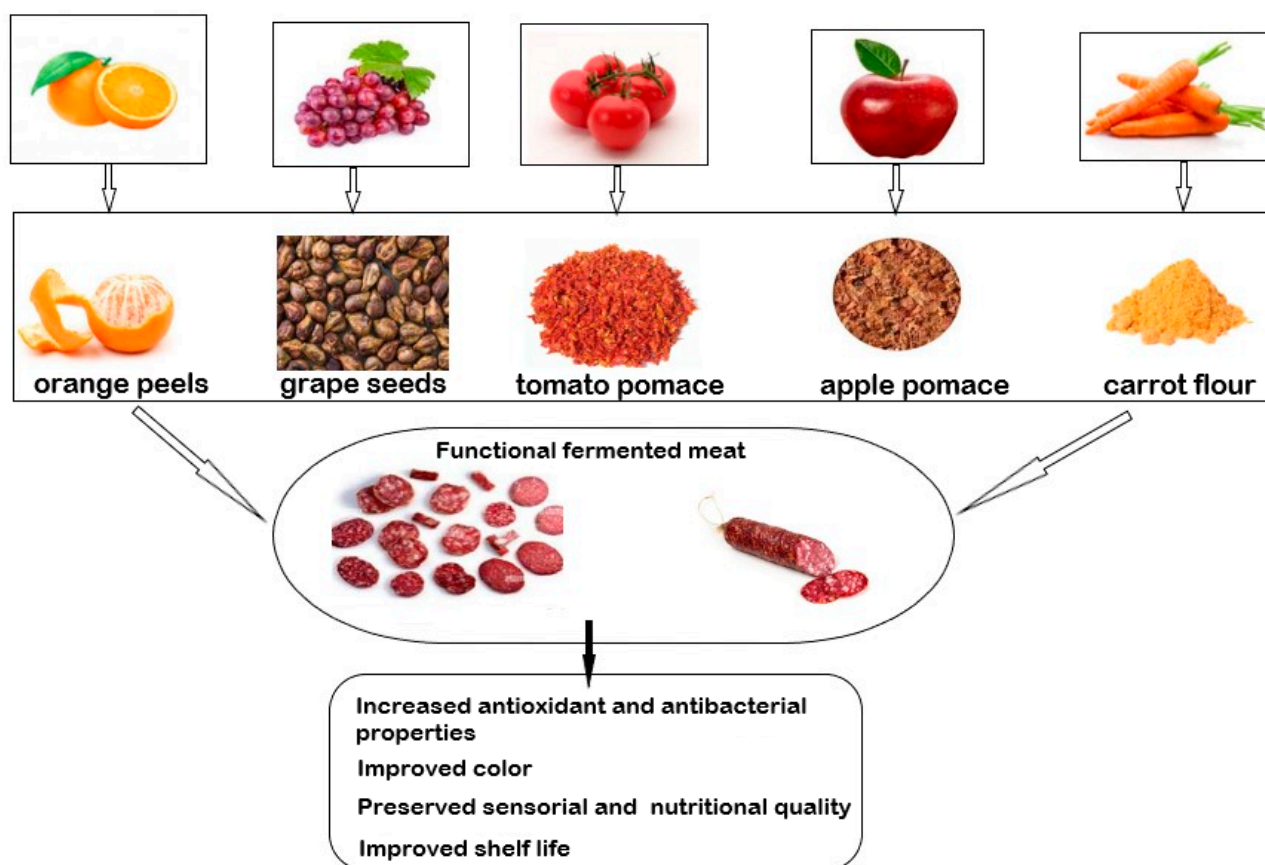


Figure 2. Different agro-food byproducts incorporated into fermented meat products.

Antioxidants will not only control rancidity and microbial contamination of the product, but will also improve the nutritional profile of the final product, as they are enriched with biologically active substances, and make the dry fermented meat product healthier.

The antioxidant activity of byproduct powder or extracts is mainly due to the presence of phenolic compounds (phenolic acids, flavonoids, procyanidins, stilbenes, etc.), but can also be associated with other substances, such as carotenoids, terpenes, and some vitamins (C and E) and minerals (selenium and zinc).

According to the mechanism of action, natural antioxidants are divided into primary and secondary antioxidants [158]. Primary antioxidants (type I) interrupt the oxidation chain reaction by donating hydrogen to free radicals and generating more stable radicals [159]. In the case of secondary antioxidants (type II), the mechanisms of oxidative inhibition are different—metal chelation, regeneration of primary antioxidants, decomposition of the formed hydroperoxide and oxygen scavenging [160]. The two types of antioxidants can act synergistically [161].

In many cases, agro-food byproducts are used directly in the form of dried powder. In this form, they are rich in antioxidants and dietary fiber. Dietary fiber occurs naturally in many different plant sources, including cereals, fruits, vegetables and legumes. In addition, fiber-rich industrial byproducts, such as apple peel, citrus peel, grape skin and sugar beet pulp, contain valuable fiber fractions such as cellulose, lignin and pectin. From a functional point of view, dietary fiber contributes significantly to the texture, water-holding capacity and emulsification of fermented meat products and provides health benefits such as cholesterol reduction and improved digestion. There is a significant number of publications describing the inclusion of various agro and food byproducts (powder, peel, extract) in fermented meat products in order to improve their quality, and some of them are presented in Table 3.

Among agro-food byproducts, tomato pomace has a significant application in fermented meat products. It is separated from the canning industry in the production of tomato paste, puree, etc. The amount of this byproduct is significant: about 3–5% (*w/w*) of the total amount of raw tomatoes [162,163]. Tomato pomace consists of peel, seeds and a small amount of pulp. It can be used in different forms—freeze-dried powder or extract. This byproduct contains various bioactive products, fibers, polyphenols, carotenoids (such as lycopene and β -carotene), oils and proteins, which can be very beneficial for human nutrition and health [164].

The red color of tomato pomace is another of its advantages, as it gives the dry fermented sausage a fresh color. Skwarek et al. [165] describe the effect of tomato pomace on the physicochemical parameters and fatty acid profile of dry fermented sausages while reducing levels of nitrites. An increase in the antioxidant activity of the sausage, as well as a reduction in antibacterial contamination, has been proven. On the other hand, the addition of tomato pomace leads to an increase in the red color of the sausage and it becomes more desirable for customers. It has been found that the best result is obtained when 1.5% freeze-dried tomato pomace is included in the fermented sausage. Later, the same collective [166] investigated the effect of tomato pomace on the oxidative and microbiological stability of raw fermented sausages with a reduced addition of nitrites. The advantages mentioned above are again proven. In addition, the obtained functional sausages are characterized by a higher heme iron content, as well as higher carbonyl groups. It has been shown that the inclusion of tomato pomace in sausage does not reduce the number of lactic acid bacteria in sausages. The best results are obtained with the addition of 2.5% tomato pomace in sausages. Doménech-Asensi et al. [167] showed that the tomato pomace improves color, antioxidant activity, reduces lipid oxidation, and increased heme iron in dry fermented sausages. They reported that the texture profile of mortadella showed no significant alteration after the addition of tomato pomace. Lipid oxidation in sausage cannot be fully inhibited, but it can be delayed with the addition of tomato pomace that is rich with antioxidant substances. Tomato peel is often used directly, to develop dry fermented sausages enriched in lycopene.

Calvo et al. [168] included the different percentage of dry tomato peel (0%, 0.6%, 0.9% and 1.2% *w/w*) in dry fermented sausages. The authors indicated a slight loss of lycopene after 21 days of ripening. The sensory and textural properties of all sausages were very good. Ghafouri-Oskuei et al. [169] investigated the chemical properties and sensory attributes of beef sausages with included tomato powder and flaxseed powder. The addition of tomato and flaxseed powders decreased the pH, residual nitrite and moisture contents and increased the protein, carbohydrate, ash, fiber and total calorie contents. The addition of flaxseed powder increased linolenic acid.

In recent years, there has been a number of publications related to the application of grape pomace and seed extracts as additives to meat and meat products [170–173]. Grape pomace is a byproduct of wine production. They contain grape skins, seeds and stalks. All three components contain valuable biologically active substances, but the largest percentage is in grape seeds (70%). This byproduct is in large quantities. Red grape seed extracts are more widely used. Therefore, grape seeds are a stable and economically viable raw material source containing valuable, biologically active substances. They mainly contain the following groups of antioxidant compounds: phenolic acids; flavonoids; procyanidins; stilbenes, in which monomeric phenolic compounds predominate; (+) catechins; (–) epicatechin; epicatechin-3-O-gallate and dimeric, in which trimeric procyanidins can be found [174,175]. Scientific studies prove that grape seed extract (GSE) is a more potent scavenger of reactive oxygen species and a more powerful antioxidant than vitamins C and E [176]. Lorenzo et al. [177] investigated the effect of grape seeds and chestnut extracts on the physico-chemical, lipid oxidation, microbial and sensory characteristics of dry fermented sausage. A parallel study was also conducted with a synthetic antioxidant, butylated hydroxytoluene (BHT). The addition of antioxidants reduced the lipid oxidation and reduced the total volatile compounds from lipid oxidation. Sensory analysis showed that the acceptability of grape seed was equal to BHT. The authors concluded that grape seeds were more effective than synthetic antioxidants. Ivanov et al. [178] included various natural antioxidants—grape seed extract (GSE), ascorbic acid (AA), α -tocopherol (TP), a combination of GSE and AA, and a combination of GSE and TP in dry fermented sausage. The results obtained with natural antioxidants were compared with the results of samples prepared according to the traditional recipe and with a synthetic antioxidant, butylated hydroxytoluene. The samples with a combination of GSE and AA showed the highest anti-lipid potential, the lowest malondialdehyde values, the highest antimicrobial capacity, the lowest color change, and the lowest change in antioxidant activity, through the sausage drying process. There was an obviously synergistic effect between GSE and AA, and their antioxidant activity was highly effective. The application of grape seed flour for the development of traditional Iraqi fermented sausage “Basturma” were described by Fadhil et al. [179]. They concluded that grape seed powder improves the preservation against infectious pathogens from contaminating the meat, and the chemical properties of beef meat with high nutritional values like protein. The use of grape seed powder could be suggested as a preservative, replacing the chemical preservatives that are in current use.

The antioxidant and antimicrobial effect of grape seed extract on beef sausage were studied by El-Zainy et al. [180]. They found that the added grape seed extract had delayed lipid oxidation and prevented bacterial growth, as well as keeping the good quality and sensory characteristics of minced beef. D’Arrigo et al. [181] compared three samples: red grape pomace added to dry cured sausage (salchichón), ascorbic acid and nitrites added to salchichón and the control, without any additive. They found that grape pomace reduced the pH of salchichón and favored the growth of lactic acid bacteria at similar levels as ascorbic acid and nitrites. The addition of grape pomace led to a less red color in the salchichón than the combination of ascorbic acid and nitrites, but reduced lipid and protein

oxidation of salchichón. The addition of ascorbic acid and nitrites resulted in a final product with a redder and less yellow color than the other samples. This cured color was not reached with the addition of red grape pomace. However, its inclusion slightly reduced lipid and protein oxidation in salchichón.

Apples are the world's most widely consumed fruit. During the industrial production of apple juice, a significant portion of the raw material is wasted in the form of apple pomace, which constitutes 25–30% of the total processed fruit [182]. Apple pomace contains carbohydrates, vitamins, and minerals [183]. According to a study by Gonelimali et al. [184] and Jung et al. [185], apple pomace has a high fiber content and a substantial amount of polyphenols. Apple pomace contains natural antioxidants with strong antioxidant activity, such as quercetin glycosides, phloridzin, and other phenolic constituents [186,187]. Koishybayeva et al. [188] investigated a turkey sausage by including a freeze-dried apple pomace. The addition of apple pomace to turkey sausages resulted in a significant decrease in the moisture and protein contents, whereas no significant difference was found in the fat and ash contents. The increased incorporation of apple pomace resulted in decreased pH, lightness, redness, and yellowness in turkey sausages, whereas an increase in total phenolic content, fiber content, ABTS and DPPH values was observed. The authors described that apple pomace, as a low-cost source of valuable phenolic content, strongly inhibited pathogenic microorganism growth during the storage of turkey sausages. Grispoldi et al. [189] investigated the addition of 7% and 14% apple pomace to pork meat to produce Italian salami. The salami was subjected to 25 days of ripening. The additive improved the fiber and phenol content in salami and decreased the fat and calorie values. They found that 7% of apple pomace had a higher overall acceptability than 14%. Younis et al. [190] found that buffalo meat sausages incorporated with apple pomace powder showed a high cooking yield and emulsion stability of 94.46% and 74.70%, respectively. The additive had antimicrobial properties and high phenolic and dietary fiber contents. The apple pomace powder in concentrations 6–8% affected the texture.

