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A New Functional Ingredient in Functional Meat Products: Postbiotic

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ABSTRACT

Postbiotics are bioactive compounds formed during fermentation which can be used to promote or maintain good health. These metabolites include short-chain fatty acids (SCFAs), microbial cell fractions, functional proteins, extracellular polysaccharides (EPS), cell lysates, teichoic acid, peptidoglycan-derived muropeptides, and pili-type structures. Recent studies have shown that postbiotics are effective against various food pathogens, increase shelf life, maintain general health status and alleviate symptoms in some diseases. Although the mechanism of these properties has not been fully elucidated, the positive effects of postbiotics continue to attract attention. In this study, postbiotics in food as a new functional ingredient and their effects on health are reviewed in line with recent scientific studies.

1. Introduction

To be healthy does not necessarily imply the absence of disease or disability. Health is rather a state of complete well-being in terms of physical, spiritual, and social aspects. Nutrition is one of the most important factors affecting human health [1]. Nutrition science first came to the fore in the 1800s preceding the idea of "diet". This new field of science combines food science with health and human physiology. Nutritional authorities have been recommending the daily intake of nutrients required for human survival and growth since the 1970s. These include information on many topics, such as recommended daily allowances (RDA) and reference daily nutrient intakes (RNI), dietary references, food guides, and more. In addition, healthy live, growth, body weight, and prevention of malnutrition have been envisaged by nutrition scientists as a new model [2], because nutritional deficiency affects negatively mental and physical development, individual health and psychology, and causes health problems (cardiovascular diseases, diabetes, cancer, etc.). A healthy eating experience, that is, being at a normal weight and regular physical activity, prevents 80% of coronary heart diseases, 90% of type-2 diabetes, and a third of all types of cancer [3]. Especially in recent years, the increase in chronic diseases and the fact that the nutrients and bioactive components of plants obtained from conventional agriculture are inadequate compared to those produced organically (the lycopene rate in tomatoes is half lower than in organic production) have led conscious consumers turn towards functional food

It is now widely recognized that foods contain bioactive compounds that support body functions and health (e.g. breathing, energy production, immune capacity, etc.). Bioactive compounds are essential and non-essential substances (e.g. vitamins and phytochemicals) found in nature or created by processing foods or plants that can provide health benefits. Currently, there is a large and growing body of scientific evidence demonstrating the benefit of various active compounds in different health and disease states. These compounds exert different beneficial effects, among which anti-inflammatory, antioxidant, lipid-lowering, antihypertensive and regulating the expression of a wide range of genes. Therefore, they offer a variety of health benefits, including anti-aging, prevention of cardiovascular disease and protection against chronic diseases such as diabetes, cancer, and neurodegenerative diseases. Many foods and their active ingredients for special purpose nutrition (foods containing polyunsaturated fats, low fat, reduced Na, gluten-free, fibre, prebiotics, probiotics, etc.) are considered functional foods. Functional foods have become a main topic of study and increasing popularity in the last 20 years [4,5].

Postbiotics are one of the research areas of great importance in the field of functional foods in recent years. The term postbiotics refers to soluble factors (products or metabolic by-products) secreted by living bacteria or released after bacterial lysis, as well as by-products produced by probiotic bacteria that can offer positive effects for the local (intestinal epithelium) and systemic (adipose tissue, liver, circulation) host [6]. The use of postbiotics has attracted attention in many studies and has been carried out with different approaches in functional foods and human nutrition. Potential

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anticarcinogenic, mantialergic and health-promoting effects of postbiotics are also being tested. However, there is still a need to elucidate the activity of postbiotics in food matrices [7].

In this study, research articles and reviews published in Web of Science, Scopus, Pub Med, especially in recent years, and dealing with the relationship between postbiotics and/or functional foods are reviewed.

2. History, Defination and Regulation of Functional Food

Hippocrates, the father of medicine, who in 400 BC considered health and nutrition to be parts of a whole, claimed "Let food be thy medicine and medicine be thy food". Hippocrates was one of the first scientists to recognise the role of diet in health and disease. He recommended lifestyle changes, including dietary factors, to prevent or treat diseases. In his book "How Doctors Think", Groopman, a Harvard Medical School faculty member, states that little is known about the effects of nutrition on many body functions (such as vitamin B12 deficiency causing pernicious anaemia or vitamin C deficiency causing scurvy) [8].

