IJPSR (2024), Volume 15, Issue 7 (Review Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 10 December 2023; received in revised form, 21 January 2024; accepted, 05 April 2024; published 01 July 2024

REVIEW ON SCOPE AND APPLICATION OF POSTBIOTICS IN FOOD PRESERVATION

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Keywords:

Postbiotics, Teichoic Acids, Bacteria Lysis, Immuno-Modulary, Anty-Inflamatory

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ABSTRACT: Food safety is at risk from several variables, including physical, chemical, and biological risks. In this context, biological risks are of utmost significance. The bacteria among them are crucial in producing food deterioration and food-borne illnesses. Additionally, a novel strategy has been applied in recent years that relies on pro-biotic and post-biotic to inhibit the increase of pathogenic microbes and the mediated corruption they cause because of their potent antimicrobial characteristics. The word "postbiotic" designates soluble elements produced by live bacteria or released following bacterial lysis, including enzymes, peptides, teichoic acids, muropeptides produced by peptidoglycans, polysaccharides, cell surface proteins, and organic acids. Postbiotics have a significant potential to be employed in the pharmaceutical, food, and nutraceutical sectors to improve health and disease prevention due to a variety of signaling substances that may have antioxidant, immune-modulatory, anti-inflammatory, antihypertensive, and antiproliferative effects. The current investigation was to determine the antagonistic potential of the secreted probiotic filtrates, also known as postbiotics, generated from some microorganisms against pathogenic microbes such as *Candida albicans*, *Staphylococcus aureus*, and *Escherichia coli* to enhance food safety. The theory behind foods having bacterial postbiotics is the fact that they are healthier than foods devoid of those modifications. This review attempts to provide a conceptual compilation regarding the application of bacterial postbiotics in food and to illustrate the health benefits of consuming foods containing bacterial postbiotics *via* both *in-vitro* and in-live experiments or clinical research.

INTRODUCTION: Many pro-biotic-beneficial bacteria and their metabolites are used as bio-protective agents. They might aid in suppressing undesirable bacteria during distribution and storage (at 25 C or 4 C), enhancing food safety and quality [3]. Pro-biotics could also have various biological impacts on the host by adapting to the challenging gastrointestinal environment, the presence of bile salts, digestive enzymes, and competition with other microorganisms.

QUICK RESPONSE CODE	DOI: 10.13040/IJPSR.0975-8232.15(7).1929-40
	This article can be accessed online on www.ijpsr.com
DOI link: https://doi.org/10.13040/IJPSR.0975-8232.15(7).1929-40	

Pro-biotics and their functional metabolites could be supplied using edible packaging through included in foods and supplements [4]. Post-biotics have a significant potential for food bio-preservation, according to recent studies. These packaging techniques may exhibit varying levels of food bio-preservation effectiveness.

Due to the safety concerns surrounding chemical preservatives, both industry and consumers are moving toward preservative-free foods. As a result, the need for developing novel, secure antimicrobial components to increase shelf life has arisen [5]. This new review indicates the knowledge pertinent to post-biotic production along with prominent aspects to apply in several sectors ranging from food to immune suppression and selective and efficient treatment. Additionally, it makes the case that post-biotics are far more successful than pro-biotics in the veterinary, food, and medical industries, various advancements and innovations aim to improve human health and reduce illness burden.

Post-Biotics in Food Preservation: Post-biotics are byproducts of pro-biotic bacteria in fermented foods, besides the metabolites generated by bacteria living in the intestine [3]. Metabolites produced by probiotics are recognized by different names, including biogenic, supernatant, abiotic, metabolic, pseudo-biotic, and post-biotic. Among these names, "postbiotic" is the one that is most frequently used and is highly prevalent [6]. Pro-biotic cells consume dietary fibers during the fermentation process and frequently generate a variety of post-biotics **Fig. 1**. Nowadays, Sonication is one of the laboratory techniques used to produce certain substances, high pressure, ultraviolet light, thermal treatment, formalin inactivation, and ultraviolet light. Teichoic acid, enzymes, short-chain fatty acids, bacteriocins, and organic acids are among the cell walls, cell fractions, and cell metabolites, which make up the three main components of inactivated microbial cells that make up postbiotics [7].

FIG. 1: POSTBIOTICS IN FOOD PRESERVATION

Special Features of Postbiotics: The host provides all of the resources needed for gut bacteria to support the expansion of the microbiota. Small molecular weight metabolites are essential for self-growth, development, reproduction, promoting the growth of other useful species, the interaction between cells, and stress resistance that is produced throughout the life cycle of bacteria. Many of these insoluble substances may be produced by bacteria that remain after bacterial lysis or are released into the environment. These have the effect of altering cellular processes and metabolic pathways, which has further physiological advantages [8].

