# Recent Studies and Publications on Postbiotics

## I- DEFINITION

### Postbiotics

The International Scientific Association for Probiotics and Prebiotics (ISAPP) defines postbiotics as "a preparation of inanimate microorganisms and/or their components that confers a health benefit on the host." This broad and flexible definition encourages innovation in product development and aligns with ongoing research and market products. Despite the existence of alternative terms and definitions for inactivated microbes, ISAPP's definition has sparked discussion.

Again, the complexity of the term "postbiotics" mirrors challenges seen with other biotic definitions. Identification of the specific components in a postbiotic responsible for health benefits yet again presents challenges similar to the uncertainty in multi-strain probiotic products. Despite these challenges, research in the field of postbiotics is growing significantly, encompassing various forms of inanimate microbial cells or their components as listed below (**Fig. 1**).

**Types of Postbiotic Components**

1. **Metabolic By-products**:
   - Organic acids (e.g., lactic acid, acetic acid)
   - Peptides
   - Bacteriocins
   - Vitamins
   - Enzymes
   - Biosurfatants

2. **Cell Surface-associated Components**:
   - Teichoic acid
   - Peptidoglycan-derived muropeptides
   - Exopolysaccharides
   - Surface proteins
   - Pili type structures

3. **Heat-killed Probiotics**: These are probiotics that have been inactivated by heat but retain their health benefits. They are considered a form of postbiotics and have shown potential as novel, alternative, and safer therapeutics.

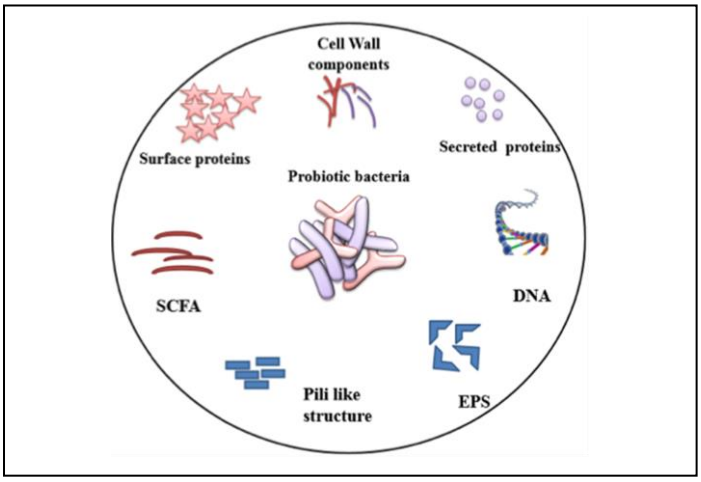


**Fig. 1 : Postbiotic Components of Probiotic Bacteria**

**Advantages of Postbiotics over Probiotics**

- **Safety**: Postbiotics do not contain live bacteria, thereby, avoiding risks associated with the administration of live probiotics such as bacteremia, especially in immunocompromised individuals and antimicrobial resistance transmission.
- **Stability**: Postbiotics have a longer shelf life and are more stable during storage and transportation compared to live probiotics.
- **Consistency**: The effects of postbiotics are more consistent as they do not depend on the survival and colonization of live bacteria in the gut.

- **Efficacy**: Postbiotics have been shown to modulate the immune response, reduce inflammation, and have anti-cancer and anti-diabetic effects.
- **No Live Organisms:** Avoids survivability issues of live bacteria, as postbiotics are non-living metabolites.
- **Applications in Food**: Versatile applications beyond supplements, including diverse group of functional foods

However, postbiotics have certain disadvantages since they can not restore microbial gut balance and nutrient production like vitamins etc. while postbiotics exert direct effects on inflammatory pathways and enhance gut barrier integrity. Several *in vitro* studies have highlighted postbiotics' efficacy, comparable to probiotics, in managing inflammation. **Based on the above definition the Postbiotics Studies are categorized under the following categories given below:**

# II- POSTBIOTICS CATEGORIES

## A. CELL WALL COMPONENTS AS POSTBIOTICS

### 1. Extractable Surface Proteins Of Indigenous Probiotic Strains Confer Anti-Adhesion Knack And Protect Against Methicillin-Resistant Staphylococcus Aureus Induced Epithelial Hyperpermeability In HT-29 Cell Line

In this study, the anti-adhesion ability of extractable ***cell surface proteins from two indigenous potential probiotic strains (Lactiplantibacillus plantarum A5 and Limosilactobacillus fermentum Lf1) [POSTBIOTICS]*** and two standard reference strains (Lactobacillus acidophilus NCFM and Lacticaseibacillus rhamnosus LGG) was evaluated against clinical isolates of Methicillin-Resistant Staphylococcus aureus (MRSA) on porcine gastric mucin and HT-29 cells.