Many of the production processes involving citrus fruits (oranges, lemon, grapefruits) generate large amounts of byproducts and wastes. These byproducts can be used in animal feed, but the problem is that they are very susceptible to microbial spoilage [191]. During orange juice production, only about 50 percent of the fresh orange weight is transformed into juice. The remaining 50 per cent is peel, pulp, seeds, orange leaves and whole orange fruits that do not reach the quality requirements. These byproducts contain valuable polyphenols and fiber and can be of interest as a food additive [192–194]. Dietary fiber may exhibit antioxidant effects due to the presence of phenolic compounds attached through hydrogen bonds to the polysaccharides (bound phenolic compounds). Free phenolic compounds are not bound to the fiber matrix and can be extracted with water and organic solvents from citrus byproducts. Free phenolic compounds can be absorbed in the upper parts of the gastrointestinal tract, but the bound phenolic compounds predominantly occur in the colon after the dietary fiber undergoes fermentation. The inclusion of these extracts in various foods will improve the quality and nutritional value of the foods. Fernandez-López et al. [195] used orange fiber to prepare functional Spanish dry fermented sausages. They reported that the inclusion of orange fiber to the sausage did not change the lactic acid content during the fermentation of the sausage, but only the pH values were affected. It was indicated that phenolic compounds and orange fiber reduced the levels of residual nitrites and favored the growth of micrococci. The reduction in the level of residual nitrites was very important, since the risk of nitrosamine formation reduced. Both effects led to the production of safe and high-quality sausages. Magalhães et al. [196] studied the effect of including lemon dietary fiber into mortadella, a bologna-type sausage, on their properties. The lemon dietary fiber and phenol compounds are the active substances. The

dietary fiber showed influence on color, texture and mineral composition of mortadella. The phenol compounds improved the antimicrobial and antibacterial properties of mortadella. They also decreased the residual nitrite levels.

Strategies to reduce the ingoing nitrite level or completely remove them from fermented meat products are very important, because the nitrite is effective in carcinogenic nitrosamine formation. In the early 2000s, the “clean label” trends in the meat industry gained increased attention [197]. A number of studies have been conducted to partially replace nitrites with vegetable powders, or using vegetable powders entirely, instead of nitrite (celery, spinach, radish, chard, and lettuce) [198–200]. The above vegetables are high in nitrates and are often considered to be alternative preservatives. Celery powder and celery juice concentrate have found wider applications as natural sources of nitrate/nitrites, as they do not impart an unpleasant, bitter taste to cured meat products and have very little effect on the product color [201–203]. From a regulatory perspective, purified sodium or potassium nitrite is not permitted for use in organic products by the National Organic Program of US Department of Agriculture (USDA). Celery powder is recommended as a meat preservative. The question of whether non-organic celery powder should remain on the National List of Allowed and Prohibited Substances or be replaced with organic alternatives is still unresolved. Comparative studies have shown that nitrate content in conventionally grown vegetables using mineral fertilization is higher than that of organically grown vegetables [204]. Furthermore, vegetables fertilized with organic fertilizers significantly increased the content of total phenolics, flavonoids, ascorbic acid, saponins and glutathione compared to inorganic fertilizers [205]. Several studies have found that meat products marinated with celery have similar quality characteristics to those marinated with traditional purified nitrite [206–208]. Swiss chard (*Beta vulgaris* L. var. *cicla*) is also a well-known alternative plant source for preservation, due to its high nitrate concentration [209]. Some authors report that compared to celery, Swiss chard imparts a less pronounced aftertaste and aromatic volatiles [210] and is associated with fewer allergenic concerns [211]. However, it is not known whether curing powder from organically grown celery or Swiss chard offers similar quality and sensory characteristics to those from conventionally grown ones. Sheng et al. [212] studied the products of deli-style turkey breast preserved with sodium nitrite, pre-converted conventionally grown celery, Swiss chard, organically grown celery, and organic Swiss chard with an input sodium nitrite. They described that regardless of the different plant sources of nitrite (celery or Swiss chard) and the cultivation practice of the plant powder (conventional or organic), the sensory evaluations were equivalent to the results obtained with sodium nitrite.

The byproduct from the sugar industry in significant amounts is sugar beet (*Beta vulgaris* var. *saccharifera* L.) molasses. Molasses mainly consist of fermentable sugars (sucrose, glucose, fructose) and non-sugar substances. The non-sugar part of molasses encompasses mineral and trace elements such as potassium, sodium, calcium, magnesium, iron, and copper. This part also included bioactive compounds, such as crude proteins, non-nitrogen substances, vitamin B complex, biotin, etc. Beet molasses have marked antioxidative potential because they contain phenolic compounds, their derivatives, melanin, melanoidins and products of sugar caramelization. Molasses were applied as a non-crystallized syrup and powder. They are mainly used as a nutrient medium for various microbiological productions. There are few publications on their application as an additive in dry fermented meat products. Molasses can completely replace nitrites in the production of dry sausages. Dilek and Karakaya [213] reported the application of sugar beet molasses for the preparation of fermented Turkish sausage. A comparison was made with samples with sodium nitrite added. The presence of nitrosomyoglobin was proven in fermented Turkish sausage, which convincingly shows the potential of sugar beet molasses as a substitute

for sodium nitrate. The complete replacement of sodium nitrate with molasses leads to a higher nitrosomyoglobin content. In this way, a clean-label product can be obtained and can meet current consumer requirements.

The above examples of the application of agro and food byproducts as additives to fermented meat products are more popular and have a greater practical focus. The discussed agro and food byproducts are separated in larger quantities from food enterprises and their valorization is economically advantageous. In parallel, the valorization of these products does not disturb the ecological balance. From the described applications, it is seen that these agro and food byproducts mainly inhibit lipid oxidation and microbial contamination and reduce or completely replace the nitrite content in fermented meat products, and some of them provide a fresh color to the final product. Each added byproduct has a different composition and properties; its influence on the fermented product is different and therefore, it is necessary to study the application of each byproduct individually. In addition, fermented products also have individual compositions and properties and require a specific approach. Dehydrated fermented sausages have a high fat content and can undergo significant lipid oxidation. Adding additives to them with strong antioxidant activity can successfully inhibit this unwanted process and replace synthetic antioxidants completely.

In scientific publications, applications of other types of agro and food byproducts are also found, but they are to a lesser extent, due to the fact that they are not released in large quantities by the food industry. For example, in the production of fruit jellies, jams, juices, fruit pulp, peels, seeds and other insoluble parts of the fruits are released as residues. Pectin is often extracted from them, which is used as a gelling agent. The combination of phenolic compounds and dietary fiber contained in these residues positively changes the properties of fermented meat products. Lau et al. [214] studied the effect of cranberry pomace on the physicochemical properties of dry fermented meat products during their manufacture. In the presence of cranberry pomace, *Staphylococcus* spp. growth was suppressed, while *Lactobacillus* spp. and *Pediococcus* spp. exhibited a stimulatory response, but the medium and high cranberry pomace levels resulted in darker, duller and redder sausages with a softer texture. They recommended the low cranberry pomace levels.

When protein-rich agro-food byproducts are introduced into meat fermentation processes, they can serve as substrates for microbial metabolism and enzymatic activity. Increased microbial degradation of proteins can lead to an increase in free amino acids, altering the cohesion of the meat matrix and affecting the chewiness or firmness [215]. Dairy byproducts, like milk proteins (casein, whey), are used in sausage making to improve the nutritional value (protein, calcium), texture (firmness, water binding), and flavor (tanginess) while creating healthier, “functional” dry sausages with reduced salt/fat by replacing traditional ingredients and adding beneficial probiotics. Karwowska et al. [216] studied the effect of acid whey on the quality of non-nitrite organic fermented sausage. They obtain a significantly lower pH and a higher lactic acid bacteria content in organic fermented sausage without nitrite.

Often, mixtures of several extracts are used. The combined action of the antioxidants in the mixture provides very good anti-lipid and antimicrobial effects. The antioxidant effect of a mixture of lyophilized beer residue extract, aqueous chestnut leaf extract and peanut skin extract was studied [217]. This mixture was included in a Spanish dry fermented sausage with partially replaced pork back fat with microencapsulated fish oil. It was found that the hexanal and total aldehyde content were reduced in the samples with the addition of the three residue extracts, confirming the anti-lipid effect of the mixture.

The color and texture of functional fermented meat products are critical sensory attributes that influence consumer acceptance and overall quality [218]. The inclusion of agro-food byproducts in fermentation systems affects their properties. One of the main

ways in which byproducts from the food industry affect the color and texture of fermented meats is through oxidative processes. The color of the meat depends on the chemical state of the myoglobin. The nitrite reacts with the meat pigment nitrosyl myoglobin to produce nitrosohemochrome. The formed nitrosohemochrome is a pigment that is responsible for the characteristic pinkish cured meat color [219]. Oxidative degradation of myoglobin results in metmyoglobin, which imparts a brownish discoloration and reduces consumer appeal. Conversely, byproducts that are rich in natural antioxidants can slow down oxidative reactions, protect color pigments, and improve color stability when appropriately incorporated. It is important to note that sometimes, the effect on color depends on the type of byproduct used as an ingredient, as it would impart color to the final product. This could happen with byproducts which contain, for example, anthocyanins (grape skin extract), carotenoids (tomato peels), betanin (red beetroot powder), lycopene (tomato pomace), etc. [219]. Depending on the concentration of the imported byproduct, the change in color of the fermented meat product could be positive (i.e., to achieve a natural fresh color in the meat product), but it could also be negative, rising to the darker nuances when used in higher concentrations.

Table 3. Agro-food byproducts used in fermented meat products.

Agro-Food Byproducts	Fermented Meat Products	Effect on the Properties of Fermented Meat Product	Reference
Tomato pomace	Dry fermented sausage	Effective alternative to nitrates, leading to a reduction in the content of synthetic nitrates, high antioxidant and anti-lipid capacity, redness color, changed the fatty acid profile	[165]
Tomato pomace	Dry fermented sausage	The oxidative and microbiological stability, a higher heme iron content as well as higher carbonyl groups, saved the number of lactic acid bacteria	[166]
Tomato paste	Fermented sausages (mortadella)	Improved color and antioxidant activity, reduced lipid oxidation, and increased heme iron in dry fermented sausages, saved the texture	[167]
Tomato peels	Dry fermented sausage	High antioxidant capacity, sensory and textural properties very good, indicated a slight loss of lycopene after 21 days of ripening	[168]
Tomato powder	Beef sausage	Decreased pH, residual nitrite and moisture contents and increased protein, carbohydrate, ash, fiber and total calorie contents	[169]
Grape seed extract	Dry fermented sausage	Reduced the lipid oxidation, reduced the total volatile compounds from lipid oxidation. Sensorial analysis was good	[177]
Grape seed extract	Dry fermented sausage	High anti-lipid potential, low malondialdehyde values, high antimicrobial capacity, unchanged color	[178]
Grape seed flour	Fermented sausage “Basturma”	Improves the preservation against infectious pathogens and protein concentration	[179]
Grape seed extract	Beef sausage	Delayed lipid oxidation and prevented bacterial growth, kept the good quality and sensory characteristics	[180]

Table 3. Cont.

Agro-Food Byproducts	Fermented Meat Products	Effect on the Properties of Fermented Meat Product	Reference
Grape pomace	Dry cured sausage (salchichón)	Decrease in TBARS value, increase in polyphenol content	[181]
Apple pomace	Turkey sausage	High total phenolic and fiber content, high antioxidant potential, strongly inhibited microorganism growth.	[188]
Apple pomace	Italian salami	Improved fiber and phenol content in salami and reduced the fat and calories	[189]
Apple pomace	Buffalo sausage	Increased water retention capacity, higher L color parameter, lower fat content, antimicrobial activity against <i>S. aureus</i> , <i>P. aeruginosa</i> , and <i>L. Monocytogenes</i> , emulsion stability	[190]
Orange fiber	Dry fermented sausage	Decrease in residual nitrite during fermentation, growth of <i>Micrococcaceae</i> (inhibits rancidity and stabilizes color)	[195]
Lemon fiber	Mortadella, a bologna-type sausage	Improved antimicrobial and antibacterial properties, improved the color, texture, and mineral composition, decreased residual nitrite levels.	[196]
Sugar beet (<i>Beta vulgaris</i> var. <i>saccharifera</i> L.) molasses	Sucuk	Substitute for sodium nitrate, complete replacement of sodium nitrate, improved the color	[213]
Cranberry skin powder	Dry fermented sausage	Reduced <i>Salmonella enterica</i> u <i>Staphylococcus</i> spp. cell count, preserved <i>Lactobacillus</i> spp. and <i>Pediococcus</i> spp.	[214]
Whey	Dry fermented sausage	Increased the nutritional value of non-nitrite organic fermented sausage, decreased pH and higher lactic acid bacteria content, improved the texture	[220]
Extracts of beer residue, chestnut leaves and peanut skin and micro-encapsulated fish oil	Spanish dry fermented sausage	Reduces the hexanal and total aldehyde content, antilipidemic effect of the mixture, partial replacement of pork back fat with microencapsulated fish oil	[221]
Pectin from fruit peel	Low-fat fermented sausage	Good texture profile of sausage, adding a small amount of pectin could replace the fat in sausage	[222]
Pectin and inulin	Frankfurter sausage	Fat could be replaced, moisture and ashes of sausages increased, shear force, hardness, fracturability, gumminess, and chewiness were slightly lower	[223]
Pistachio shells	Fermented sausage	Effective alternative to nitrates, leading to a reduction in the content of synthetic nitrates, high antioxidant and anti-lipid capacity	[224]

The texture of fermented meat is influenced by proteolysis, pH reduction, and changes in water activity during fermentation. These processes denature proteins and promote gel formation, which contributes to texture firmness [218]. For these reasons, various textural agents are added to meat products (pectin, whey, apple pomace, citrus peels, grape pomace) [219]. One of the most commonly used texturizing agents in the meat production industry is pectin. It can be obtained from different sources as a byproduct (peels, seeds

of watermelon, mango, tomato, etc.) [220]. Due to its good interaction with meat proteins, based on the H-bond formation and free binding energy, pectin can be used as an emulsifier in the production of meat products [221]. Pectin occurs naturally in the cell walls of fruits and vegetables. It is a water-soluble fiber. Pectin forms a gel in the presence of Ca^{2+} ions or sugar and acid. It can be used as a gelling agent and emulsifier, as it has good water–fat binding properties. It is used as a fat and sugar substitute in the production of low-calorie meat products.