The term "Functional Food" first appeared in Japan in 1984. The Japanese government defined a new product classification called Food for Specific Health Uses (FOSHU-Food for Specific Health Uses) as "food that has health benefits and contains an ingredient that has been officially approved to have physiological effects on human health" and was regulated in a special legal framework. Japan was followed by the USA, which developed the first health law in the 1990s but did not provide an official definition of functional food [9]. In the USA, definitions such as novel foods, nutraceuticals, designer foods, pharmaceuticals, phytosmeceuticals are used for functional foods [10]. In European countries, the concept of functional food was introduced 10 years later by the Regulation of the European Parliament and of the Council on nutrition and health claims (Reg. (EU) n. 1924/2006 of the European Parliament and the Council on nutrition and health claims (Reg. (EU) n. 1924/2006), the conditions necessary for the definition of food as functional are explained below [4].

- In addition to its nutritional qualities, it has the potential to improve human health and/or
- It should have an effect such as preventing the occurrence of diseases [11,12].

In Turkey, functional foods were introduced into our legislation for the first time within the framework of the Law No. 5179 on the Amendment and Adoption of the Decree Law on the Production, Consumption and Supervision of Foods. Within the scope of the Law, functional foods are defined as "foods that have health-protective, corrective and/or disease risk-reducing effects depending on one or more effective components in addition to their nutritional effects, and these effects have been scientifically and clinically proven". The Turkish Food Codex Regulation on Nutrition and Health Declarations, published in the Official Gazette dated 26 January 2017 and numbered 29960 in the Official Gazette dated 26 January 2017 within the framework of harmonisation with the European Union Regulation 1924/2006/EC on Nutrition and Health Declarations in Foods, specifies the requirements for the nutrition declaration and health declaration of functional foods. In this case, it is necessary to define the health declaration and nutrition declaration.

Nutrition Declaration covers the information that expresses the excess of health-positive nutrients or other components (such as vitamins, minerals, protein, dietary fibre) and the excess or deficiency of health-negative components (such as energy, sugar, saturated fat, saturated fat, unsaturated fat, salt, omega 3) contained in the food and must be present on the food label. The health claim refers to the relationship of a food group or food or the specific ingredients contained in the food with health, its positive effect on health or its contribution [13;14]. In order to have the expression "fat-free" on the label of the food, "the amount of fat in 100g of solid food should not be more than 3g, or the amount of fat in 100ml of liquid food should not be more than 1.5g". This statement includes nutrition declaration and declaration condition. In the Regulation, walnut is one of the 4 foods (along prunes, meat/fish, and walnuts) that possesses a health declaration. The health declaration of walnut is that "walnut contributes to increase the elasticity of the vessels". Declaration condition is that "the daily consumption amount of the food must contain 30 g of walnuts. The consumer is informed that the beneficial effect will be achieved when 30 g of walnuts are taken daily". The relationship with health is "facilitates endothelium-dependent vasodilatation".

The following are the features that a food should carry as a functional food [14]:

- food or its components must be GRAS;
- these foods should be used in food form in the daily diet and should not be in capsule, dragee, or another format;
- the health beneficial components of the food should be naturally present in the foods consumed daily and the effective level should manifest itself during consumption; functional food can be created by adding the beneficial component to another food, such as eggs containing Omega 3;
- in order to be called a functional food, a health declaration about itself or its component and its relationship with health must be included on the label;
- it is important to note that functional foods are not medicines as they do not cure/prevent diseases;

The following are the functional food/nutrient types according to the American Academy of Nutrition and Dietetics [15]:

1) Traditional foods (vegetables, fruits, meat, fish, cereals, etc.) that contain natural bioactive components as well as the basic nutrients of the food. Probiotic starter cultures in yoghurt, salmon being rich in omega 3 polyunsaturated

fatty acids, or cherry being rich in melatonin can be given as examples.

2) Foods produced by adding bioactive components that are not present in the structure of the food but are produced by adding bioactive components from outside (feeding chickens with rich in omega 3 foods and producing eggs containing omega 3, vitamin supplemented fruit juices, etc.).

3) Synthesised nutrients (indigestible carbohydrates such as oligosaccharides, dietary fibres, which provide prebiotic benefits).