The phrases "nonviable bacterial products", cell components or metabolic by-products from microorganisms that have a biological function in the host" are used to produce and describe post-biotic and pro-biotic. These substances have several desirable characteristics, including displaying chemical structures with transparency, dosage ranges that are safe and free from risk, and long shelf life [9].

It has been demonstrated that postbiotics have beneficial absorption, metabolism, transportation, and elimination abilities. Postbiotics also have a substantial ability to interact with many different types of organs and tissues in the host, triggering a range of biological processes. Some probiotics have been shown to induce a localized inflammatory response in an *ex-vivo* study that is comparable to the Salmonella-induced response **Fig. 2** [10].

In various research reports, theoretical issues regarding the administration of live probiotic bacteria have been discussed also in clinical studies, and experimental models in patients with major and mild illnesses. Employing post-biotic may therefore be a useful and risk-free alternative because it inactive the pathogenic microorganisms and produces teichoic acid which may lead to cell fraction after that postbiotics secrete secondary metabolites such as an enzyme that inhibits the growth of the pathogens **Fig. 2** [11].

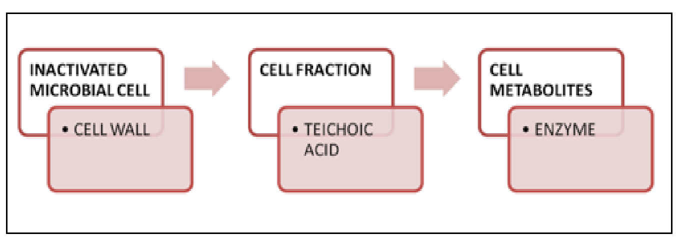

FIG. 2: SPECIAL FEATURES OF POSTBIOTICS

Clinical Significance: The production of teichoic acids, peptides, enzymes, peptidoglycan, polysaccharides, and organic acids, the process of creating post-biotic involves the production of proteins of interior and exterior of cells products, or metabolites by living probiotic bacteria

Post biotic could, however, offer anti-inflammatory, antioxidant, cholesterol-lowering, anti-bacterial, antagonistic, anti-inflammation, diabetes, hypertension, and obesity all affect retinopathy [9]. The review we present here aims to: show how effective posts biotic are against bacteria. We took microbial strains into account in this regard as sources for post-biotic in food products as anti-bacterial agents for their many beneficial features **Fig. 3.**

Special characteristics of post-biotics are antimicrobial action, anti-inflammatory, and low cholesterolemia **Fig. 4**. Further various types of fiber (pre-biotic) molecules are being administered to post-biotic [2].

TABLE 1: LIST OF SOME BACTERIA USED AS POST-BIOTICS

Bacteria	Components	Special Features	Pathogen	References
Lactobacillusamylovorus CP1563	Fragmented cells	Anti-obesogenic	*Salmonella typhimurium*	Team et al. 2020
Lactobacillus rhamnosus GG	Cell-free supernatants	Anti-inflammatory	*Candida albicans*	Vera-Santander et al., 2023
Lactobacillus plantarum K8 (KCTC10887BP)	Lipoteichoic acids	Immunomodulation	*Escherichia coli*	Diez-Gutiérrez et al. 2022
Lactobacillus acidophilus (KCTC 3111, L)	Intracellular content	Antioxidant	*Bacillus cereus*	Preston et al. 2018
Bacillus coagulans	Cell wall components	Immunomodulation anti-inflammatory effect	*Helicobacter pyruli*	Thorakkattu et al., 2022
Lactobacillus casei ATCC 393	Sonicated-cell suspension	Antiproliferative	*Helicobacter pyruli*	Preston et al. 2018
Lactobacillus fermentum BGHV110	Cell lysate suspension	Hepatoprotective	*Escherichia coli*	González-Lozano et al. 2022

Post-biotics can function as an antihypertensive because it has been demonstrated that they decrease arterial pressure. There are many biological processes, including swelling, infection assurance, and immune system improvement, that is reportedly influenced by the gut microbiota [1].