The surface protein quantification and SDS-PAGE profiling indicated that the yield and **protein patterns were strain-specific.** Surface proteins significantly **hampered the mucoadhesion of MRSA isolates via protective, competitive, and displacement**. Similarly, the treatment with surface proteins probiotic strains displayed **anti-adhesion against MRSA isolates on HT-29 cells without affecting the viability of the cell line**. Surface proteins treatment to the confluent monolayer of **HT-29 cells maintained the epithelial integrity**; however, **MRSA isolates** (109 cells/mL) **showed considerable alteration in the epithelial integrity** by exacerbating the FITC-dextran transflux. Contrarily, the co-treatment with surface proteins with **MRSA isolates significantly lowered the FITC-dextran transflux across the differentiated HT-29 monolayer**. ***Overall, the findings of this study suggest that probiotic-derived surface proteins could be the novel biotherapeutics to combat the MRSA colonization and their concomitant intestinal infections.***

***Source: Rashmi Hogarehalli Mallappa, Molecular Biology Unit, Dairy Microbiology Division, Icar-National Dairy Research Institute, Karnal, Haryana, India. Extractable Surface Proteins Of Indigenous Probiotic Strains Confer Anti-Adhesion Knack And Protect Against Methicillin-Resistant Staphylococcus Aureus Induced Epithelial Hyperpermeability In HT-29 Cell Line. Microbial Pathogenesis, Volume 158, September 2021, 104974. DOI: https://doi.org/10.1016/j.micpath.2021.104974***

### 2. Host-Microbe Interaction And Pathogen Exclusion Mediated By An Aggregation-Prone Surface Layer Protein Of Lactobacillus Helveticus

Probiotic surface layer proteins (Slps) have multiple functions and bacterial adhesion to host cells is one of them. The precise role of Slps in cellular adhesion is not well understood due to its low native protein yield and self-aggregative nature.

**This study reports the recombinant expression and purification of biologically active Slp of Lactobacillus helveticus NCDC 288 (SlpH) in high yield.** SlpH is a highly basic protein (pI = 9.4), having a molecular weight of 45 kDa.

Circular Dichroism showed a prevalence of beta-strands in SlpH structure and resistance to low pH. SlpH showed binding to human intestinal tissue, enteric Caco-2 cell line, and porcine gastric mucin, but not with fibronectin, collagen type IV and laminin. SlpH inhibited the binding of the enterotoxigenic E. coli by 70 % and 76 % and that of Salmonella Typhimurium SL1344 by 71 % and 75 % to enteric Caco-2 cell line in the exclusion and competition assays, respectively. ***The pathogen exclusion and competition activity and tolerance to harsh gastrointestinal conditions show the potential for developing SlpH as a prophylactic or therapeutic agent against enteric pathogens.***

***Source: Jai Kumar Kaushik, Animal Biotechnology Centre, Icar-National Dairy Research Institute, Karnal, Haryana, India. Host-Microbe Interaction And Pathogen Exclusion Mediated By An Aggregation-Prone Surface Layer Protein Of Lactobacillus Helveticus. International Journal Of Biological Macromolecules, Volume 244, 31 July 2023, 125146. DOI: https://doi.org/10.1016/j.ijbiomac.2023.125146***

### 3. Mechanistic Insights Into The Host-Microbe Interaction And Pathogen Exclusion Mediated By The Mucus-Binding Protein Of Lactobacillus Plantarum

Surface adhesins of pathogens and probiotics strains are implicated in mediating the binding of microbes to host. Mucus-binding protein (Mub) is unique to gut inhabiting lactic acid bacteria; however, the precise role of Mub proteins or its structural domains in host-microbial interaction is not well understood.