4) New foods that have not been consumed before with the selection of genetically modified or new varieties with beneficial health effects, such as rice with high iron content, allergen-free food, wheat with more lutein or fruits with higher antioxidant levels [16].

With the popularity of functional foods, people are becoming increasingly aware of food quality and the health benefits associated with different foods. As a result, people's interest in consuming healthy food and the demand for healthy food products is increasing significantly and new functional foods need to be developed to meet these demands [7]. Postbiotics are used in studies to maintain microbial quality and ensure safety of consumption, and to provide a proactive approach against various disease occurrences.

3. Postbiotics

Probiotics are live microorganisms that, when taken as supplements, generally provide health benefits by improving or restoring the intestinal microflora. Probiotics have been defined by the Food and Agriculture Organization of the United Nations as "providing health benefits to the host when taken in adequate amounts" [6]. Probiotics generally include the following groups:

❖ *Lactobacilli* such as *L. acidophilus, L. casei, L. delbrueckii subsp. bulgaricus, L. brevis, L. cellobiosus*.

❖ *Gram-positive cocci* such as *Lactococcus lactis, Streptococcus salivarius subsp. thermophilus, Enterococcus faecium*.

❖ *Bifidobacteria* such as *B.bifidun, B.adolescentis, B.infantis, B.longum, B. thermophilum* [7].

Traditional LAB consist of different genera, mainly Streptococcus, Lactococcus, Lactobacillus and Leuconostoc. LAB are a very heterogeneous group of gram positive and catalase microorganisms. Within functional foods, Lactobacillus is used as primary and secondary (probiotic and preservative strains) starter cultures in fermented products [18]. Some fermented products (yogurt, cheese, etc.) or non-fermented foods (cereals, chocolate, fruit juices, smoothies) may also contain probiotics [19]. Prebiotics are a class of nutrients digested by gut flora. Synbiotics are a combination of probiotics and prebiotics that work together to provide health benefits. However, in recent years new terms such as paraprobiotics (inactive cells of probiotics) and postbiotics (metabolites of probiotics) have been added. Recent research suggests that dead probiotic cells, whether intact/fragmented (cell free supernatant) or their by-metabolites, may be important for human health. The health effects of gut microbiomes depend on the viability of the microbiome but also on non-viable microbiome products, whereas postbiotics derived from probiotic cells are reported to have health benefits for the host when taken in sufficient quantities and when can be used as alternative biological preservatives to food additives to ensure food safety [20].

The following are some ways in which postbiotics can be characterized [6; 21; 22] :

a) Postbiotics are characterized as metabolites consisting of SCFAs, exopolysaccharides, degraded cell wall substances, enzymes/proteins, and other metabolites.

b) Postbiotics, also structurally such as peptides, teichoic acid, and plasmalogens.

c) Also, carbohydrates (polysaccharides rich in teichoic acids and galactose), proteins (p40, p75 molecule, lactosepin), lipids (butyrate, acetate, propionate, lactate) according to their elemental composition, dimethyl acetyl-derived plasmalogen), vitamins (group B, organic acids (3-phenyllactic acid and propionic), and other complex molecules (lipoteichoic acids, peptidoglycan-derived muropeptides).

d) Postbiotics can also be classified according to their physiological functions as anti-obesogenic, antioxidant, anti-inflammatory, hypocholesterolemic, anti-hypersensitive and anti-proliferative effects exhibiting immunomodulatory properties.

The following are the reasons for postbiotics becoming an alternative to probiotics to continue to be an extensive concern in scientific studies and to be rapidly produced commercially:

❖ Probiotics can be affected by many factors (ambient pH, interaction with other microorganisms present, water activity, temperature, presence of prebiotics, growth inhibitors, dissolved oxygen, as well as processing processes such as freeze-dry, spray-dry and freezing, etc.) during product production and storage. Since postbiotics are not living cells, such factors seem to be less important.

❖ There is a growing trend towards postbiotics, which are safer and more effective bioactive compounds derived from the fermentation of probiotics. It is also known that postbiotics in the cell-free supernatant isolated from bacteria have equivalent activity to live probiotics [21].

❖ Postbiotics have a safe profile, no identified toxicity, longer shelf life than probiotics, resistance to mammalian gut enzymes, and are anti-inflammatory are immunomodulatory (regulating immune system reactions). They also contain various signalling molecules that can have anti-obesogenic, antihypertensive, hypocholesterolemic, antiproliferative (inhibit cell proliferation) and antioxidant activities, and they remain stable in the gastrointestinal trac, which makes them a reliable alternative [7]. Since postbiotics do not contain live microorganisms, the risks associated with their consumption are considered to be minimal [23].