Huynh and Tran [222] developed a low-fat sausage by using pectin from passion fruit peel. They described that adding a small amount of pectin can replace the fat sausage. Pectin ensures a good texture profile in sausage. Mendez-Zamora et al. [223] studied the influence of different concentrations of inulin and pectin as fat substitutes on the chemical composition, texture, and sensory acceptance of frankfurter sausages. The addition of fibers increased the yield and the color parameters were slightly reduced. The moisture and ashes of sausages with inulin and pectin were higher, while shear force, hardness, fracturability, gumminess, and chewiness were slightly lower than those of the control. Fat can be replaced with inulin and pectin in frankfurter sausages to produce healthy and functional products.

The effect of pistachio hull extract as an antioxidant, antimicrobial and textural agent for the preservation of dry fermented sausages during the fermentation and storage period was studied [224]. Pistachio hull extract significantly decreased the lipid oxidation of the sausage samples and showed antimicrobial activity compared to the control, but it did not affect the color of the samples during the storage period.

Agro-food byproducts present an interesting source of bioactive compounds with a low commercial value. They potentially decrease the lipid and protein oxidation in meat products and increase their shelf life and product quality. However, the addition of byproducts in meat has a positive and negative impact. They can change the sensory characteristics of meat. These characteristics are very important and play a significant role in the consumer acceptance of meat [225,226]. Sensory evaluation is carried by different methods [227,228]. Sensory quality can generally be described by appearance, flavor, and texture [229]. The type of byproduct, the level of inclusion and the type of meat products influence the sensory quality of meat.

It is therefore very important to determine the optimal dose for addition to the fermented product, so as to ensure optimal nutritional values, optimal anti-lipid and antimicrobial properties and optimal sensory characteristics. For example, Pereira et al. [230] reported that when grape skins were added in a higher concentration (4%) to a beef burger, lower sensory characteristics (texture, taste) were obtained compared to the control sample. In addition, phenolic compounds imparted a bitter, astringent and sour taste to the meat. The addition of a mixture of grape seed extract, olive oil skins and chestnut tannin to a Cinta Senese Frankfurter sausage also gave a negative result [231]. A positive sensory evaluation was obtained for fermented beef sucuk with 305 g of sugar beet molasses added [213]. Sojic et al. [232] included tomato pomace extract (0.150 $\mu\text{L/g}$) in pork sausages. They found that the addition of tomato extract did not have a negative impact on the taste. Apparently, by combining the type and amount of the added agro-food byproduct, as well as the type of meat product, good sensory characteristics of the product can be ensured.

Despite their good antioxidant activity, the use of natural antioxidants must consider their safe consumption, low concentrations, availability, low cost, compatibility with the food matrix and regulatory guidelines. Only a few natural antioxidants derived from nature are permitted for use as food additives in meat products, according to European Regulation 1333/2008 [150]. Furthermore, it should be noted that plant-derived curing ingredients are typically sourced from purpose-grown crops for extraction, rather than from

agricultural byproducts. The use of synthetic and natural antioxidants is legally controlled by permissible levels, as it is known that excessive addition of antioxidants can lead to pro-oxidant effects. Nevertheless, scientific research into the production of functional fermented meat products has obtained results in this area that are very promising.

5. Conclusions

This review includes the application of various types of agro-food byproducts to obtain functional fermented meat products. The effect of these biologically active additives on the properties of fermented meat products is commented on in detail. The fermented meat products themselves are enriched with useful peptides and amino acids, due to fermentation, and thanks to the microorganisms carrying out the fermentation, they have a valuable probiotic effect. Nevertheless, fermented meat products have a number of problems, especially during storage. This is mainly due to the oxidative processes of fats and lipids in meat products and microbial contamination in them. In addition, these processes lead to a change in the sensory qualities of the products and make them undesirable for customers. Until recently, these problems were solved by adding a higher concentration of salt, or adding nitrites or synthetic antioxidants, which are known to have an unhealthy effect on the body. In recent years, the inclusion of agro-food byproducts in fermented meat products has found increasing applications. Due to the antioxidants and dietetic fiber contained in them, the mentioned undesirable processes are inhibited and even completely replaced by synthetic antioxidants. Therefore, the production of functional fermented meat products is a promising direction for the development of food technologies. The valorization of agro and food byproducts has another important advantage, as it solves environmental problems and issues that are related to the current requirements for sustainability and achieving a circular economy.

Author Contributions: Conceptualization, T.G.; methodology, T.G. and M.A.; investigation, T.G., Y.I. and M.A.; resources, T.G., M.A. and Y.I.; data curation, T.G., M.A. and Y.I.; writing—original draft preparation, T.G., Y.I. and M.A.; writing—review and editing, T.G. and M.A.; visualization, Y.I.; supervision, T.G.; project administration, T.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ABTS	2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid)
CUPRAC	Cupric reducing antioxidant capacity
DPPH	1,1-diphenyl-2-picrylhydrazyl
FMPs	Fermented meat products
FRAP	Ferric reducing antioxidant power
LAB	Lactic acid bacteria
ORAC	Oxygen radical absorbance capacity
PUFA	Polyunsaturated fatty acids
TRABS	Thiobarbituric acid reactive substances
TPC	Total phenolic content

References

1. Aziz, T.; Hussain, N.; Hameed, Z.; Lin, L. Elucidating the role of diet in maintaining gut health to reduce the risk of obesity, cardiovascular and other age-related inflammatory diseases: Recent challenges and future recommendations. *Gut Microbes* **2024**, *16*, 2297864. [\[CrossRef\]](#)
2. Negi, R.; Jan, T.; Kaur, T.; Khan, S.S.; Yadav, N.; Rai, A.K.; Rustagi, S.; Shreaz, S.; Kour, D.; Ahmed, N.; et al. Bioactive compounds as plant-based functional foods for human health: Current scenario and future challenges. *J. Appl. Biol. Biotechnol.* **2025**, *13*, 1–23. [\[CrossRef\]](#)
3. Subramanian, P.; Anandharamakrishnan, C. Introduction to functional foods and nutraceuticals. In *Industrial Application of Functional Foods, Ingredients and Nutraceuticals*; Subramanian, P., Anandharamakrishnan, C., Eds.; Academic Press: Cambridge, MA, USA, 2023; pp. 3–43.
4. Arshad, M.S.; Khalid, W.; Ahmad, R.S.; Khan, M.K.; Ahmad, M.H.; Safdar, S.; Kousar, S.; Munir, H.; Shabbir, U.; Zafarullah, M.; et al. Functional foods and human health: An overview. In *Functional Foods Phytochemicals and Health Promoting Potential*; Arshad, M.S., Ahmad, M.H., Eds.; IntechOpen: London, UK, 2021; p. 3. [\[CrossRef\]](#)
5. Granato, D.; Barba, F.J.; Kovačević, D.B.; Lorenzo, J.M.; Cruz, A.G.; Putnik, P. Functional foods: Product development, technological trends, efficacy testing, and safety. *Annu. Rev. Food Sci. Technol.* **2020**, *11*, 93–118. [\[CrossRef\]](#)
6. Goksen, G.; Demir, D.; Dhama, K.; Kumar, M.; Shao, P.; Xie, F.; Echegaray, N.; Lorenzo, J.M. Mucilage polysaccharide as a plant secretion: Potential trends in food and biomedical applications. *Int. J. Biol. Macromol.* **2023**, *230*, 123146. [\[CrossRef\]](#)
7. Indriyani, N.N.; Anshori, J.A.; Permadi, N.; Nurjanah, S.; Julaeha, E. Bioactive components and their activities from different parts of *Citrus aurantifolia* (Christm.) Swingle for food development. *Foods* **2023**, *12*, 2036. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Lazović, M.Č.; Jović, M.D.; Petrović, M.; Dimkić, I.Z.; Gašić, U.M.; Opsenica, D.M.M.; Ristivojević, P.M.; Trifković, J.Đ. Potential application of green extracts rich in phenolics for innovative functional foods: Natural deep eutectic solvents as media for isolation of biocompounds from berries. *Food Funct.* **2024**, *15*, 4122–4139. [\[CrossRef\]](#)
9. Steinkraus, K.H. Fermentations in world food processing. *Compr. Rev. Food Sci. Food Saf.* **2002**, *1*, 23–32. [\[CrossRef\]](#)
10. Marco, M.L.; Heeney, D.; Binda, S.; Cifelli, C.J.; Cotter, P.D.; Foligné, B.; Gänzle, M.; Kort, R.; Pasin, G.; Pihlanto, A.; et al. Health benefits of fermented foods: Microbiota and beyond. *Curr. Opin. Biotechnol.* **2017**, *44*, 94–102. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Sanders, M.E.; Merenstein, D.J.; Reid, G.; Gibson, G.R.; Rastall, R.A. Probiotics and prebiotics in intestinal health and disease: From biology to the clinic. *Nat. Rev. Gastroenterol. Hepatol.* **2019**, *16*, 605–616. [\[CrossRef\]](#) [\[PubMed\]](#)
12. Tamang, J.P.; Watanabe, K.; Holzapfel, W.H. Diversity of microorganisms in global fermented foods and beverages. *Front. Microbiol.* **2016**, *7*, 377. [\[CrossRef\]](#)
13. Toldrá, F. Biochemical changes during the fermentation of dry-cured meat products. *Meat Sci.* **2006**, *77*, 71–80. [\[CrossRef\]](#)
14. Leroy, F.; Verluyten, J.; De Vuyst, L. Functional meat starter cultures for improved sausage fermentation. *Int. J. Food Microbiol.* **2006**, *106*, 270–285. [\[CrossRef\]](#)
15. Tadesse, S.A.; Emire, S.A. Production and processing of antioxidant bioactive peptides: A driving force for the functional food market. *Heliyon* **2020**, *6*, e04765. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Stobiecka, M.; Król, J.; Brodziak, A. Antioxidant activity of milk and dairy products. *Animals* **2022**, *12*, 245. [\[CrossRef\]](#)
17. Conte, P.; Pulina, S.; Del Caro, A.; Fadda, C.; Urgeghe, P.P.; De Bruno, A.; Difonzo, G.; Caponio, F.; Romeo, R.; Piga, A. Gluten-free breadsticks fortified with phenolic-rich extracts from olive leaves and olive mill wastewater. *Foods* **2021**, *10*, 923. [\[CrossRef\]](#)
18. Zhu, Y.; Lao, F.; Pan, X.; Wu, J. Food protein-derived antioxidant peptides: Molecular mechanism, stability and bioavailability. *Biomolecules* **2022**, *12*, 1622. [\[CrossRef\]](#)
19. Rogel-Castillo, C.; Latorre-Castañeda, M.; Muñoz-Muñoz, C.; Agurto-Muñoz, C. Seaweeds in food: Current trends. *Plants* **2023**, *12*, 2287. [\[CrossRef\]](#)
20. Cuamatzin-García, L.; Rodríguez-Rugarcía, P.; El-Kassis, E.G.; Galicia, G.; Meza-Jiménez, M.D.L.; Baños-Lara, M.D.R.; Zaragoza-Maldonado, D.S.; Pérez-Armendáriz, B. Traditional fermented foods and beverages from around the world and their health benefits. *Microorganisms* **2022**, *10*, 1151. [\[CrossRef\]](#) [\[PubMed\]](#)
21. Ubeyitogullari, A.; Ahmadzadeh, S.; Kandhola, G.; Kim, J. Polysaccharide-based porous biopolymers for enhanced bioaccessibility and bioavailability of bioactive food compounds: Challenges, advances, and opportunities. *Compr. Rev. Food Sci. Food Saf.* **2022**, *21*, 4610–4639. [\[CrossRef\]](#)
22. Chourasia, R.; Phukon, L.C.; Abedin, M.M.; Padhi, S.; Singh, S.P.; Rai, A.K. Bioactive peptides in fermented foods and their application: A critical review. *Syst. Microbiol. Biomanuf.* **2023**, *3*, 88–109. [\[CrossRef\]](#)
23. Laya, A.; Wangso, H.; Fernandes, I.; Djakba, R.; Oliveira, J.; Carvalho, E. Bioactive ingredients in traditional fermented food condiments: Emerging products for prevention and treatment of obesity and type 2 diabetes. *J. Food Qual.* **2023**, *2023*, 5236509. [\[CrossRef\]](#)
24. Harahap, I.A.; Suliburska, J.; Karaca, A.C.; Capanoglu, E.; Esatbeyoglu, T. Fermented soy products: A review of bioactives for health from fermentation to functionality. *Compr. Rev. Food Sci. Food Saf.* **2025**, *24*, e70080. [\[CrossRef\]](#) [\[PubMed\]](#)