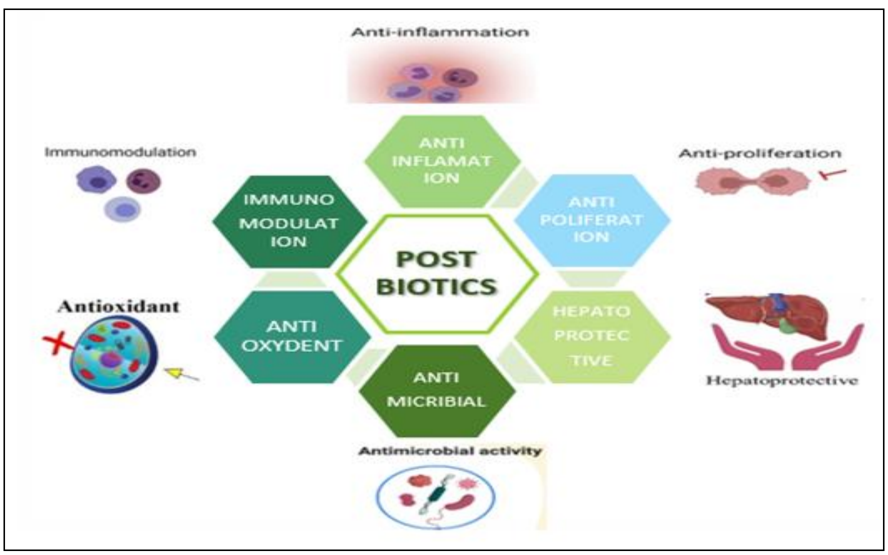

FIG. 3: CLINICAL SIGNIFICANCE OF POST BIOTICS

As evidenced by the recent development of the postbiotic concept, there is growing support for the hypothesis that these beneficial effects may be due to chemicals produced or derived [14]. Mucosal-like dendritic cells stimulated by retinoic acid regulate immune stimulation by their effects on T cell regulation by producing the anti-inflammatory cytokine IL-10, superoxide dismutase (SOD), and nicotinamide, among others **Fig. 4** [9].

Application of Post–Bioticsin Food Preservation: Different post-biotics perform a wide range of established and recently discovered food safety tasks, including food biopreservation and packaging, control, and removal of bio-films produced by food-borne pathogens, biodegradation of dangerous chemical pollutants (such as mycotoxins, pesticides, and BAs), and many more [15]. The kind of intended microbe or pollutant, the concentration and application method, the food matrix properties, and the LAB culture from which the postbiotics are created all affect how effective postbiotics are in food systems **Fig. 4** [7]. The following sections cover the potential applications of postbiotics in various food matrices to ensure food safety [16].

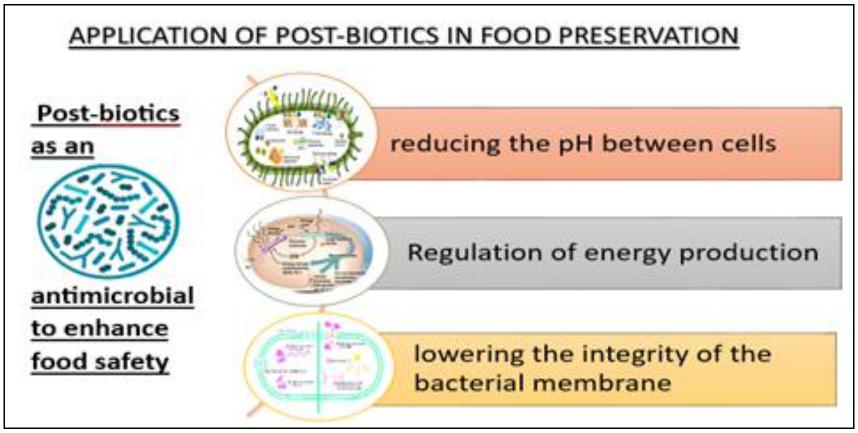

FIG. 4: APPLICATION OF POSTBIOTICS IN FOOD PRESERVATION

Despite offering several benefits over antibiotics and chemical preservatives, the application of LABs with antimicrobial properties in food is facing challenges. The difficulty in using cultured organisms directly in food products is ensuring that they can grow and survive in a variety of food matrices and conditions. In this way, the direct inclusion of postbiotic mixtures or individual postbiotics eliminates the undesirable interactions between live initial and additional starters for antimicrobial reasons **Fig. 4**. However, using postbiotic starter and protection cultures individually impacts certain challenges [3].

Despite the high cost involved in the process of separating and purifying bacteriocins, it is still a necessary step to ensure their effectiveness and safety. The antimicrobial metabolites have a restricted range, and infections controlled by some of them, including bacteriocins, may acquire resistance. Food may benefit fully from the broad-spectrum antimicrobial properties, the function of the post-biotics combination, as well as the synergistic activities between organic acids between organic acids and other metabolites, along with the postbiotics mixture's high heat stability [12].