- The long shelf life of postbiotics (up to 3-5 years) makes them more commercially preferable [24].

Due to these advantages of postbiotics, the products that are commercially produced to increase the shelf life of various foods (dairy products, meat products, seafood, etc.) and to protect/enhance human health are given in Table 1 [18].

The use of postbiotics in various forms (powder, liquid) and applications (personal care, cosmetics, food and beverages, animal nutrition, pharmaceuticals, etc.) is leading to an increasing market share. According to a new report titled "Postbiotics Market" published by Allied Market Research, the Postbiotics market was valued at $1.6 billion in 2021 and is estimated to reach $3 billion by 2031, growing at a Compound Growth Rate of 6.8% from 2022 to 2031 [43].

3.1. Characterization of Postbiotics

Lactobacillus, Lactococcus, Pediococcus, Leuconostoc and Streptococcus are LAB strains that have been widely used in research. Organic acids, bacteriocins or bacteriocin-like inhibitory substances (BLIS), CO_2, H_2O_2, reuterin, reuterocycline, diacetyl and alcohols are the main components of postbiotics [26]. The names and components of postbiotics studied in published articles are given in Table 2.

The benefits of postbiotics are due to the metabolic by-products which they contain. SCFA (short-chain fatty acids) such as butyrate, propionate and acetate are fatty acids that have effects on immunity and are formed as a result of fermentation of undigested carbohydrates by intestinal anaerobic bacteria. In addition, they provide energy to the gut microbiota, maintain

Table 1. Strains used commercially worldwide

Trademark	Microorganism	Food	Benefits	
FreshQ®	*Lact. rhamnosus* and *Lact. paracasei*	Yogurt and cheese	Reduction of yeast and mold	Chr. Hansen (Denmark)
Bactoferm™	Pediocin- and sakacin-producing strains	Fermented sausages and dry-cured meat	Inhibition of spoilage and pathogen bacteria	Chr. Hansen (Denmark)
Viniflora®	Citrate-negative *Oenococcus oeni*	Wine	Prevention of undesirable flora and protection the flavor of wine	Chr. Hansen (Denmark)
SAFEPRO®	Not reported	Meat, salmon, and ready-to-eat salad	Prevention of spoilage and extension of shelf life	Chr. Hansen (Denmark)
Lyofast LPR A	*Lact. rhamnosus* and *Lact. plantarum*	Dairy products	Inhibition of spoilers and pathogens	Sacco (Italy)
HOLDBAC®	A mix of bacteriocin-producing strains	Different type of food	Inhibition of spoilers (i.e., mold and yeasts) and Listeria	DuPont Nutrition & Biosciences (USA)
Dairy Safe™	Nisin-producing and nisin-resistant *L. lactis* strains	Dairy products	Inhibition of late-blowing	CSK (Netherlands)
Delvo®Pro	Probiotic strains like *Bifidobacterium*, *Lact. casei*, *Lact. acidophilus*, *Lact. rhamnosus* GG, and *Lact. johnsonii*	Dairy products	Increase the shelf life and stability of dairy products	DSM (Netherlands)
Befresh™	A group of bacterial strains including *Lactobacillus* spp. and *Propionibacterium freudenreichii* subsp. *shermanii*	Fresh and fermented dairy and fruits	Offer a strong protection against yeast, mold, *Listeria* and *Clostridium*	HANDARY Natural Shelf Life Specialist (Belgium)
Otemcghi	A group of bacterial strains contain LAB bioAXTive TM (*L. acidhophilus and L rhamnosus* GG)	Chocalate	Not reported	Otemchi Biotechnologies, Singapore
Epicor ®	*Saccharomyces cerevisiae*	Fruit juice, chocalate, tea etc	Immune and gut immunity	Cargill Health Technologies, USA

the intestinal mucosal barrier, and play a role in immunity as they have histone deacetylase (HDAC) with anti-inflammatory effects. As a result, SCFAs regulate intestinal homeostasis by affecting both non-immune and immune intestinal cells [30]. Exopolysaccharides are also rare sugars defined as postbiotics and are applied in the food industry to create physicochemical properties (increased viscosity, stability or water binding) and sensory properties (flavor) in food products [19]. It has been also pointed out that LAB strains belonging to the same species, in which the amount of phenolic components (t-caffeic acid, vanillic acid, gallic acid, 2-5 Dihydroxy benzoic, Quercetin-3-Glucoside etc.) in the postbiotic is high, produce different metabolites [31].