25. Galanakis, C.M.; Rizou, M.; Aldawoud, T.M.S.; Ucak, I.; Rowan, N.J. Innovations and technology disruptions in the food sector within the COVID-19 pandemic and post-lockdown era. *Trends Food Sci. Technol.* **2021**, *110*, 193–200. [\[CrossRef\]](#)
26. Liu, Z.; de Souza, T.S.P.; Holland, B.; Dunshea, F.; Barrow, C.; Suleria, H.A.R. Valorization of food waste to produce value-added products based on its bioactive compounds. *Processes* **2023**, *11*, 840. [\[CrossRef\]](#)
27. Ezeorba, T.P.C.; Okeke, E.S.; Mayel, M.H.; Nwuche, C.O.; Ezike, T.C. Recent advances in biotechnological valorization of agro-food wastes: Optimizing integrated approaches for sustainable biorefinery and circular bioeconomy. *Bioresour. Technol. Rep.* **2024**, *26*, 101823. [\[CrossRef\]](#)
28. Xie, Y.; Kang, R.; Tang, D. The flavone baicalein and its use in gastrointestinal disease. In *Dietary Interventions in Liver Disease*; Elsevier: Amsterdam, The Netherlands, 2019; pp. 145–155. [\[CrossRef\]](#)
29. Sut, S.; Dall'Acqua, S.; Zengin, G.; Senkardes, I.; Bulut, G.; Cvetanović, A.; Stupar, A.; Mandić, A.; Picot-Allain, C.; Dogan, A.; et al. Influence of different extraction techniques on the chemical profile and biological properties of *Anthemiscotula* L.: Multifunctional aspects for potential pharmaceutical applications. *J. Pharm. Biomed. Anal.* **2019**, *173*, 75–85. [\[CrossRef\]](#)
30. Varghese, S.A.; Pulikkalparambil, H.; Promhuad, K.; Srisa, A.; Laurenza, Y.; Jarupan, L.; Nampitch, T.; Chonhenchob, V.; Harnkarnsujarit, N. Renovation of agro-waste for sustainable food packaging: A review. *Polymers* **2023**, *15*, 648. [\[CrossRef\]](#) [\[PubMed\]](#)
31. Ngoc, L.T.N.; Moon, J.-Y.; Lee, Y.-C. Insights into bioactive peptides in cosmetics. *Cosmetics* **2023**, *10*, 111. [\[CrossRef\]](#)
32. Cermeño, M.; Bascón, C.; Amigo-Benavent, M.; Felix, M.; FitzGerald, R.J. Identification of peptides from edible silkworm pupae (*Bombyx mori*) protein hydrolysates with antioxidant activity. *J. Funct. Foods* **2022**, *92*, 105052. [\[CrossRef\]](#)
33. Jiang, J.; Xiong, Y.L. Natural antioxidants as food and feed additives to promote health benefits and quality of meat products: A review. *Meat Sci.* **2016**, *120*, 107–117. [\[CrossRef\]](#)
34. Lorenzo, J.M.; Munekata, P.E.; Gómez, B.; Barba, F.J.; Mora, L.; Pérez-Santaescolástica, C.; Toldrá, F. Bioactive peptides as natural antioxidants in food products—A review. *Trends Food Sci. Technol.* **2018**, *79*, 136–147. [\[CrossRef\]](#)
35. Carocho, M.; Morales, P.; Ferreira, I.C. Antioxidants: Reviewing the chemistry, food applications, legislation and role as preservatives. *Trends Food Sci. Technol.* **2018**, *71*, 107–120. [\[CrossRef\]](#)
36. Roca-Saavedra, P.; Méndez-Vilabrille, V.; Miranda, J.M.; Nebot, C.; Cardelle-Cobas, A.; Franco, C.M.; Cepeda, A. Food additives, contaminants and other minor components: Effects on human gut microbiota—A review. *J. Physiol. Biochem.* **2017**, *74*, 69–83. [\[CrossRef\]](#)
37. Pisoschi, A.M.; Pop, A. The role of antioxidants in the chemistry of oxidative stress: A review. *Eur. J. Med. Chem.* **2015**, *97*, 55–74. [\[CrossRef\]](#)
38. Benchabane, L.; Samghouli, A.; Abderrahim, L.A.; Allali, H. Chemical composition and biological activity of *Thymus wilddenowii* essential oil and its application in yogurt. *J. Food Meas. Charact.* **2022**, *16*, 4165–4175.
39. Fawzy, N.; Abo El-Nor, S.A.H.; El-Deeb, D.A.; El-Tanboly, E.S.; El Sayed, M.A. The role of thyme and clove essential oil nanoemulsions in quality improvement of soft cheese. *Suez Canal Vet. Med. J.* **2024**, *29*, 99–108. [\[CrossRef\]](#)
40. El Gabali, T.M.; Jadain, O.A.; El Zubeir, I.E. Effect of addition of Syrian thyme (*Thymus syriacus*) on physiochemical and sensory quality of Sudanese Mudaffara cheese during storage. *J. Food Sci. Technol.* **2023**, *60*, 517–527. [\[CrossRef\]](#) [\[PubMed\]](#)
41. Lončar, B.; Pezo, L.; Iličić, M.; Kanurić, K.; Vukić, D.; Degenek, J.; Vukić, V. Modeling and Optimization of Herb-Fortified Fresh Kombucha Cheese: An Artificial Neural Network Approach for Enhancing Quality Characteristics. *Foods* **2024**, *13*, 548. [\[CrossRef\]](#) [\[PubMed\]](#)
42. Zeng, Y.; Zhou, W.; Yu, J.; Zhao, L.; Wang, K.; Hu, Z.; Liu, X. By-products of fruit and vegetables: Antioxidant properties of extractable and non-extractable phenolic compounds. *Antioxidants* **2023**, *12*, 418. [\[CrossRef\]](#)
43. Faraoni, P.; Laschi, S. Bioactive compounds from agrifood by-products: Their use in medicine and biology. *Int. J. Mol. Sci.* **2024**, *25*, 5776. [\[CrossRef\]](#)
44. Khursheed, S.; Akhtar, M.; Saeed, S.M.A.; Fazal, A.; Rehman, F.; Bashir, Z.; Khanam, U.; Hani, U.; Mustafa, H.M.; Haris, M.; et al. Valorization of pomegranate and banana by-products into value-added products: Influence on physicochemical, rheological, and consumer attributes. *Indus. J. Biosci. Res.* **2025**, *3*, 427–440. [\[CrossRef\]](#)
45. Villamil-Galindo, E.; Van de Velde, F.; Piagentini, A.M. Strawberry agro-industrial by-products as a source of bioactive compounds: Effect of cultivar on the phenolic profile and the antioxidant capacity. *Bioresour. Bioprocess.* **2021**, *8*, 61. [\[CrossRef\]](#)
46. Devatkal, S.K.; Narsaiah, K.; Borah, A. Effect of salt, kinnnow and pomegranate fruit by-product extracts on colour and oxidative stability of raw chicken patties during refrigerated storage. *J. Food Sci. Technol.* **2011**, *48*, 472–477. [\[CrossRef\]](#)
47. Nour, V.; Trandafir, I.; Cosmulescu, S. Antioxidant capacity, phenolic compounds and mineral content of blackcurrant (*Ribes nigrum* L.) leaves as influenced by harvesting date and extraction method. *Ind. Crops Prod.* **2014**, *53*, 133–139. [\[CrossRef\]](#)
48. Lafarga, T.; Hayes, M. Bioactive peptides from meat muscle and by-products: Generation, functionality and application as functional ingredients. *Meat Sci.* **2014**, *98*, 227–239. [\[CrossRef\]](#)
49. Toldrá, F.; Mora, L.; Reig, M. Current developments in meat by-products. In *New Aspects of Meat Quality*, 2nd ed.; Purslow, P., Ed.; Woodhead Publishing: Cambridge, UK, 2022; pp. 649–665.