***Study results show that Mub plays an important role in the host-microbial cross-talk and possesses the potential for pathogen exclusion to a greater extent than mediated by L. plantarum cells. The functional and technological characteristics of Mubs5s6 make it suitable for breaking the host-pathogen interaction.***

***Source: Jai Kumar Kaushik, Animal Biotechnology Centre, Icar-National Dairy Research Institute, Karnal, Haryana, India. Mechanistic Insights Into The Host-Microbe Interaction And Pathogen Exclusion Mediated By The Mucus-Binding Protein Of Lactobacillus Plantarum. Sci Rep 8, 14198 (2018). DOI: https://doi.org/10.1038/s41598-018-32417-y***

### 4. Expression Of Fibronectin-Binding Protein Of L. Acidophilus NCFM And In Vitro Refolding To Adhesion Capable Native-Like Protein From Inclusion Bodies

The ability of Lactobacilli to adhere to host epithelial surface and intestinal tracts is important for colonization and persistence of bacteria in the host gut. Extracellular matrix components like fibronectin, mucin, collagen and other adhesion molecules serve as substratum for attachment of bacteria.

To study adhesion of its Fibronectin-Binding Protein (FBP) (64 kDa), the fbp gene of L. acidophilus NCFM was cloned and expressed in E. coli. However, the fibronectin-binding protein expressed in soluble form could not be purified by Ni-NTA affinity chromatography possibly because of partially buried Histidine tag in the recombinant fusion protein. Therefore, the protein was expressed as inclusion bodies (IBs) at 37 °C and solubilized in urea followed by purification in denatured form by Ni-NTA affinity chromatography. The purified denatured protein was refolded in vitro to structurally stable and biologically active form.

***The conformational properties of the refolded protein show that there is a prominence of α+ β structural element. The refolded FBP also show that there is significant binding to human intestinal tissue sections. This optimized refolding protocol from IBs of this recombinant probiotic FBP led into high amounts of biologically active protein. This study result helps in increasing understanding of structure-function relation of surface adhesion proteins and host-microbial interactions.***

***Source: Jai Kumar Kaushik, Animal Biotechnology Centre, Icar-National Dairy Research Institute, Karnal, Haryana, India. Expression Of Fibronectin-Binding Protein Of L. Acidophilus NCFM And In Vitro Refolding To Adhesion Capable Native-Like Protein From Inclusion Bodies. Protein Expression And Purification, Volume 145, May 2018, Pages 7-13. DOI: Https://Doi.Org/10.1016/J.Pep.2017.11.007***

## B. BIOSURFACTANTS AS POSTBIOTICS

### 1. Characterization Of Biosurfactants Derived From Probiotic Lactic Acid Bacteria Against Methicillin-Resistant And Sensitive Staphylococcus Aureus Isolates

Metabolites of lactic acid bacteria (LAB) are gaining renewed interest as postbiotics to curb the growth of undesirable microorganisms in food and pharmaceutical industries. ***This study extracts and characterizes the biosurfactants (BS) of Lactobacillus acidophilus NCFM and Lacticaseibacillus rhamnosus GG.***

The analysis of BS (NCFM) revealed hexadecanoic acid, 9-octadecenoic acid, and methyl stearate as principal fatty acids. Researchers found that BS shows dose-dependent antibacterial and antibiofilm activities against methicillin-resistant and sensitive staphylococcal isolates. Upon visual inspection through scanning electron microscopy confirmed the cell death via alternations in the cell surface coherence. ***Overall, the findings of the study suggest that BS from LGG and NCFM may be the potential candidates to abrogate staphylococcal biofilms,*** and therefore further technology intervention to scale up the production process could be noteworthy.

***Source: Rashmi Hogarehalli Mallappa, Molecular Biology Unit, Dairy Microbiology Division, Icar-National Dairy Research Institute, Karnal, Haryana, India. Characterization Of Biosurfactants Derived From Probiotic Lactic Acid Bacteria Against Methicillin-Resistant And Sensitive Staphylococcus Aureus Isolates. LWT, Volume 151, November 2021, 112195. DOI: https://doi.org/10.1016/j.lwt.2021.112195***

## 2. Functional Group Characterization Of Lactic Bacterial Biosurfactants And Evaluation Of Antagonistic Actions Against Clinical Isolates Of Methicillin-Resistant Staphylococcus Aureus

The present study investigated the antimicrobial and antibiofilm potential of biosurfactants derived from Lactobacillus fermentum Lf1, L. fermentum LbS4 and Lactobacillus plantarum A5 against clinical isolates of methicillin-resistant Staphylococcus aureus (MRSA).