Post-Biotics in Packaged Foods: Using food packaging to increase the shelf life of food has been suggested as a viable solution to resolve the problems. An active packaging system aims to increase the shelf life of food by enhancing connections among the food product, the packaging material, and the environment. Anti-microbial active packaging is a type of packaging system that contains materials that can actively inhibit the growth of microorganisms such as bacteria or fungi, helping to preserve the quality and safety of the packaged product.

It safeguards food from microbial deterioration during transport and storage by incorporating anti-microbial substances (AAs) from animal, plant, and microbial origins or their metabolites, and antimicrobial nanoparticles into the package [15].

Postbiotic food packaging is the term used to describe technologies that directly include postbiotics and specific LAB in food packaging [7].

By manufacturing and dispensing antimicrobial components, or participating in postbiotic competition with pathogens and microbes that cause food to spoil on the surface, the addition of bacterial cells inside the material used for packaging can increase the package's antimicrobial capabilities **Fig. 5** [16].

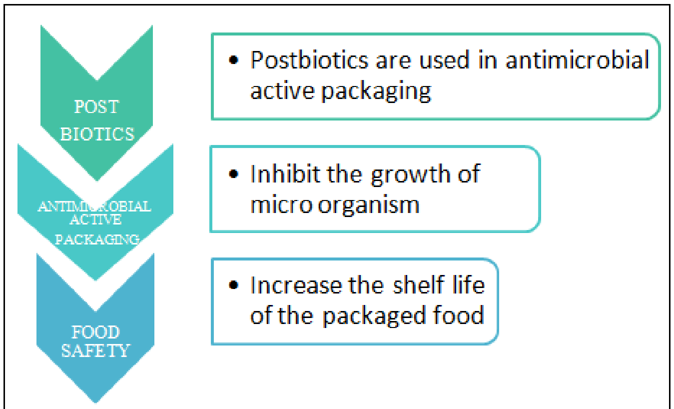

FIG. 5: POSTBIOTICTS IN PACKAGED FOOD

Postbiotics in Packaged Food:

Inter-Connection between Postbiotics in Dietary Ingredients: In reality, the characteristics of postbiotic substances are significantly affected by alterations such as pH changes, heat exposure, NaCl, and proteolytic enzymes. The antibacterial activity was ineffective against curvatus CWBI-B28.8 days of fish preservation resulted in a loss of the target pathogens at 10 °C. Considering that bacteriocins may interact, it is important to mention that several substances are present in the nutritional matrix, including proteins, carbs, and enzymes, under *in-vitro* conditions, certain factors can cause harm [3]. High levels of bacteriocin in postbiotics can inhibit certain activities. It represents a significant challenge for postbiotics applications. The diet needs further research to be resolved. Hurdle Technology can help us solve this issue. Additionally, as some postbiotics (such as organic acids and peroxides) affect a consumer's perception of food as a whole, it is important to consider each postbiotic's compatibility when adding it to a particular dish. The possible interaction between a postbiotic combination and the food matrix is a major concern, even though the interactions of several postbiotics alone, such as nisin, and food components have been thoroughly examined and analyzed [16, 17].

These issues call upon the successful use of postbiotics for food safety goals and necessitate more research. On the negative side, certain matters require attention. Metabolites could promote microbial growth in food and shield pathogens from environmental stressors like pH and temperature. Active postbiotic metabolites and food-specific components such as lipids, proteins, carbs, enzymes, and endogenous microflora may work together to lessen the inhibitory effects of metabolites. To the best of our knowledge, there is no information on the interactions between postbiotics and dietary components that could be synergistic or antagonistic [18].

Technical Features: To survive large-scale industrial manufacturing and maintain freshness until consumption, bacterial strains must follow particular parameters in the development of probiotic goods. Probiotic supplement's viability of cells during factory processing may have various factors that can have an impact, including the food matrix's components (carbohydrates, pH, lipids, and protein concentrations), water activity, the presence of naturally occurring antibiotics, and handling and storage conditions [19]. Because post-probiotics and para-probiotics are safer and more reliable throughout production, including them in food products may provide food makers several technological advantages over using the same live microorganisms. A major problem for utilizing postbiotics in goods is identifying and isolating safer and functioning postbiotic strains that will determine the unique population and the specific environment [20].

Postbiotics as Secondary Metabolites of Probiotics: Secondary metabolites of probiotics are commonly known as postbiotics, due to their potential benefits for human health, including the prevention or treatment of diseases like diabetes, inflammatory diseases, disorders of the brain, or cancer, are concerned recently. Postbiotic metabolites are a broad class of substances that require particular physical and chemical conditions, such as amino acids, vitamins, or antimicrobial substances. The food business is always evolving to produce new fermented foods that are capable of satisfying the demands of the market today because of the health advantages associated with probiotics and postbiotics. To maintain the effectiveness of probiotics and postbiotics, encapsulation techniques are required [21]. Although it has been demonstrated that consuming these beneficial microbes can positively affect one's health, probiotics have been the subject of in-depth research in health care, pharmacy, and food [17].