50. Sánchez, A.; Vázquez, A. Bioactive peptides: A review. *Food Qual. Saf.* **2017**, *1*, 29–46. [\[CrossRef\]](#)
51. Toldrá, F.; Mora, L.; Reig, M. New insights into meat by-product utilization. *Meat Sci.* **2016**, *120*, 54–59. [\[CrossRef\]](#) [\[PubMed\]](#)
52. Ryder, K.; Ha, M.; Bekhit, A.E.-D.; Carne, A. Characterization of novel fungal and bacterial protease preparations and evaluation of their ability to hydrolyse meat myofibrillar and connective tissue proteins. *Food Chem.* **2015**, *172*, 197–206. [\[CrossRef\]](#) [\[PubMed\]](#)
53. Yang, Q.; Liu, Y.; Guo, Y.; Jiang, Y.; Wen, L.; Yang, B. New insights of fig (*Ficus carica* L.) as a potential functional food. *Trends Food Sci. Technol.* **2023**, *140*, 104146. [\[CrossRef\]](#)
54. Rasool, I.F.u.; Aziz, A.; Khalid, W.; Koraqi, H.; Siddiqui, S.A.; Al-Farga, A.; Lai, W.-F.; Ali, A. Industrial application and health prospective of fig (*Ficus carica*) by-products. *Molecules* **2023**, *28*, 960. [\[CrossRef\]](#)
55. Blejana, A.M.; Nour, V.; Păcularu-Burada, B.; Popescu, S.M. Wild bilberry, blackcurrant, and blackberry by-products as a source of nutritional and bioactive compounds. *Int. J. Food Prop.* **2023**, *26*, 1579–1595. [\[CrossRef\]](#)
56. Pedišić, S.; Zorić, Z.; Repajić, M.; Levaj, B.; Dobrincic, A.; Balbino, S.; Ćosić, Z.; Dragović-Uzelac, V.; Garofulić, I.E. Valorization of berry fruit by-products: Bioactive compounds, extraction, health benefits, encapsulation and food applications. *Foods* **2025**, *14*, 1354. [\[CrossRef\]](#)
57. Pukalskienė, M.; Pukalskas, A.; Dienaitė, L.; Revinytė, S.; Pereira, C.V.; Matias, A.A.; Venskutonis, P.R. Recovery of bioactive compounds from strawberry (*Fragaria × ananassa*) pomace by conventional and pressurized liquid extraction and assessment of their bioactivity in human cell cultures. *Foods* **2021**, *10*, 1780. [\[CrossRef\]](#) [\[PubMed\]](#)
58. Santos, D.I.; Martins, C.F.; Amaral, R.A.; Brito, L.; Saraiva, J.A.; Vicente, A.A.; Moldão-Martins, M. Pineapple (*Ananas comosus* L.) by-products valorization: Novel bioingredients for functional foods. *Molecules* **2021**, *26*, 3216. [\[CrossRef\]](#)
59. Wang, Z.; Fu, Q.; Hao, G.; Gu, Y.; Sun, T.; Gao, L.; Wang, B.; Wang, S.; Zheng, X.; Yang, Z.; et al. Physical aspects, phytochemical profiles, and nutritional properties of lemon (*Citrus limon*) slices under different drying technologies. *Foods* **2025**, *14*, 2586. [\[CrossRef\]](#)
60. Noreen, S.; Hashmi, B.; Aja, P.M.; Atoki, A.V. Phytochemicals and pharmacology of pomegranate (*Punica granatum* L.): Nutraceutical benefits and industrial applications. *Front. Nutr.* **2025**, *12*, 1528897. [\[CrossRef\]](#)
61. Aqilah, N.M.N.; Rovina, K.; Felicia, W.X.L.; Vonnice, J.M.A. A review on the potential bioactive components in fruits and vegetable wastes as value-added products in the food industry. *Molecules* **2023**, *28*, 2631. [\[CrossRef\]](#) [\[PubMed\]](#)
62. Szabo, K.; Varvara, R.A.; Ciont, C.; Macri, A.M.; Vodnar, D.C. An updated overview on the revalorization of bioactive compounds derived from tomato production and processing by-products. *J. Clean. Prod.* **2025**, *497*, 145151. [\[CrossRef\]](#)
63. Karastergiou, A.; Gancel, A.; Jourdes, M.; Teissedre, P. Transforming winemaking waste: Grape pomace as a sustainable source of bioactive compounds. *OENO One* **2025**, *59*, 2. [\[CrossRef\]](#)
64. Zhao, Q.-C.; Zhao, J.-Y.; Ahn, D.U.; Jin, Y.-G.; Huang, X. Separation and identification of highly efficient antioxidant peptides from eggshell membrane. *Antioxidants* **2019**, *8*, 495. [\[CrossRef\]](#) [\[PubMed\]](#)
65. Zhu, L.; Li, Z.; Ma, M.; Huang, X.; Guyonnet, V.; Xiong, H. Exploration of novel DPP-IV inhibitory peptides from discarded eggshell membrane: An integrated in silico and in vitro study. *Food Biosci.* **2024**, *59*, 104036. [\[CrossRef\]](#)
66. Liu, R.; Wang, M.; Duan, J.-A. Antipyretic and antioxidant activities of the aqueous extract of *Cornu bubali* (water buffalo horn). *Am. J. Chin. Med.* **2010**, *38*, 293–306. [\[CrossRef\]](#)
67. Adje, E.Y.; Balti, R.; Kouach, M.; Dhulster, P.; Guillochon, D.; Nedjar-Arroume, N. Obtaining antimicrobial peptides by controlled peptic hydrolysis of bovine hemoglobin. *Int. J. Biol. Macromol.* **2011**, *49*, 143–153. [\[CrossRef\]](#) [\[PubMed\]](#)
68. Ciurlia, L.; Bleve, M.; Rescio, L. Supercritical carbon dioxide co-extraction of tomatoes (*Lycopersicon esculentum* L.) and hazelnuts (*Corylus avellana* L.): A new procedure for obtaining a source of natural lycopene. *J. Supercrit. Fluids* **2009**, *49*, 338–344. [\[CrossRef\]](#)
69. Viuda-Martos, M.; Sanchez-Zapata, E.; Sayas-Barberá, E.; Sendra, E.; Pérez-Álvarez, J.A.; Fernández-López, J. Tomato and tomato by-products: Human health benefits of lycopene and its application to meat products—A review. *Crit. Rev. Food Sci. Nutr.* **2014**, *54*, 1032–1049. [\[CrossRef\]](#)
70. Sung, K.; Khan, S.A.; Nawaz, M.S.; Cerniglia, C.E.; Tamplin, M.L.; Phillips, R.W.; Kelley, L.C. Lysozyme as a barrier to growth of *Bacillus anthracis* strain Sterne in liquid egg white, milk and beef. *Food Microbiol.* **2011**, *28*, 1231–1234. [\[CrossRef\]](#)
71. Barbiroli, A.; Bonomi, F.; Capretti, G.; Iametti, S.; Manzoni, M.; Piergiovanni, L.; Rollini, M. Antimicrobial activity of lysozyme and lactoferrin incorporated in cellulose-based food packaging. *Food Control* **2012**, *26*, 387–392. [\[CrossRef\]](#)
72. Novais, C.; Molina, A.K.; Abreu, R.M.V.; Santo-Buelga, C.; Ferreira, I.C.F.R.; Pereira, C.; Barros, L. Natural food colorants and preservatives: A review, a demand, and a challenge. *J. Agric. Food Chem.* **2022**, *70*, 2789–2805. [\[CrossRef\]](#)
73. Ayala-Zavala, J.F.; González-Aguilar, G.A. Use of additives to preserve the quality of fresh-cut fruits and vegetables. In *Advances in Fresh-Cut Fruits and Vegetables Processing*; CRC Press: Boca Raton, FL, USA, 2010; pp. 233–256. [\[CrossRef\]](#)
74. Caleja, C.; Barros, L.; Antonio, A.L.; Oliveira, M.B.P.P.; Ferreira, I.C.F.R. A comparative study between natural and synthetic antioxidants: Evaluation of their performance after incorporation into biscuits. *Food Chem.* **2017**, *216*, 342–346. [\[CrossRef\]](#) [\[PubMed\]](#)
75. McCusker, M.M.; Durrani, K.; Payette, M.J.; Suchecki, J. An eye on nutrition: The role of vitamins, essential fatty acids, and antioxidants in age-related macular degeneration, dry eye syndrome, and cataract. *Clin. Dermatol.* **2016**, *34*, 276–285. [\[CrossRef\]](#)

76. Roldán, E.; Sánchez-Moreno, C.; de Ancos, B.; Cano, M.P. Characterization of onion (*Allium cepa* L.) by-products as food ingredients with antioxidant and antibrowning properties. *Food Chem.* **2008**, *108*, 907–916. [\[CrossRef\]](#)
77. Larrosa, M.; Llorach, R.; Espín, J.C.; Tomás-Barberán, F.A. Increase of antioxidant activity of tomato juice upon functionalisation with vegetable by-product extracts. *LWT—Food Sci. Technol.* **2002**, *35*, 532–542. [\[CrossRef\]](#)
78. Chandel, V.; Biswas, D.; Roy, S.; Vaidya, D.; Verma, A.; Gupta, A. Current advancements in pectin: Extraction, properties and multifunctional applications. *Foods* **2022**, *11*, 2683. [\[CrossRef\]](#)
79. Karim, A.A.; Bhat, R. Fish gelatin: Properties, challenges, and prospects as an alternative to mammalian gelatins. *Food Hydrocoll.* **2009**, *23*, 563–576. [\[CrossRef\]](#)
80. Gómez-Guillén, M.C.; Giménez, B.; López-Caballero, M.E.; Montero, M.P. Functional and bioactive properties of collagen and gelatin from alternative sources: A review. *Food Hydrocoll.* **2011**, *25*, 1813–1827. [\[CrossRef\]](#)
81. Smithers, G.W. Whey-ing up the options—Yesterday, today and tomorrow. *Int. Dairy J.* **2015**, *48*, 2–14. [\[CrossRef\]](#)
82. Gbogouri, G.; Linder, M.; Fanni, J.; Parmentier, M. Influence of hydrolysis degree on the functional properties of salmon by-products hydrolysates. *J. Food Sci.* **2004**, *69*, C615–C622. [\[CrossRef\]](#)
83. Sathivel, S.; Bechtel, P.J.; Babbitt, J.; Prinyawiwatukul, W.; Negulescu, I.I.; Reppond, K.D. Properties of protein powders from arrowtooth flounder (*Atheresthes stomias*) and herring (*Clupea harengus*) by-products. *J. Agric. Food Chem.* **2004**, *52*, 5040–5046. [\[CrossRef\]](#)
84. Sathivel, S.; Bechtel, P.J.; Babbitt, J.; Smiley, S.; Crapo, C.; Reppond, K.D.; Prinyawiwatukul, W. Biochemical and functional properties of herring (*Clupea harengus*) by-product hydrolysates. *J. Food Sci.* **2003**, *68*, 2196–2200. [\[CrossRef\]](#)
85. Vieira, E.F.; Gomes, L.R.; Grosso, C.; Delerue-Matos, C. Recent advances on seaweed-derived pigments for food application and current legal framework. *Foods* **2025**, *14*, 3265. [\[CrossRef\]](#)
86. Cazón, P.; Silva, A.S. Natural pigments from food wastes: New approaches for the extraction and encapsulation. *Curr. Opin. Green Sustain. Chem.* **2024**, *47*, 100929. [\[CrossRef\]](#)
87. Ofori, J.A.; Hsieh, Y.-H.P. Issues related to the use of blood in food and animal feed. *Crit. Rev. Food Sci. Nutr.* **2014**, *54*, 687–697. [\[CrossRef\]](#)
88. Boronat, Ò.; Sintes, P.; Celis, F.; Díez, M.; Ortiz, J.; Aguiló-Aguayo, I.; Martín-Gómez, H. Development of added-value culinary ingredients from fish waste: Fish bones and fish scales. *Int. J. Gastron. Food Sci.* **2023**, *31*, 100657. [\[CrossRef\]](#)
89. Abdel-Moemin, A.R. Healthy cookies from cooked fish bones. *Food Biosci.* **2015**, *12*, 114–121. [\[CrossRef\]](#)
90. Akalın, A.; Unal, G.; Dinkci, N.; Hayaloglu, A.A. Microstructural, textural, and sensory characteristics of probiotic yogurts fortified with sodium calcium caseinate or whey protein concentrate. *J. Dairy Sci.* **2012**, *95*, 3617–3628. [\[CrossRef\]](#)
91. Zhang, T.; McCarthy, J.; Wang, G.; Liu, Y.; Guo, M. Physiochemical properties, microstructure, and probiotic survivability of nonfat goats' milk yogurt using heat-treated whey protein concentrate as fat replacer. *J. Food Sci.* **2015**, *80*, M788–M794. [\[CrossRef\]](#) [\[PubMed\]](#)
92. Saffon, M.; Richard, V.; Jiménez-Flores, R.; Gauthier, S.F.; Britten, M.; Pouliot, Y. Behavior of heat-denatured whey: Buttermilk protein aggregates during the yogurt-making process and their influence on set-type yogurt properties. *Foods* **2013**, *2*, 444–459. [\[CrossRef\]](#)
93. Iriondo-DeHond, M.; Miguel, E.; del Castillo, M.D. Food by-products as sustainable ingredients for innovative and healthy dairy foods. *Nutrients* **2018**, *10*, 1358. [\[CrossRef\]](#)
94. Saraç, M.G.; Dogan, M. Incorporation of dietary fiber concentrates from fruit and vegetable wastes in butter: Effects on physicochemical, textural, and sensory properties. *Eur. Food Res. Technol.* **2016**, *242*, 1331–1342. [\[CrossRef\]](#)
95. Kaur, D.; Wani, A.A.; Singh, D.P.; Sogi, D.S. Shelf-life enhancement of butter, ice cream, and mayonnaise by addition of lycopene. *Int. J. Food Prop.* **2011**, *14*, 1217–1231. [\[CrossRef\]](#)
96. Rizk, E.M.; El-Kady, A.T.; El-Bialy, A.R. Characterization of carotenoids (lyco-red) extracted from tomato peels and their use as natural colorants and antioxidants in ice cream. *Ann. Agric. Sci.* **2014**, *59*, 53–61. [\[CrossRef\]](#)
97. Tseng, A.; Zhao, Y. Wine grape pomace as antioxidant dietary fiber for enhancing nutritional value and improving storability of yogurt and salad dressing. *Food Chem.* **2013**, *138*, 356–365. [\[CrossRef\]](#) [\[PubMed\]](#)
98. Sadilova, E.; Stintzing, F.C.; Carle, R. Anthocyanins, color and antioxidant properties of eggplant (*Solanum melongena* L.) and violet pepper (*Capsicum annuum* L.) peel extracts. *Z. Naturforschung C* **2006**, *61*, 527–535. [\[CrossRef\]](#)
99. De Ancos, B.; Colina-Coca, C.; González-Peña, D.; Sánchez-Moreno, C. Bioactive compounds from vegetable and fruit by-products. In *Biotechnology of Bioactive Compounds: Sources and Applications*; Wiley: Hoboken, NJ, USA, 2015; pp. 1–36. [\[CrossRef\]](#)
100. Ajila, C.; Leelavathi, K.; Rao, U.P. Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *J. Cereal Sci.* **2008**, *48*, 319–326. [\[CrossRef\]](#)
101. Tung, Y.-C.; Chang, W.-T.; Li, S.; Wu, J.-C.; Badmeav, V.; Ho, C.-T.; Pan, M.-H. Citrus peel extracts attenuate obesity and modulate gut microbiota in mice with high-fat diet-induced obesity. *Food Funct.* **2018**, *9*, 3363–3373. [\[CrossRef\]](#)
102. Ghasemi, K.; Ghasemi, Y.; Ebrahimzadeh, M.A. Antioxidant activity, phenol and flavonoid contents of 13 citrus species peels and tissues. *Pak. J. Pharm. Sci.* **2009**, *22*, 277–281. [\[PubMed\]](#)