Fourier-transform infrared spectroscopy-based characterization of biosurfactants revealed the heterogeneous chemical composition involving proteins, fatty acids and carbohydrate moieties in LbS4 and A5, while only the sugar and lipid fractions in Lf1. Fatty acid profiling indicated hexadecanoic acid and stearic acid as the predominant fatty acids in the biosurfactants of all these strains. Biosurfactants demonstrated dose-dependent antibacterial action against MRSA isolates with the highest inhibition zone diameter (30·0 ± 0·0 to 35·0 ± 0·0 mm) recorded at 400 mg ml–1. Biosurfactants shows that it hasan excellent staphylococcal antibiofilm activity by preventing the biofilm formation and disrupting the preformed biofilms. Visual inspection through scanning electron microscopy witnessed the biosurfactants-induced alteration in the cell membrane integrity and subsequent membrane pore formation on staphylococcal cells.

***This study findings emphasize the prospects of biomedical applications of biosurfactants as bactericidal and biofilm controlling agents to confront staphylococcal nosocomial infections.***

***Source: Rashmi Hogarehalli Mallappa, Molecular Biology Unit, Dairy Microbiology Division, Icar-National Dairy Research Institute, Karnal, Haryana, India. Functional Group Characterization Of Lactic Bacterial Biosurfactants And Evaluation Of Antagonistic Actions Against Clinical Isolates Of Methicillin-Resistant Staphylococcus Aureus. Letters In Applied Microbiology, Volume 73, Issue 3, 1 September 2021, Pages 372–382. DOI: https://doi.org/10.1111/lam.13523***

# C. EXOPOLYSACCHARIDES AS POSTBIOTICS

## 1. Biofunctional Attributes Of Surface Layer Protein And Cell-Bound Exopolysaccharide From Probiotic Limosilactobacillus Fermentum (MTCC 5898)

The probiotic extracellular matrix components (ECM) have been considered as an important factor in eliciting the beneficial roles of the bacteria. The study involved the growth phase–dependent extraction of the surface layer protein (SLP) and cell-bound exopolysaccharide (EPS-b) from novel Limosilactobacillus fermentum (MTCC 5898).

**Scientists discovered that the major role of SLP was related to bacterial adhesion to mucin, which was linked to its hydrophobic nature.** Under in vitro conditions, **no effect of SLP and EPS-b was observed on the proliferation of murine splenocytes**; however, **both the components stimulated the phagocytosis of murine peritoneal macrophages at varying concentrations**. Furthermore, **all the components exhibited strong radical scavenging, chelating, and reducing potential with increasing concentration**. ***Therefore, the ECM components of L. fermentum exhibited a variable biofunctional effect, providing crucial information to enable its further use as functional foods and overcome the challenges posed by probiotics.***

***Source: Rajeev Kapila, Animal Biochemistry Division, ICAR-National Dairy Research Institute, Karnal, Haryana, India. Biofunctional Attributes Of Surface Layer Protein And Cell-Bound Exopolysaccharide From Probiotic Limosilactobacillus Fermentum (MTCC 5898). Probiotics & Antimicro. Prot. 14, 360–371 (2022). DOI: https://doi.org/10.1007/s12602-021-09891-4***

## 2. Multi-Faceted Bioactivity Assessment Of An Exopolysaccharide From Limosilactobacillus Fermentum NCDC400: Antioxidant, Antibacterial, And Immunomodulatory Proficiencies

Exopolysaccharides (EPS) are acknowledged for their diverse functional and technological properties. This study presents the characterization of EPS400, an acidic exopolysaccharide sourced from the native probiotic Limosilactobacillus fermentum NCDC400. Notably, this strain has demonstrated previous capabilities in enhancing dairy food texture and displaying in vivo hypocholesterolemic activity.