Short-Chain Fatty ACIDs: The most important metabolites of intestinal microbial fermentation are short-chain fatty acids that develop when the intestinal microbiota ferments indigestible carbohydrates or prebiotics. Butyrate, propionate, and acetate are the main by-products of short-chain fatty acids). The fermentation of food fibers by the anaerobic microbes in the intestines releases short-chain fatty acids (SCFAs) **Fig. 6** [22]. Numerous advantageous impacts on human energy metabolism have been demonstrated by this short-chain fatty acid (SCFA). A significant amount of study has been done on the processes mediating these benefits, which include the intricate relationships between host energy metabolism, gut flora, and dietary nutrients [23].

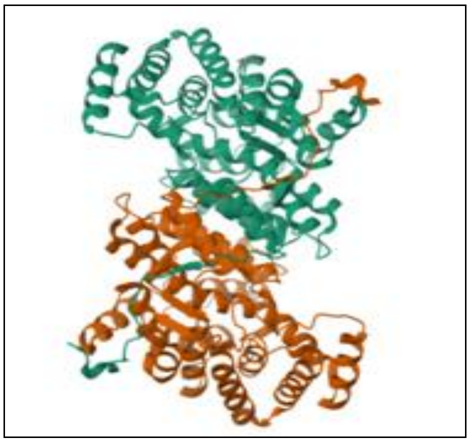

FIG. 6: STRUCTURE OF SCFAs. PDB DOI: https://doi.org/10.2210/pdb3O8J/pdb

Propionate and butyrate production depends on a specific substrate, however, the metabolic paths for acetate are extremely distinct and dependent upon the type of bacteria participating. It has been established that heterofermentative bacteria, involving bifidobacteria, generate pyruvate through the phosphoketolase path, although homo-fermentative bacteria synthesize SCFAs from the fermentation of carbohydrates [22].

Organic Acid: Postbiotic chemicals, which are organic acids generated by probiotic bacteria, could potentially use 1D as antibiotics against viruses. One of the most prominent organic acids generated by probiotics with antiviral effects is lactic acid. There are two isomers of lactic acid: L and D. When it comes to opposing viral infections, the L-shape works the most [1]. Through generating an acidic environment, acetic and citric acids also restrict the growth of viruses. By adhering to the viral glycoprotein and inhibiting the virus from complying with the angiotensin converting enzyme, organic acids generated by probiotic bacteria are demonstrated to have antiviral activity [21].

Teichoic Acid: In addition to defining cell shape, coordinating cell division, and generating important metabolic constituents for cell physiology, teichoic acid. Antibiotic resistance and pathogenicity in Gram-positive bacteria may be conferred by teichoic acids. One of the essential elements of the cell surface, teichoic acids can only be identified in Gram-positive bacteria [12]. Teichoic acids bond to their host bacterium while performing significant physiological effects. A lot of attention has been placed on lipoteichoic acid (LTA) connected to the cell membrane as a host immunomodulator Fig. Features of teichoic acid from numerous microbes have been described in terms of their biological and chemical properties [23].

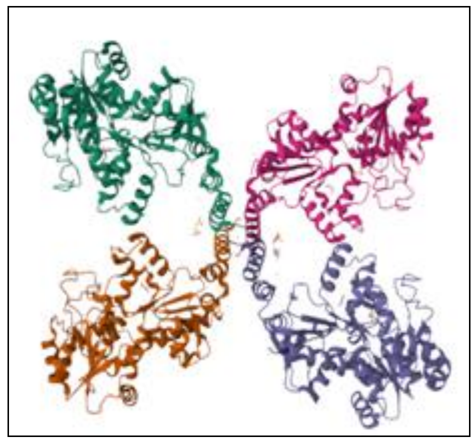

FIG. 7: STRUCTURE OF TEICHOIC ACID. PDB DOI: https://doi.org/10.2210/pdb3L7I/pdb

Enzymes: The physiological, biochemical, and regulatory roles of the enzymes produced by microbes are extensive. Bacillus microbes are likely the most significant bacterial source of proteases due to their ability to generate large quantities of alkaline and neutral digestive enzymes *via* distinctive features, which include durability at high pH, solvent-based chemicals, and reducing agents [21]. Enzyme health benefits include the defense of cells from cellular oxidative damage as well as protection against cardiovascular disease and carcinoma [19].