103. Food and Agriculture Organization of the United Nations. *What Is Organic Agriculture?* Food and Agriculture Organization of the United Nations: Rome, Italy, 2020. Available online: <http://www.fao.org/3/ad818s/ad818s03.htm> (accessed on 17 June 2020).
104. Gontijo, L.N.; da Silva, C.O.; Stort, L.G.; Duarte, R.M.T.; Betanho, C.; Tassi, E.M.M. Nutritional composition of vegetables grown in organic and conventional cultivation systems in Uberlândia, MG. *Afr. J. Agric. Res.* **2017**, *12*, 1848–1851. [\[CrossRef\]](#)
105. Popa, M.E.; Mitelut, A.C.; Popa, E.E.; Stan, A.; Popa, V.I. Organic Foods Contribution to Nutritional Quality and Value. *Trends Food Sci. Technol.* **2019**, *84*, 15–18. [\[CrossRef\]](#)
106. Reeve, J.R.; Hoagland, L.A.; Villalba, J.J.; Carr, P.M.; Atucha, A.; Cambardella, C.; Davis, D.R.; Delate, K. Organic Farming Soil. Health, and Food Quality: Considering Possible Links. *Adv. Agron.* **2016**, *137*, 319–368. [\[CrossRef\]](#)
107. Manyaku, A.; Witbooi, H.; Laubscher, C.P. The significance of organic horticulture in mitigating climate change and promoting the production of healthier fruits and vegetables. *Appl. Sci.* **2024**, *14*, 4966. [\[CrossRef\]](#)
108. Lairon, D. Nutritional quality and safety of organic food: A review. *Agron. Sustain. Dev.* **2010**, *30*, 33–41. [\[CrossRef\]](#)
109. Rabiee, M.; Kaviani, B.; Sedaghatthoor, S.; Eslami, A. Nutritional and qualitative comparison of temperate fruits from conventional and organic orchards. *Sci. Rep.* **2025**, *15*, 6835. [\[CrossRef\]](#)
110. Suja, G.; Byju, G.; Jyothi, A.N.; Veena, S.S.; Sreekumar, J. Yield, quality and soil health under organic vs. conventional farming in taro. *Sci. Hortic.* **2017**, *218*, 334–343. [\[CrossRef\]](#)
111. Gaśtoł, M.; Domagała-Świątkiewicz, I.; Krosniak, M. Organic versus conventional—A comparative study on quality and nutritional value of fruit and vegetable juices. *Biol. Agric. Hortic.* **2011**, *27*, 310–319. [\[CrossRef\]](#)
112. Kazimierczak, R.; Srednicka-Tober, D.; Hallmann, E.; Kopczynska, K.; Zarzyńska, K. The impact of organic vs. conventional agricultural practices on selected quality features of eight potato cultivars. *Agronomy* **2019**, *9*, 799. [\[CrossRef\]](#)
113. Lombardo, S.; Pandino, G.; Mauromicale, G. The influence of growing environment on the antioxidant and mineral content of early crop potato. *J. Food Compos. Anal.* **2013**, *32*, 28–35. [\[CrossRef\]](#)
114. Vrček, I.V.; Čepo, D.V.; Rašić, D.; Peraica, M.; Žuntar, I.; Bojić, M.; Mendaš, G.; Medić-Šarić, M. A comparison of the nutritional value and food safety of organically and conventionally produced wheat flours. *Food Chem.* **2014**, *143*, 522–529. [\[CrossRef\]](#)
115. Carillo, P.; Cacace, D.; Pascale, S.D.; Rapacciuolo, M.; Fuggi, A. Organic vs. traditional potato powder. *Food Chem.* **2012**, *133*, 1264–1273. [\[CrossRef\]](#)
116. Verma, R.; Saini, J.P.; Dhaliwal, Y.S.; Bhat, F.M. Comparative study of organic and inorganic legumes for their chemical composition, nutritional and amino acid profiling—An Analytical Study. *J. Hum. Nutr. Food Sci.* **2023**, *11*, 1173. [\[CrossRef\]](#)
117. Maggio, A.; Carillo, P.; Bulmetti, G.S.; Fuggi, A.; Barbieri, G.; Pascale, S.D. Potato yield and metabolic profiling under conventional and organic farming. *Eur. J. Agron.* **2008**, *28*, 343–350. [\[CrossRef\]](#)
118. Hunter, D.; Foster, M.; McArthur, J.O.; Ojha, R.; Petocz, P.; Samman, S. Evaluation of the micronutrient composition of plant foods produced by organic and conventional agricultural methods. *Crit. Rev. Food Sci. Nutr.* **2011**, *51*, 571–582. [\[CrossRef\]](#) [\[PubMed\]](#)
119. Yu, X.; Guo, L.; Jiang, G.; Song, Y.; Muminov, M.A. Advances of organic products over conventional productions with respect to nutritional quality and food security. *Acta Ecol. Sin.* **2018**, *38*, 53–60. [\[CrossRef\]](#)
120. Warman, P.R.; Havard, K.A. Yield, vitamin and mineral contents of organically and conventionally grown potatoes and sweet corn. *Agric. Ecosyst. Environ.* **1998**, *68*, 207–216. [\[CrossRef\]](#)
121. Araújo, D.F.d.S.; da Silva, A.M.R.B.; Lima, L.L.d.A.; Vasconcelos, M.A.d.S.; Andrade, S.A.C.; Sarubbo, L.A. The concentration of minerals and physicochemical contaminants in conventional and organic vegetables. *Food Control* **2014**, *44*, 242–248. [\[CrossRef\]](#)
122. Sheng, J.P.; Liu, C.; Shen, L. Analysis of nutrients and minerals in organic and traditional cherry tomato by ICP-OES method. *Spectrosc. Spectr. Anal.* **2009**, *29*, 2244–2246.
123. Reddy, A.A.; Vimala, Y.; Goudar, G.; Mergu, N.; Rao, J.S. Nutritional compilation of commonly consumed organic and conventional fruits and vegetables from India. *Food Humanit.* **2023**, *1*, 1652–1658. [\[CrossRef\]](#)
124. Worthington, V. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *J. Altern. Complement. Med.* **2001**, *7*, 161–173. [\[CrossRef\]](#)
125. de González, M.T.N.; Osburn, W.N.; Hardin, M.D.; Longnecker, M.; Garg, H.K.; Bryan, N.S.; Keeton, J.T. A survey of nitrate and nitrite concentrations in conventional and organic-labeled raw vegetables at retail. *J. Food Sci.* **2015**, *80*, C942–C949. [\[CrossRef\]](#)
126. Chausali, N.; Saxena, J. Conventional versus organic farming: Nutrient status. In *Advances in Organic Farming*; Woodhead Publishing: Cambridge, UK, 2021; pp. 241–254. [\[CrossRef\]](#)
127. Mohamed, N. Determination of nitrate content in organic and conventionally grown vegetable leaves in Sri Lanka using spectrophotometry. *J. Nutr. Health Sci.* **2017**, *1*, 16.
128. Xu, M.J.; He, W.L. Effects of organic, special and conventional farming systems on vegetable quality. *Acta Agric. Jiangxi* **2009**, *21*, 68–70.
129. Calderon, R.; García-Hernández, J.; Palma, P.; Leyva-Morales, J.B.; Godoy, M.; Zambrano-Soria, M.; Bastidas-Bastidas, P.J.; Valenzuela, G. Heavy metals and metalloids in organic and conventional vegetables from Chile and Mexico: Implications for human health. *J. Food Compos. Anal.* **2023**, *123*, 105527. [\[CrossRef\]](#)

130. Brazinskiene, V.; Asakaviciute, R.; Miezelienė, A.; Alencikiene, G.; Ivanauskas, L.; Jakstas, V.; Viskelis, P.; Razukas, A. Effect of farming systems on yield, quality parameters and sensory properties of conventionally and organically grown potato (*Solanum tuberosum* L.) tubers. *Food Chem.* **2014**, *145*, 903–909. [\[CrossRef\]](#)
131. Czech, A.; Szmigielski, M.; Sembratowicz, I. Nutritional value and antioxidant capacity of organic and conventional vegetables of the genus. *Sci. Rep.* **2022**, *12*, 18713. [\[CrossRef\]](#)
132. Cruz-Carrión, Á.; Ruiz de Azua, M.J.; Muguerza, B.; Mulero, M.; Bravo, F.I.; Arola-Arnal, A.; Suarez, M. Organic vs. Non-Organic Plant-Based Foods—A Comparative Study on Phenolic Content and Antioxidant Capacity. *Plants* **2023**, *12*, 183. [\[CrossRef\]](#) [\[PubMed\]](#)
133. Carrillo, C.; Wilches-Pérez, D.; Hallman, E.; Kazimierzczak, R.; Rembiałkowska, E. Organic versus conventional beetroot: Bioactive compounds and antioxidant properties. *LWT* **2019**, *116*, 108552. [\[CrossRef\]](#)
134. Faller, A.L.K.; Fialho, E. Polyphenol content and antioxidant capacity in organic and conventional plant foods. *J. Food Compos. Anal.* **2010**, *23*, 561–568. [\[CrossRef\]](#)
135. Carbonaro, M.; Mattera, M.; Nicoli, S.; Bergamo, P.; Cappelloni, M. Modulation of antioxidant compounds in organic vs. conventional fruit (Peach, *Prunus persica* L., and Pear, *Pyrus communis* L.). *J. Agric. Food Chem.* **2002**, *50*, 5458–5462. [\[CrossRef\]](#)
136. Barański, M.; Rempelos, L.; Iversen, P.O.; Leifert, C. Effects of organic food consumption on human health; The jury is still out! *Food Nutr. Res.* **2017**, *61*, 1287333. [\[CrossRef\]](#) [\[PubMed\]](#)
137. Zhou, D.D.; Li, J.; Xiong, R.-G.; Saimaiti, A.; Huang, S.-Y.; Wu, S.-X.; Yang, Z.-J.; Shang, A.; Zhao, C.-N.; Gan, R.-Y.; et al. Bioactive compounds, health benefits and food applications of grape. *Foods* **2022**, *11*, 2755. [\[CrossRef\]](#)
138. Zaky, A.A.; Akram, M.U.; Rybak, K.; Witrowa-Rajchert, D.; Nowacka, M. Bioactive compounds from plants and by-products: Novel extraction methods, applications, and limitations. *AIMS Mol. Sci.* **2024**, *11*, 150–188. [\[CrossRef\]](#)
139. Majida, I.; Khana, S.; Aladelb, A.; Dara, A.H.; Adnan, M.; Khand, M.I.; Awadelkareem, A.M.; Ashraf, S.A. Recent insights into green extraction techniques as efficient methods for the extraction of bioactive components and essential oils from foods. *J. Food* **2023**, *21*, 101–114. [\[CrossRef\]](#)
140. Herzyk, F.; Piłakowska-Pietras, D.; Korzeniowska, M. Supercritical extraction techniques for obtaining biologically active substances from a variety of plant by-products. *Foods* **2024**, *13*, 1713. [\[CrossRef\]](#)
141. Ranade, A.; Malav, O.P. Fermented meat products—A review. *Int. J. Adv. Biochem. Res.* **2025**, *9*, 1003–1011. [\[CrossRef\]](#)
142. Flores, M.; Piornos, J.A. Fermented meat sausages and the challenge of their plant-based alternatives: A comparative review on aroma-related aspects. *Meat Sci.* **2021**, *182*, 108636. [\[CrossRef\]](#)
143. Sirini, N.; Munekata, P.E.S.; Lorenzo, J.M.; Stegmayer, M.Á.; Pateiro, M.; Pérez-Álvarez, J.Á.; Sepúlveda, N.; Sosa-Morales, M.E.; Teixeira, A.; Fernández-López, J.; et al. Development of Healthier and Functional Dry Fermented Sausages: Present and Future. *Foods* **2022**, *11*, 1128. [\[CrossRef\]](#) [\[PubMed\]](#)
144. Karwowska, M.; Munekata, P.E.S.; Lorenzo, J.M.; Tomasevic, I. Functional and Clean Label Dry Fermented Meat Products: Phytochemicals, Bioactive Peptides, and Conjugated Linoleic Acid. *Appl. Sci.* **2022**, *12*, 5559. [\[CrossRef\]](#)
145. Toldrá, F. Biochemistry of Fermented Meat. In *Food Biochemistry and Food Processing*, 2nd ed.; Simpson, B.K., Ed.; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2012; pp. 331–343. [\[CrossRef\]](#)
146. Skowron, K.; Budzyńska, A.; Grudlewska-Buda, K.; Wiktorczyk-Kapischke, N.; Andrzejewska, M.; Walecka-Zacharska, E.; Gospodarek-Komkowska, E. Two Faces of Fermented Foods—The Benefits and Threats of Its Consumption. *Front. Microbiol.* **2022**, *13*, 845166. [\[CrossRef\]](#)
147. Šojić, B.V.; Petrović, L.S.; Mandić, A.I.; Sedej, I.J.; Džinić, N.R.; Tomović, V.M.; Jokanović, M.R.; Tasić, T.A.; Škaljac, S.B.; Ikonić, P.M. Lipid oxidative changes in traditional dry fermented sausage Petrovská klobása during storage. *Hem. Ind.* **2014**, *68*, 27–34. [\[CrossRef\]](#)
148. Coton, M.; Deniel, F.; Mounier, J.; Joubrel, R.; Robieu, E.; Pawtowski, A.; Jeuge, S.; Taminiau, B.; Daube, G.; Coton, E.; et al. Microbial ecology of French dry fermented sausages and mycotoxin risk evaluation during storage. *Front. Microbiol.* **2021**, *12*, 737140. [\[CrossRef\]](#)
149. Ji, X.; Liu, J.; Li, J.; Xiaoxia, F. The hidden diet: Synthetic antioxidants in packaged food and their impact on human exposure and health. *Environ. Int.* **2024**, *186*, 108613. [\[CrossRef\]](#)
150. European Union. European Commission Regulation (EU) 2018/1481 of 4 October 2018 amending Annexes II and III to Regulation (EC) No 1333/2008 of the European Parliament and of the Council and the Annex to Commission Regulation (EU) No 231/2012 as regards octyl gallate (E 311) and dodecyl gallate (E 312). *Off. J. Eur. Union* **2018**, *L251*, 13–18.
151. Zhang, Y.; Zhang, Y.; Jia, J.; Peng, H.; Qian, Q.; Pan, Z.; Liu, D. Nitrite and nitrate in meat processing: Functions and alternatives. *Curr. Res. Nutr. Food Sci.* **2023**, *6*, 100470. [\[CrossRef\]](#)
152. European Union; European Commission. Commission Regulation (EU) No 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives. *Off. J. Eur. Union* **2011**, *54*, 205–211.