Gallic acid or 3,4,5-trihydroxybenzoic acid (CAS No 149-91-7) and its derivatives, such as lauryl gallate, propyl gallate, octyl gallate, tetradecyl gallate and hexadecyl gallate, can prevent oxidation and rancidity of oils and fats as free radical scavengers and antioxidants. In addition, it can show cytotoxic and antitumor effects on cancer cells by adjusting the antioxidant/pro-oxidant balance in terms of health [32]. Serter et al. (2023) [33] claimed that the absence of pathogen inhibition after neutralizing the pH of the postbiotic with NaOH is due to the presence of acidic metabolics (diacetyl, hydrogen peroxide, bacteriocins, peptides, short and long chain fatty acids) rather than bacteriocins and other metabolites [34]. It is reported that organic acids dissolve the lipids in the cell walls of bacteria showing pathogenic activity and enter the cytoplasm easily and inhibit enzyme activity and cell growth by increasing acidity in the environment [35]. Intracellular enzymes (glutathione peroxidase (GPx), superoxide dismutase (SOD), nicotinamide adenine dinucleotide (NADH)-oxidase and NADH-peroxidase) have beneficial effects as antioxidants, etc. Cell wall components lipoteichoic acids (LTA), and S-layer proteins are reported to have immunomodulatory properties. It has been also observed that most postbiotics show multiple bioactivities (antitumor, antioxidant and immunomodulator) [34]. H_2O_2 (hydrogen peroxide) inhibits bacteria through peroxidation and disruption of cell membranes, oxidation of oxygen scavengers and thiol groups, and disruption of protein synthesis [36].

Table 2. Postbiotic components of some microorganisms used in the studies.

Potstbiotics derived from microorganisms	Postbiyotic ingredients
***Lactobacillus curvatus* B.67 [27]**	**Organic Acids** -Lactic Acid, Acetic Acid. **Amino Acids** -L-Valine, L-Alanine, Lysine, Tyramine, Glycine And L-Threonine and lots of sugar
***P. acidilactici* [28]**	-Carboxylic Acids (74.68%) - Piranone, Pyrazine and Pyrrolo Compounds (16.5%) Lactic Acid (48.62%) L(+) Lactic Acids (3.32%) - Pyrazine, Esters, Alcohols 2,6-Dimethyl Ketones (7.24%)
***Staphylococcus boulardii* [29]**	-Polyamines (Spermine, Spermidine, And Putrescine) -Acetic Acid, Decanoic Acids, Lactic Acid -Protein -Hydrogen Peroxide (H_2O_2) -Diacetyl

3.2. Postbiotic-Disease Relationship

The postbiotics of probiotic cultures have antagonist activity on major foodborne pathogens and are a rich source of bacteriocins and bacteriocin-like (BLIS). In addition, cell metabolites and substances found in the cell wall (exopolysaccharide; teichoic acids, peptidoglycans, polar lipids and proteins) are also included in the term postbiotic by breaking down the cell wall of the microorganism by various processes (heat treatment, enzyme application, ultrasonic treatment, etc.). These components show immunomodulating and antiproliferative activity. Therefore, postbiotics have started to be applied in food safety, functional foods, nutrition, disease prevention, animal new and medicines, and allergy treatment [24]. Studies on health effects of postbiotics in recent years are given in Table 3.