Bacteriocin: Lactobacillus belongs to the category of bacteria that generate bacteriocins, which are composed of amino acids or proteins with antimicrobial properties. People have been fermenting food for thousands of years through bacteriocins, which have powerful antibacterial properties. The methods of action, antagonistic spectrum, and size of bacteriocins are utilized to categorize them [16]. Apart from being susceptible to heat and pH, bacteriocins have other advantageous characteristics, including their prevention of pathogenic bacterial development and advancement **Fig. 8**. Bacteriocins are the polypeptides and proteins of some specific microbes that have the special physiological features to create pores in bacterial membranes and hamper the formation of the cell [24].

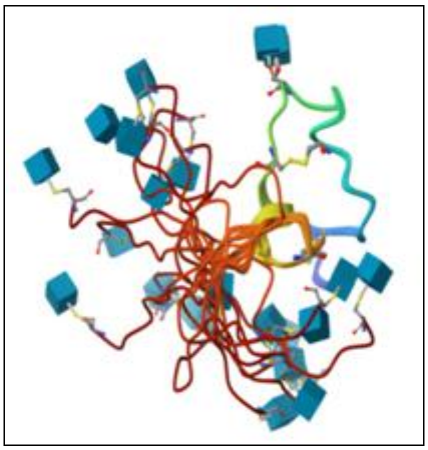

Fig. 8: STRUCTURE OF BACTERIOCIN. PDB DOI: https://doi.org/10.2210/pdb2MVI/pdbBMRB: 25269

Bacteriocins derived from Enterococcus and Lactobacillus have also been found to be beneficial to the gastrointestinal system, urinary system, genital system, and infections that are resistant to antibiotics [25].

Biosurfactants: Polysaccharide complexes of peptides, free fatty acids, phospholipids, glycolipids, and lipopeptides are the basic elements of biosurfactants. According to research on the biosurfactants Lactobacillus species are being examined the most [3]. Various polymers referred to as biosurfactants are generated throughout the initial and final exponential stationary phases of a microorganism's development cycle. Several characteristics, including emulsion stabilization, antioxidant, anti-adhesion, anti-biofilm, anticancer, antiviral, immunological, and antimicrobial capabilities, are demonstrated in biosurfactants [25].

Exopolysaccharides: During bacterial growth and development, they synthesize biopolymers known as exopolysaccharides. They encompass severely branched to purely linear molecules contingent upon the type of branching. Prominent exopolysaccharide developers are lactic acid bacteria. One of the postbiotics, lactic acid bacteria derived exopolysaccharides, is recognized to have technological qualities including thickening, emulsification, sustaining, and regulating biological processes [19].

Because of their great structural heterogeneity, exopolysaccharides generated from lactic acid bacteria are multipurpose polymers with a range of biological functions **Fig. 9.** Numerous physiological benefits, including enhancing immune systems, cholesterol reduction, antimicrobial agents, anti-inflammatory, gut microbiota regulation, and anticancer activity, have been proven through Exopolysaccharides [26].

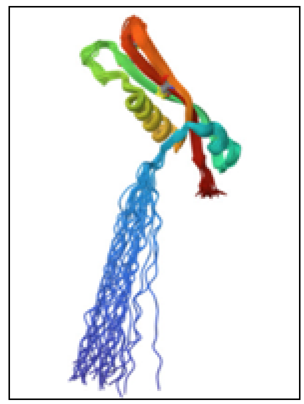

FIG. 9: STRUCTURE OF EXOPOLYSACCHARIDE. PDBDOI: https://doi.org/10.2210/pdb2L8Y/pdbBMRB**:** 17431

Lactobacillus as Postbiotics: It is possible to develop creative approaches and effective therapeutic strategies to avoid the risks associated with administering live bacteria, as the concept of "postbiotics" was recently established to define the insoluble constituents generated by probiotics. Additionally, these components can produce probiotic-fermented functional foods [16]. These foods are biogenic because microorganisms produce bioactive metabolites during the fermentation process. Several probiotic strains have been identified as well, though the majority of the existing research concentrates on lactobacilli. It illustrates the pharmacological evidence that has been made accessible for the study by emphasizing the established functions of a variety of secondary metabolites from different strains of Lactobacillus [27, 25].