153. Boruah, B.; Ray, S. Current progress in the valorization of food industrial by-products for the development of functional food products. *Food Sci. Appl. Biotech.* **2024**, *7*, 289–317. [\[CrossRef\]](#)
154. Prakash, A.; Baskaran, R. Acerola, an untapped functional superfruit: A review on latest frontiers. *J. Food Sci. Technol.* **2018**, *55*, 3373–3384. [\[CrossRef\]](#)
155. Monteiro, S.A.; Barbosa, M.M.; da Silva, F.F.M.; Bezerra, R.F.; da Silva Maia, K. Preparation, phytochemical and bromatological evaluation of flour obtained from the acerola (*Malpighia punicifolia*) agroindustrial residue with potential use as fiber source. *LWT* **2020**, *134*, 110142. [\[CrossRef\]](#)
156. da Silva, N.C.; Dourado, P.L.A.; Tosi, M.M. A review about acerola (*Malpighia emarginata* DC) by-products as a promising raw material for the generation of green products. *Braz. J. Food Technol.* **2023**, *26*, e2023039. [\[CrossRef\]](#)
157. Rezende, Y.R.R.S.; Nogueira, J.P.; Narain, N. Microencapsulation of extracts of bioactive compounds obtained from acerola (*Malpighia emarginata* DC) pulp and residue by spray and freeze drying: Chemical, morphological and chemometric characterization. *Food Chem.* **2018**, *254*, 281–291. [\[CrossRef\]](#) [\[PubMed\]](#)
158. Gulcin, I. Antioxidants: A comprehensive review. *Arch. Toxicol.* **2025**, *99*, 1893–1997. [\[CrossRef\]](#)
159. Shao, H.-B.; Chu, L.-Y.; Lu, Z.-H.; Kang, C.-M. Primary antioxidant free radical scavenging and redox signaling pathways in higher plant cells. *Int. J. Biol. Sci.* **2007**, *7*, 8–14. [\[CrossRef\]](#) [\[PubMed\]](#)
160. Choe, E.; Min, D.B. Mechanisms of antioxidants in the oxidation of foods. *Compr. Rev. Food Sci. Food Saf.* **2009**, *8*, 345–358. [\[CrossRef\]](#)
161. Gao, X.; Xiao, Y.; Li, W.; Xu, L.; Yuan, J. Synergistic effects of antioxidant blends: A comparative study on oxidative stability of lipids in feed matrices. *Antioxidants* **2025**, *14*, 981. [\[CrossRef\]](#) [\[PubMed\]](#)
162. Bugatti, V.; Brachi, P.; Viscusi, G.; Gorrasi, G. Valorization of tomato processing residues through the production of active bio-composites for packaging. *Appl. Front. Mater.* **2019**, *6*, 34. [\[CrossRef\]](#)
163. Szabo, K.; Cătoi, A.F.; Vodnar, D.C. Bioactive compounds extracted from tomato processing by-products as a source of valuable nutrients. *Plant Foods Hum. Nutr.* **2018**, *73*, 268–277. [\[CrossRef\]](#)
164. Eslami, E.; Carpentieri, S.; Pataro, G.; Ferrari, G. A comprehensive overview of tomato processing by-product valorization by conventional methods versus emerging technologies. *Foods* **2023**, *12*, 166. [\[CrossRef\]](#)
165. Skwarek, P.; Karwowska, M. Fatty acids profile and antioxidant properties of raw fermented sausages with the addition of tomato pomace. *Biomolecules* **2022**, *12*, 1695. [\[CrossRef\]](#)
166. Skwarek, P.; Karwowska, M. The Effect of Tomato Pomace on the Oxidative and Microbiological Stability of Raw Fermented Sausages with Reduced Addition of Nitrites. *Int. J. Food Sci.* **2025**, *2025*, 6146090. [\[CrossRef\]](#)
167. Doménech-Asensi, G.; García-Alonso, J.; Martínez, E.; Santaella, M.; Martín-Pozuelo, G.; Bravo, S.; Periago, M.J. Effect of the Addition of Tomato Paste on the Nutritional and Sensory Properties of Mortadela. *Meat Sci.* **2013**, *93*, 213–219. [\[CrossRef\]](#)
168. Calvo, M.M.; García, M.L.; Selgas, M.D. Dry Fermented Sausages Enriched with Lycopene from Tomato Peel. *Meat Sci.* **2008**, *80*, 167–172. [\[CrossRef\]](#) [\[PubMed\]](#)
169. Ghafouri-Oskuei, H.; Javadi, A.; Asl, M.R.S.; Azadmard-Damirchi, S.; Armin, M. Quality Properties of Sausage Incorporated with Flaxseed and Tomato Powders. *Meat Sci.* **2020**, *161*, 107957. [\[CrossRef\]](#) [\[PubMed\]](#)
170. Lopes, J.d.C.; Madureira, J.; Margaca, F.M.A.; Cabo Verde, S. Grape Pomace: A Review of Its Bioactive Phenolic Compounds, Health Benefits, and Applications. *Molecules* **2025**, *30*, 362. [\[CrossRef\]](#)
171. Bhutani, M.; Gaur, S.S.; Shams, R.; Dash, K.K.; Shaikh, A.M.; Bela, K. Valorization of Grape By-Products: Insights into Sustainable Industrial and Nutraceutical Applications. *Future Food* **2025**, *12*, 100710. [\[CrossRef\]](#)
172. Caponio, G.R.; Minervini, F.; Tamma, G.; Gambacorta, G.; De Angelis, M. Promising Application of Grape Pomace and Its Agri-Food Valorization: Source of Bioactive Molecules with Beneficial Effects. *Sustainability* **2023**, *15*, 9075. [\[CrossRef\]](#)
173. Silva, V.; Igrejas, G.; Falco, V.; Santos, T.; Torres, C.; Oliveira, A.; Pereira, E.J.; Amaral, S.A.; Poeta, P. Chemical Composition, Antioxidant and Antimicrobial Activity of Phenolic Compounds Extracted from Wine Industry By-Products. *Food Control* **2018**, *92*, 516–522. [\[CrossRef\]](#)
174. Di Stefano, V.; Buzzanca, C.; Melilli, M.G.; Indelicato, S.; Mauro, M.; Vazzana, M.; Arizza, V.; Lucarini, M.; Durazzo, A.; Bongiorno, D. Polyphenol Characterization and Antioxidant Activity of Grape Seeds and Skins from Sicily: A Preliminary Study. *Sustainability* **2022**, *14*, 6702. [\[CrossRef\]](#)
175. Jebur, A.B.; El-Sayed, R.A.; El-Demerdash, F.M. Grape Seeds: Nutritional Value, Health Advantages, and Industrial Applications. *Food Med. Homol.* **2026**, *3*, 9420100. [\[CrossRef\]](#)
176. Songsermsakul, P.; Pornphairin, E.; Porasuphatana, S. Comparison of antioxidant activity of grape seed extract and fruits containing high β -carotene, vitamin C, and E. *Int. J. Food Prop.* **2013**, *16*, 643–648. [\[CrossRef\]](#)
177. Lorenzo, J.M.; González-Rodríguez, R.M.; Sánchez, M.; Amado, I.R.; Franco, D. Effects of Natural (Grape Seed and Chestnut Extract) and Synthetic Antioxidants (Buthylated Hydroxytoluene, BHT) on the Physical, Chemical, Microbiological and Sensory Characteristics of Dry Cured Sausage “Chorizo”. *Food Res. Int.* **2013**, *54*, 611–620. [\[CrossRef\]](#)

178. Ivanov, Y.; Godjevargova, T.; Atanasova, M.; Nakov, G. The Effect of Grape Seed Extract on Lipid Oxidation, Color Change, and Microbial Growth in a Beef–Pork Sausage Model System. *Molecules* **2025**, *30*, 1739. [[CrossRef](#)] [[PubMed](#)]
179. Fadhil, Y.S. Effect of Grape Seed Extract on the Quality of Local Meat Product (Basturma) during Storage. *Food Sci. Technol.* **2023**, *43*, e4423. [[CrossRef](#)]
180. El-Zainy, A.; Morsy, A.; Sedki, A. Polyphenols Extracted from Grape Seeds and Its Effects as Antioxidant and Antimicrobial on Beef Sausage. *J. Food Dairy Sci.* **2016**, *7*, 19–25. [[CrossRef](#)]
181. D'Arrigo, M.; Petrón, M.J.; Delgado-Adámez, J.; García-Parra, J.J.; Martín-Mateos, M.J.; Ramírez-Bernabé, M.R. Dry-Cured Sausages “Salchichón” Manufactured with a Valorized Ingredient from Red Grape Pomace (Var. Tempranillo). *Foods* **2024**, *13*, 3133. [[CrossRef](#)] [[PubMed](#)]
182. Skinner, R.C.; Gigliotti, J.C.; Ku, K.-M.; Tou, J.C. A Comprehensive Analysis of the Composition, Health Benefits, and Safety of Apple Pomace. *Nutr. Rev.* **2018**, *76*, 893–909. [[CrossRef](#)]
183. Gonelimali, F.D.; Szabo-Notin, B.; Szalokidorko, L.; Ribarski, A.; Mate, M. Evaluation of Polyphenol Extraction from Apple Pomace. *AGROFOR Int. J.* **2021**, *6*, 103–110. [[CrossRef](#)]
184. Gonelimali, F.D.; Szabo-Notin, B.; Mate, M. Optimal Drying Conditions for Valorization of Industrial Apple Pomace: Potential Source of Food Bioactive Compounds. *Prog. Agric. Eng. Sci.* **2021**, *17*, 69–75. [[CrossRef](#)]
185. Jung, J.; Cavender, G.; Zhao, Y. Impingement Drying for Preparing Dried Apple Pomace Flour and Its Fortification in Bakery and Meat Products. *J. Food Sci. Technol.* **2015**, *52*, 5568–5578. [[CrossRef](#)] [[PubMed](#)]
186. Pascoalino, L.A.; Finimundy, T.C.; Pires, T.C.; Pereira, C.; Barros, L.; Ferreira, I.C.; Oliveira, M.B.P.; Barreira, J.C.; Reis, F.S. Investigating Bioactive Compounds in Apple Pomace: Potential to Develop High Added-Value Products from an Industrial Surplus. *Food Biosci.* **2025**, *63*, 105664. [[CrossRef](#)]
187. Ciurlă, L.; Enache, I.-M.; Buterchi, I.; Mihalache, G.; Lipsa, F.D.; Patras, A. A New Approach to Recover Bioactive Compounds from Apple Pomace: Healthy Jelly Candies. *Foods* **2025**, *14*, 39. [[CrossRef](#)]
188. Koishybayeva, A.; Korzeniowska, M. Utilization and Effect of Apple Pomace Powder on Quality Characteristics of Turkey Sausages. *Foods* **2024**, *13*, 2807. [[CrossRef](#)]
189. Grispoli, 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. [[CrossRef](#)]
190. Younis, K.; Ahmad, S. Waste Utilization of Apple Pomace as a Source of Functional Ingredient in Buffalo Meat Sausage. *Cogent Food Agric.* **2015**, *1*, 1119397. [[CrossRef](#)]
191. Rashwan, A.K.; Bai, H.; Osman, A.I.; Eltohamy, K.M.; Chen, Z.; Younis, H.A.; Al-Fatesh, A.; Rooney, D.W.; Yap, P.S. Recycling Food and Agriculture By-Products to Mitigate Climate Change: A Review. *Environ. Chem. Lett.* **2023**, *21*, 3351–3375. [[CrossRef](#)]
192. Vilas-Boas, A.A.; Magalhães, D.; Campos, D.A.; Porretta, S.; Dellapina, G.; Poli, G.; Istanbulu, Y.; Demir, S.; San Martín, Á.M.; García-Gómez, P.; et al. Innovative Processing Technologies to Develop a New Segment of Functional Citrus-Based Beverages: Current and Future Trends. *Foods* **2022**, *11*, 3859. [[CrossRef](#)]
193. Rao, N.; Sharma, M.; Sharma, A. Development of Product Rich in Dietary Fiber and Antioxidant Prepared from Lemon Peel. *Glob. J. Biol. Agric. Health Sci.* **2016**, *5*, 120–123.
194. Yang, Y.-Y.; Ma, S.; Wang, X.-X.; Zheng, X.-L. Modification and Application of Dietary Fiber in Foods. *J. Chem.* **2017**, *2017*, 9340427. [[CrossRef](#)]
195. Fernández-López, J.; Sendra, E.; Sayas-Barberá, E.; Navarro, C.; Pérez-Alvarez, J.A. Physico-Chemical and Microbiological Profiles of “Salchichón” (Spanish Dry-Fermented Sausage) Enriched with Orange Fiber. *Meat Sci.* **2008**, *80*, 410–417. [[CrossRef](#)]
196. Magalhães, D.; Rodrigues, C.V.; Botella-Martinez, C.; Muñoz-Tebar, N.; Pérez-Álvarez, J.A.; Viuda-Martos, M.; Teixeira, P.; Pintado, M. Lemon Dietary Fibre-Based Powder as a Promising Ingredient for the Food Industry: Enhancing *Mortadella* Nutritional Quality. *Foods* **2025**, *14*, 1693. [[CrossRef](#)]
197. Delgado-Pando, G.; Ekonomou, S.I.; Stratakos, A.C.; Pintado, T. Clean Label Alternatives in Meat Products. *Foods* **2021**, *10*, 1615. [[CrossRef](#)]
198. Kim, M.; Bae, S.M.; Yoo, Y.; Park, J.; Jeong, Y.J. Clean-Label Strategies for the Replacement of Nitrite, Ascorbate, and Phosphate in Meat Products: A Review. *Foods* **2025**, *14*, 2442. [[CrossRef](#)]
199. Jeong, J.Y.; Bae, S.M.; Yoon, J.; Jeong, D.H.; Gwak, S.H. Effect of Using Vegetable Powders as Nitrite/Nitrate Sources on the Physicochemical Characteristics of Cooked Pork Products. *Food Sci. Anim. Resour.* **2020**, *40*, 831–843. [[CrossRef](#)]
200. Pennisi, L.; Verrocchi, E.; Paludi, D.; Vergara, A. Effects of Vegetable Powders as Nitrite Alternative in Italian Dry Fermented Sausage. *Ital. J. Food Saf.* **2020**, *9*, 8422. [[CrossRef](#)]
201. Alahakoon, A.U.; Jayasena, D.D.; Ramachandra, S.; Jo, C. Alternatives to Nitrite in Processed Meat: Up to Date. *Trends Food Sci. Technol.* **2015**, *45*, 37–49. [[CrossRef](#)]
202. Alessi, A.C.S.B.; Brito, N.L.H.; Droval Arcain, A.A.; Reitz Cardoso, F.A. Evaluation of Celery Extract as a Natural Alternative to Sodium Nitrite in Fresh Chicken Sausages during Refrigerated Storage. *J. Sci. Food Agric.* **2025**, *106*, 2251–2258. [[CrossRef](#)]