3.3. Use of Postbiotics in Meat and Meat Products

Studies on postbiotics related to meat and meat products are carried out by incorporating them into edible film or coatings based on alginate, chitosan, and others. İncili et al. [30](2022) added postbiotics obtained from *Pediococcus acidilactici* to the coating material prepared with chitosan in two ratios (0.5% and 1%) and performed microbial analysis of Frankfurter sausages against Escherichi coli O157: H7, Salmonella typhimurium, *Listeria monocytogenes* pathogens during 35 days storage. Total number of microorganisms and lactic acid bacteria decreased during storage ($p<0.05$). The combination of postbiotic and chitosan was again effective in reducing the number of *Listeria monocytogenes* and *S. Typhimurium*. According to the International Commission on Microbiological Specifications for Food (ICMSF), the highest acceptable limit for TVC is 7.0 log_{10} CFU/g for meat and meat products. (ICMSF (International Commission on Microbiological Specifications for Foods), 1986[44]. In the study, all chitosan+postbiotic groups except the control did not reach this number. In another study, the addition of *Lactiplantibacillus plantarum* subsp. *plantarum* (*L. plantarum*) W2 strain postbiotic to sodium alginate-based film and the effect of postbiotic-added films on gram-positive (*L. monocytogenes, S. aureus,* and *B. cereus*) and gram-negative bacteria (E. coli O157: H7) were examined. It was reported that the addition of probiotic to alginate-based film showed strong antibacterial activity against gram positive (*L. monocytogenes, S. aureus and B. cereus)* strains, but did not show any antibacterial effect against gram negative bacteria *(E. coli* O157:H7) strains [34].

The effect of postbiotics from *Pediococcus acidilactici, Lactiplantibacillus plantarum,* and *Latilactobacillus sakei* produced in sterile cow's milk and De Man Rogosa and Sharpe (MRS) Broth against some food pathogens (*Salmonella spp., Listeria monocytogenes, Escherichia coli O157:H7* and *Brucella melitensis*) was investigated. It was observed that lactic acid bacteria postbiotics produced in MRS Broth produced a larger zone of inhibition against pathogenic bacteria than those developed in cow's milk [33].

Table 3. Clinical and preclinical studies on postbiotics derived from some bacterial strains

Study	Use of postbiotic	Disease	Effect
[37] Shen,vd. (2023). Postbiotic gel relieves clinical symptoms of bacterial vaginitis by regulating the vaginal microbiota. *Frontiers in Cellular and Infection Microbiology, 13*, 42.	Postbiotic gel cream	Bacterial Vaginitis	In a clinical study applied in 50 patients, it was reported that the postbiotic gel was effective on patients and the flora lactic acid bacteria increased.
[6] Alan vd. (2022) Postbiotic metabolites, antioxidant and anticancer activities of probiotic Leuconostoc pseudomesenteroides strains in natural pickles. *Archives of Microbiology, 204*(9), 571.	*Leuconostoc pseudomesenteroides 5 strains of L. plantarum and L. bulgaricus* (isolated from pickles produced in various cities)	Cancer	In particular, it was reported that *Leuconostoc pseudomesenteroides* y6 strain showed good biological activity, which should be supported by new in vivo study.
[38] Rossoni vd. (2020). The postbiotic activity of Lactobacillus paracasei 28.4 against Candida auris. *Frontiers in cellular and infection microbiology, 10*, 397.	*Lactobacillus paracasei* 28.4 postbiotic Effect on *G. mellonella* larvae infected with *Candida auris*	Candida (*Candida auris)*	It has been reported to strengthen the immune system of *G. mellonella* larvae
[39] Algieri vd.,(2023). Lactobacillus paracasei CNCM I-5220-derived postbiotic protects from the leaky-gut. *Frontiers in Microbiology, 14*, 724.	Short-chain fructooligosaccharide postbiotic from *Lactobacillus paracasei*	*S. typhimurium* Infection (in vivo)	Postbiotics have been reported to prevent the formation of a permeable bowel and may help in the course of the disease.
[40] Cicenia, vd. (2014). Postbiotic activities of lactobacilli-derived factors. *Journal of clinical gastroenterology, 48*, S18-S22	*Lactobacillus paracasei* supernatant	Dendritic Cell Exposed to *Salmonella Typhimurum*	*L. paracasei* supernatants were able to inhibit the potential of dendritic cells to both produce inflammatory cytokines (IL-12 and TNF-a) and to mobilize Th1 T cells in response to Salmonella.
[41] Gao vd., (2019). A novel postbiotic from Lactobacillus rhamnosus GG with a beneficial effect on intestinal barrier function. *Frontiers in microbiology, 10*, 477.	*Lactobacillus rhamnus* GG postbiotic	*Intestinal barrier function*	Identified a novel *Lactobacillus rhamnus* GG postbiotic HM0539 that shows a protective effect on intestinal barrier function. It has been shown that HM0539 has the potential to be a useful agent for the prevention and treatment of diseases associated with intestinal barrier dysfunction (irritable bowel syndrome (IBS) etc.).
[42] Moradi vd. (2019). Characterization and application of postbiotics of *Lactobacillus spp. on Listeria monocytogenes* in vitro and in food models. *LWT, 111*, 457-464.	*Lactobacillus acidophilus* ATTC 4356	*Campyolbacter jejuni* infection	*Lactobacillus acidophilus* ATTC4356 cell-free supernatant has been reported to be effective in the management of *Campylobacter jejuni* infection, which is known as both a human and food pathogen.
[43] Rahardja vd. (2019). The ınhıbıtıon of *Salmonella typhi* growth by the cell free supernatans of lactobacıllus acıdophılus cultures. *Carpathian Journal of Food Science & Technology, 11*(5).	*Lactobacillus acidophilus* ATTC 4356	*Salmonella typhi*-typhoid	It has been reported that the cell-free supernatant of *Lactobacillus acidophilus* ATTC 4356 has an antimicrobial effect on *Salmonella typhi* due to its organic acid content, making it a promising substitute for the antibiotic ciprofloxacin.