TABLE 2: LIST OF THE LACTOBACILLUS SPECIES AND THEIR SPECIAL FEATURES

Name of the bacteria	Special features	References
Lactobacillus acidophilus	Luminal effect	Abbasi et al., (2022)
Lactobacillus rhamnosus GG	Mucosal effect	Mousavi et al. (2020)
Lactobacillus paracasei	Anti-inflammatory response	González-Lozano et al., (2022)
Lactobacillus reuteri	Luminal effect	Mousavi et al. (2019)

Lactobacillus Acidophilus: Multiple aspects of human well-being have been observed to be significantly influenced by L. acidophilus. Excellent defense against both bile salts and acid indicate that it can be used in an extensive variety of therapeutic consumable probiotic compositions (Hossain et al., 2020). In several food fermentation processes, L. acidophilus can be employed as an additive to provide food with a distinctive flavor, and appearance, and taste **Fig. 11**. By generating lactic acid and bacteriocins, it additionally safeguards the products [9]. Throughout the past few years, an abundance of newly discovered information about Lactobacillus acidophilus's bacteriocins emerged. They belong to a significant class of Bio-preservatives as they have substantial antimicrobial properties towards pathogenic bacteria and food deteriorating, as well as essential technical attributes which include thermostability and preserving action at a wide pH range [30].

***Lactobacillus rhamnosus* GG:** According to current research, probiotic-derived effector molecules, referred to as postbiotics, may have gut-protective defense mechanisms that are comparable to those of their parent probiotics. Identification and characterization of these "postbiotics" have emerged as an emerging approach to gut health maintenance; they correspond to insoluble compounds (products or metabolic by-products) secreted by living microbes or released after the breakdown of bacteria with physiological advantages to the host [31]. Previous studies have shown that the GG strain of *Lactobacillus rhamnosus* culture supernatant (LCS) protects neonatal rats against oral E. coli K1 infection and promotes the development of intestinal defense mechanisms. Postbiotics have been demonstrated as well to boost the viability of the mucosal gastrointestinal barrier in numerous techniques **Fig. 11**. *Lactobacillus rhamnosus* GG supernatants minimize alcohol-induced permeability in the intestines by reducing restrictive junction protein and mucin-producing factor concentrations to normality [32].

***Lactobacillus paracasei*:** When dendritic cell cultures had been subjected to pathogenic *Salmonella typhimurium*, the antimicrobial properties of *Lactobacillus paracasei* soluble cytokines were first discovered. The capability of dendritic cells to secrete inflammatory mediators and activate Th1 T cells in reactions to Salmonella has been demonstrated to be suppressed by L. paracasei's residues [3]. Antimicrobial properties. Immune regulating, anti-inflammatory, antiproliferative, and antioxidant biological activities have been demonstrated by Lactobacillus parasail to be involved among particular postbiotics and para-probiotics. Despite the existing scientific evidence, these bioactivities may contribute to the health-promoting effects seen among humans and experimental studies **Fig. 11** [31, 13].

***Lactobacillus reuteri*:** One of the initial substances with significant antipathogenic effects documented was reuterin, a glycerol a byproduct of *Lactobacillus reuteri* L. reuteri prevents the development of both pathogenic and beneficial microbes in the gut, which is essential for maintaining healthy gut microbiota along with regulating the genetic makeup and physical structure of the microbiota in the gastrointestinal tract [23, 35]. It provides defense against a broad spectrum of microorganisms, many of which are potentially hazardous to humans, such as *Salmonella*, *Escherichia coli*, *Shigella*, *Proteus*, *Pseudomonas*, *Clostridium*, and *Staphylococcus*, along with fungus and protozoa **Fig. 11** [33].

Several microbe groups, which include *Listeria monocytogenes*, *Staphylococcus aureus*, *Escherichia coli*, *Salmonella spp.*, *Yersinia spp.*, *Aeromonas spp.*, *Bacillus spp.*, *viruses*, and yeast, are adversely influenced by postbiotics that originate from lactic acid bacteria, according to recent studies [3, 34].

Health Benefits of Postbiotics in Human Health: Based on the available experimental data, compounds derived from probiotics, additionally referred to as "postbiotics," indicate anti-inflammatory qualities against pathogen-induced inflammation and are related to the regulation of cytokine production [37, 15].

A multitude of distinct physiological and molecular mechanisms have been proposed and explained comprising the enhancement of innate immunity as well as the promotion of barrier function and intestinal epithelial growth [17, 38]. Since the control of host immunity is one of the most frequently reported beneficial consequences of consuming probiotics, a significant amount of research has been performed in recent years to develop an improved awareness of the cellular and biochemical actions of these microorganisms [39, 3]. Postbiotics have also been shown to increase the integrity of the mucosal gut barrier in an assortment of ways. The intestinal permeability brought on by alcohol is decreased by *Lactobacillus rhamnosus* GG supernatants by recovering normal levels of tight binding protein and mucin-producing factor [8, 40].