203. Bhusal, A.; Muriana, P.M. Isolation and Characterization of Nitrate Reducing Bacteria for Conversion of Vegetable-Derived Nitrate to 'Natural Nitrite'. *Appl. Microbiol.* **2021**, *1*, 11–23. [\[CrossRef\]](#)
204. Nguyen, N.T.T.; Nguyen, B.X.; Habibi, N.; Dabirimirhosseinloo, M.; Oliveira, L.d.A.; Terada, N.; Sanada, A.; Kamata, A.; Koshio, K. Effect of Organic and Synthetic Fertilizers on Nitrate, Nitrite, and Vitamin C Levels in Leafy Vegetables and Herbs. *Plants* **2025**, *14*, 917. [\[CrossRef\]](#)
205. Ibrahim, M.N.; Jaafar, H.Z.E.; Karimi, E.; Ghasemzadeh, A. Impact of Organic and Inorganic Fertilizers Application on the Phytochemical and Antioxidant Activity of Kacip Fatimah (*Labisia pumila* Benth). *Molecules* **2013**, *18*, 10973–10988. [\[CrossRef\]](#)
206. Alkazzaz, S.R.M.A.; Abdelrahman, H.A.; Ahmed, A.M.; Dora, E.-D.H.I.; Helal, I.M.; Ahmed, N.I.H. Effect of Replacing Sodium Nitrite with Celery on Sensory and Chemical Quality of Popular Dry Sausage. *J. Adv. Vet. Res.* **2022**, *12*, 404–408.
207. Jin, S.-K.; Choi, J.S.; Yang, H.-S.; Park, T.-S.; Yim, D.-G. Natural Curing Agents as Nitrite Alternatives and Their Effects on the Physicochemical, Microbiological Properties and Sensory Evaluation of Sausages during Storage. *Meat Sci.* **2018**, *146*, 34–40. [\[CrossRef\]](#) [\[PubMed\]](#)
208. Posthuma, J.A.; Rasmussen, F.D.; Sullivan, G.A. Effects of Nitrite Source, Reducing Compounds, and Holding Time on Cured Color Development in a Cured Meat Model System. *LWT* **2018**, *95*, 47–50. [\[CrossRef\]](#)
209. Katmer, B.; Kaya, M. The Effect of Swiss Chard Powder as a Curing Agent on Volatile Compound Profile and Other Qualitative Properties of Heat-Treated Sucuk. *Foods* **2025**, *14*, 3785. [\[CrossRef\]](#)
210. Sheng, S.; Silva, E.M.; Ricke, S.C.; Claus, J.R. Characterization of Volatilized Compounds in Conventional and Organic Vegetable-Source Alternative Meat-Curing Ingredients. *Molecules* **2025**, *30*, 835. [\[CrossRef\]](#)
211. Cau, S.; Tilocca, M.G.; Spanu, C.; Soro, B.; Tedde, T.; Salza, S.; Melillo, R.; Piras, G.; Virgilio, S.; Vodret, B.; et al. Detection of Celery (*Apium graveolens*) Allergen in Foods of Animal and Plant Origin by Droplet Digital PCR Assay. *Food Control* **2021**, *130*, 108407. [\[CrossRef\]](#)
212. Sheng, S.; Silva, E.M.; Ricke, S.C.; Claus, J.R. Organic and Conventional Alternative Curing Ingredients Effects on Quality and Sensory Attributes of Deli-Style Turkey. *Poult. Sci.* **2025**, *104*, 105370. [\[CrossRef\]](#)
213. Dilek, N.M.; Karakaya, M. Natural Alternative Curing Agent in Fermented Sucuk Production: Sugar Beet (*Beta vulgaris* var. *saccharifera* L.) Molasses. *Selcuk J. Agric. Food Sci.* **2022**, *36*, 380–386. [\[CrossRef\]](#)
214. Lau, A.T.Y.; Arvaj, L.; Strange, P.; Goodwin, M.; Barbut, S.; Balamurugan, S. Effect of Cranberry Pomace on the Physicochemical Properties and Inactivation of *Salmonella* during the Manufacture of Dry Fermented Sausages. *Curr. Res. Food Sci.* **2021**, *4*, 636–645. [\[CrossRef\]](#)
215. Zhou, J.; Li, D.; Zhang, X.; Liu, C.; Chen, Y. Valorization of Protein-Rich Waste and Its Application. *Sci. Total Environ.* **2023**, *901*, 166141. [\[CrossRef\]](#)
216. Karwowska, M.; Kononiuk, A. Addition of Acid Whey Improves Organic Dry-Fermented Sausage without Nitrite Production and Its Nutritional Value. *Int. J. Food Sci. Technol.* **2018**, *53*, 246–253. [\[CrossRef\]](#)
217. Selani, M.M.; Herrero, A.M.; Ruiz-Capillas, C. Plant Antioxidants in Dry Fermented Meat Products with a Healthier Lipid Profile. *Foods* **2022**, *11*, 3558. [\[CrossRef\]](#)
218. Stadnik, J.; Kęska, P.; Gazda, P.; Siłka, L.; Kołożyn-Krajewska, D. Influence of LAB Fermentation on the Color Stability and Oxidative Changes in Dry-Cured Meat. *Appl. Sci.* **2022**, *12*, 11736. [\[CrossRef\]](#)
219. Faustino, M.; Veiga, M.; Sousa, P.; Costa, E.M.; Silva, S.; Pintado, M. Agro-Food Byproducts as a New Source of Natural Food Additives. *Molecules* **2019**, *24*, 1056. [\[CrossRef\]](#)
220. Valdés, A.; Burgos, N.; Jiménez, A.; Garrigós, M.C. Natural Pectin Polysaccharides as Edible Coatings. *Coatings* **2015**, *5*, 865–886. [\[CrossRef\]](#)
221. Ahmad, S.S.; Khalid, M.; Younis, K. Interaction Study of Dietary Fibers (Pectin and Cellulose) with Meat Proteins Using Bioinformatics Analysis: An In-Silico Study. *LWT* **2020**, *119*, 108889. [\[CrossRef\]](#)
222. Huynh, D.T.; Tran, U.P.N. Low-Fat Vietnamese Sausage (Lap Xuong) Formulated with Passion-Fruit Peel Pectin as a Sustainable Fat Replacer. *Chem. Eng. Trans.* **2015**, *122*, 319–324. [\[CrossRef\]](#)
223. Méndez-Zamora, G.; García-Macías, J.A.; Santellano-Estrada, E.; Chávez-Martínez, A.; Durán-Meléndez, L.A.; Silva-Vázquez, R.; Quintero-Ramos, A. Fat Reduction in the Formulation of Frankfurter Sausages Using Inulin and Pectin. *Food Sci. Technol. Camp.* **2015**, *35*, 25–31. [\[CrossRef\]](#)
224. Lashgari, S.S.; Noorolah, Z.; Sahari, M.A.; Gavlighi, H.A. Improvement of Oxidative Stability and Textural Properties of Fermented Sausage via Addition of Pistachio Hull Extract. *Food Sci. Nutr.* **2020**, *8*, 2920–2928. [\[CrossRef\]](#) [\[PubMed\]](#)
225. Fiorentini, M.; Kinchla, A.J.; Nolden, A.A. Role of Sensory Evaluation in Consumer Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review. *Foods* **2020**, *9*, 1334. [\[CrossRef\]](#) [\[PubMed\]](#)
226. Bouked, F. Chickpea (*Cicer arietinum* L.) Protein as a Prospective Plant-Based Ingredient: A Review. *Food Sci. Technol.* **2021**, *56*, 5435–5444. [\[CrossRef\]](#)
227. Marques, C.; Correia, E.; Dinis, L.-T.; Vilela, A. An Overview of Sensory Characterization Techniques: From Classical Descriptive Analysis to the Emergence of Novel Profiling Methods. *Foods* **2022**, *11*, 255. [\[CrossRef\]](#)

228. Ray, S. Sensory Properties of Foods and Their Measurement Methods. In *Techniques to Measure Food Safety and Quality*; Khan, M.S., Rahman, M.S., Eds.; Springer Nature Switzerland AG: Cham, Switzerland, 2021; pp. 345–381. [\[CrossRef\]](#)
229. Drake, M.A.; Delahunty, C.M. Chapter 20—Sensory Character of Cheese and Its Evaluation. In *Cheese: Chemistry, Physics and Microbiology*, 4th ed.; Academic Press: London, UK, 2017; pp. 517–545. [\[CrossRef\]](#)
230. Pereira, A.; Lee, H.C.; Lammert, R., Jr.; Wolberg, C., Jr.; Ma, D.; Immoos, C.; Casassa, F.; Kang, I. Effects of Red-Wine Grape Pomace on the Quality and Sensory Attributes of Beef Hamburger Patty. *Food Sci. Technol.* **2022**, *57*, 1814–1823. [\[CrossRef\]](#)
231. Parrini, S.; Sirtori, F.; Acciaioli, A.; Becciolini, V.; Crovetto, A.; Franci, O.; Romani, A.; Scardigli, A.; Bozzi, R. Effect of Replacement of Synthetic vs. Natural Curing Agents on Quality Characteristics of Cinta Senese Frankfurter-Type Sausage. *Animals* **2020**, *10*, 14. [\[CrossRef\]](#)
232. Šojić, B.; Pavlić, B.; Tomović, V.; Kočić-Tanackov, S.; Đurović, S.; Zeković, Z.; Belović, M.; Torbica, A.; Jokanović, M.; Urumović, N.; et al. Tomato Pomace Extract and Organic Peppermint Essential Oil as Effective Sodium Nitrite Replacement in Cooked Pork Sausages. *Food Chem.* **2020**, *330*, 127202. [\[CrossRef\]](#) [\[PubMed\]](#)

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.