Chicken breast meat was immersed in postbiotic solutions, 2.1% lactic acid solution and distilled water for 10 minutes and infected with *Salmonella* and *Listeria monocytogenes* and microbial changes were investigated during storage at 4℃ for 17 days. While the number of *L. monocytogenes* increased during storage in the control and distilled water coated groups, postbiotics and 2.1% lactic acid treated groups showed bacteriostatic effect on *L. monocytogenes* during storage. *Salmonella* spp. decreased by 1.8 $\log_{10}$ in chicken breast meat washed with 2.1% lactic acid compared to postbiotics. While the shelf life of chicken breast meat in the control and distilled water groups was determined as 5 days, the shelf life of the chicken breast meat group coated with postbiotic was 9 days and 2.1% lactic acid application extended the shelf life up to 12 days [28].

Chicken drumstick was coated with *Pediococcus acidilactici* (PA), *Latilactobacillus sakei/Staphylococcus xylosus* postbiotics and their bacteriostatic effect against *L. monocytogenes* and *S. Typhimurium* was investigated. In addition, the postbiotics were characterized and antioxidant activity and phenolic compounds were determined. *Pediococcus acidilactici, Latilactobacillus sakei/Staphylococcus xylosus* postbiotics showed the highest antioxidant activity and the total amount of phenolic compounds was determined as 1819.44 ± 0.39 mg gallic acid equivalent

(GAE)/ L. A total of 19 different phenolic and flavanoids were also analyzed in postbiotics. At the end of the study, it was revealed that the postbiotic-EDTA combination showed bactericidal effect against *L. monocytogenes* and bacteriostatic effect against *S. Typhimurium*. Consequently, the shelf life of chicken drumsticks was increased with the addition of postbiotics [31].

There are many new studies on postbiotics in terms of food safety. Recently, studies on the postbiotics of yeasts have also started to be conducted. It has been also reported that postbiotics obtained by fermentation of *Saccharomyces cerevisiae* can decrease *Salmonella enteriditis* concentration in chickens, especially in chickens raised as egg layers [45].

4. Conclusion

Postbiotics have significant potential for the development of new biotechnological products with functional components. Postbiotics have many advantages over probiotics and are more stable and long-lasting for industrial scale use. Studies on meat and meat products are mostly focused on ensuring food safety and extending shelf life. Studies have shown that postbiotics increase the microbial stability of meat products and reduce lipid oxidation due to their organic acids, bateriocins, hydrogen peroxide, short staple fatty acids, phenolic components, flavanoids, and so on. In this respect, postbiotics can be used as active ingredients in meat and meat products instead of artificial additives. According to the term functional food, in that "it can provide functionality to the product by adding bioactive raw components that are not present in itself", it can be concluded that meat and meat products can be made functional meat and meat products by the use of postbiotics. More studies are needed in terms of both health and food safety in order to approve the legal use of postbiotics and to determine the limits of their use.

Declaration

Author Contribution: Conceive – E.C.K.; Design - E.C.K.; Supervision - E.C.K.; Experimental Performance, Data Collection and/or Processing - E.C.K.; Analysis and/or Interpretation - E.C.K.; Literature Review - E.C.K.; Writer - E.C.K.; Critical Reviews - E.C.K.

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