Furthermore, certain residues inhibit enterocyte destruction and enhance the growth of intestinal epithelial cells. The impacts on cell kinetics appear to be different depending on the kind of intestinal cell. The soluble molecule was isolated from the leftovers of the *Lactobacillus casei* subspecies (*Lactobacillus casei* and *Lactobacillus rhamnosus*), and it increased the death of intestinal epithelial cells only, not the human immune cells [41, 42]. Initially, *L. rhamnosus* supernatants were first shown to have effects on young grown-up animal gastrointestinal cells, where it was demonstrated that the supernatants' capacity to inhibit cytokine-induced apoptosis was dose-dependent [27].

It has also been demonstrated that *L. rhamnosus* GG supernatants had anti-inflammatory qualities in primary cultures of human colonic smooth muscle cells. The lipopolysaccharide (LPS)-induced NFkB damage was reversed and the morphofunctional cellular alterations decreased in these cells by the supernatants [3]. By research, postbiotics decrease the risk of infectious diseases and food spoiling by having antibacterial qualities against infectious and deteriorating bacteria. These compounds defend the colon from the growth of pathogenic microbes and prevent intestinal conditions such as irritable bowel syndrome and diarrheal illness [1, 43].

Identifiable microorganisms known as "postbiotics" strengthen human health by promoting the body's microbial biodiversity, reducing the growth of pathogenic bacteria in the gut wall, generating antimicrobial compounds, and influencing the pH of the surrounding environment [4, 44].

CONCLUSION: Current definitions of postbiotics consist of bioactive soluble factors (products or metabolic residues) produced by certain edible microbes through the growth and fermentation process of complex microbial cultures, food, or the gut that have some beneficial effects on the food or the consumer [18]. A large number of Lactobacillus bacteria are thought to be probiotic, and their postbiotic components offer consumers comparable or even greater health advantages. The goal of this study was to discuss the most present applications of postbiotics regarding food safety [9].

The abundance of physiologically active metabolites with varying different molecular weights. Addressing these compounds, there are still unresolved issues, predominantly regarding their application in food. Postbiotics can defeat microorganisms associated with food safety [3]. They should be examined primarily by studying the composition of their molecules and executing the antagonistic experiments, even though recent research on the development and consumption of postbiotics derived from various probiotics is extremely promising [24, 43].

We learned about postbiotics and their prospective applications in food packaging, biofilm management, and also in bio-preservation of food. Consideration was also given to the present applications of postbiotics in promoting the elimination and breakdown of certain chemical substances associated with food safety. We also talked about the potential applications of postbiotics in food processing, as well as their safety concerns and limitations. Therefore, an established postbiotic with particular benefits can be useful for food in the most effective manner. The most recent advances in the lactic acid bacteria-based postbiotics synthesis have been examined in this review.

There was also an extensive examination of the roles performed by the various experimental methods of analysis and variables regulating the chemical constitution of postbiotics.

Postbiotics are secondary metabolites of probiotics, have successfully adapted to these difficult conditions, and could be an adequate probiotic supplement [30, 43]. Postbiotics may have anti-inflammatory properties, immunomodulatory agents, anti-hypertensive, and antioxidant activity effects due to their unique chemical composition, safe profile, extended shelf life, and presence of several transmitting molecules. They can also prevent abnormal cell proliferation. This review focused mainly on defining postbiotics and their beneficial effects on the food bio-preservation. The concept of postbiotics is relatively new in the food industry and some current applications such as biofilm removal, biodegradation of food chemical contaminants, and preparation of nanomaterials using postbiotics have been proposed.

As a result, the present study encourages the claim that postbiotics may replicate the basic and clinical properties of probiotics. Based on their special qualities, postbiotics may also be employed in an oral delivery system (food bio-preservation), as a food safety barrier, to boost the shelf life of food products, to create novel functional foods, or even to develop health benefits and therapeutic goals. In terms of commercial food-based products, this overview highlights the most significant postbiotics and their applications.

ACKNOWLEDGEMENT: The authors would like to express their sincere gratitude to everyone who assisted in making this article possible. The authors additionally acknowledge the principal and faculty of Guru Nanak Institute of Pharmaceutical Science and Technology for their insightful thoughts and helpful discussions, which greatly enhanced the standards of this review research.

CONFLICT OF INTEREST: The Authors have no conflict of interest.

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How to cite this article:
Chakraborty T, Parwez Z, Verma N, Gupta T, Deb K and Chakraborty T: Review on scope and application of post-biotics in food preservation. Int J Pharm Sci & Res 2024; 15(7): 1929-40. doi: 10.13040/IJPSR.0975-8232.15(7).1929-40.