The results underscore EPS400s prowess in scavenging radicals, including the 2,2-diphenyl-1-picrylhydrazyl radical, 2,2-azino-di-(3-ethylbenzthiazoline sulfonic acid) radical, superoxide radical, hydroxyl radical, and chelating activity targeting the ferrous ion. Furthermore, EPS400 displayed substantial antibacterial effectiveness against prevalent food spoilage bacteria such as Pseudomonas aeruginosa NCDC105 and Micrococcus luteus. Remarkably, EPS400 exhibited the ability to modulate cytokine production, downregulating pro-inflammatory cytokines TNF-α, IL-1β, IL-6, and nitric oxide, while concurrently promoting the release of anti-inflammatory cytokine IL-10 within lipopolysaccharide-activated murine primary macrophages. Additionally, EPS400 significantly ($p \leq 0.05$) enhanced the phagocytic potential of macrophages.

***Collectively, the findings of the study show that EPS400 is a promising contender endowed with significant antioxidant, antibacterial, and immunomodulatory attributes. These characteristics propose EPS400 as a potential pharmaceutical or bioactive component, with potential applications in the realm of functional food development.***

***Source: Pradip V. Behare, Technofunctional Starters Lab, National Collection Of Dairy Cultures (NCDC), Dairy Microbiology Division, ICAR-National Dairy Research Institute, Karnal, India. Multi-Faceted Bioactivity Assessment Of An Exopolysaccharide From Limosilactobacillus Fermentum NCDC400: Antioxidant, Antibacterial, And Immunomodulatory Proficiencies. Foods 2023, 12(19), 3595. DOI: https://doi.org/10.3390/foods12193595***

## 3. Effect Of Bacteriocin And Exopolysaccharides Isolated From Probiotic On P. Aeruginosa PAO1 Biofilm

This study assessed the anti-biofilm potential of postbiotics derived from probiotic organisms against most prevalent biofilm-forming Pseudomonas aeruginosa PAO1.

**Eighty lactic acid bacteria isolated from eight neonatal fecal samples** possessed antibacterial activity against P. aeruginosa PAO1. Among these, only four lactic acid bacteria produced both bacteriocin and exopolysaccharides but only one isolate was found to maximally attenuate the P. aeruginosa PAO1 biofilm. The phenotypic and probiotic characterization shows that the isolated lactic acid bacteria were gram positive, non-motile, and catalase and oxidase negative; tolerated acidic and alkaline pH; has bile salt concentration; showed 53% hydrophobicity; and found to be non-hemolytic.

Phylogenetically, the organism was found to be probiotic Lactobacillus fermentum with accession no. KT998657. Interestingly, pre-coating of a microtiter plate either with bacteriocin or with exopolysaccharides as well as their combination significantly ($p < 0.05$) reduced the number of viable cells forming biofilms to 41.7% compared with simultaneous coating of postbiotics that had 72.4% biofilm-forming viable cells as observed by flow cytometry and confocal laser scanning microscopy. Therefore, it can be anticipated that ***postbiotics as the natural biointerventions can be employed as the prophylactic agents for medical devices used to treat gastrointestinal and urinary tract infections.***

***Source: Geeta Shukla, Department of Microbiology, Panjab University, Chandigarh, India. Effect Of Bacteriocin And Exopolysaccharides Isolated From Probiotic On P. Aeruginosa PAO1 Biofilm. Folia Microbiol 63, 181–190 (2018). DOI: https://doi.org/10.1007/s12223-017-0545-4***

## 4. Synergistic Effect Of Biogenics Derived From Potential Probiotics Together With Zingerone Against Biofilm Formation By Pseudomonas Aeruginosa PAO1

Biogenics are compounds produced by living organisms such as animals, plants, bacteria, etc. Probiotics and their biogenics are known for their antimicrobial potential. Therefore, this study evaluates the antibiofilm potential of probiotic-derived biogenics in conjunction with zingerone against the Pseudomonas aeruginosa PAO1 biofilm.

***The study result shows that cell-free supernatant (CFS) of potential probiotics Pediococcus acidilactici BNS5B and Lactobacillus fermentum PUM inhibit the growth of Ps. aeruginosa PAO1 maximally among the nineteen isolated lactic acid bacteria. L. fermentum PUM produced precipitated protein fraction (PP), organic acids (OAs), exopolysaccharides (EPSs), biosurfactants (BSs) and various volatile antimicrobial compounds, while Ped. acidilactici BNS5B produce PP, OA, EPS, BS and fewer volatile antimicrobial compounds only.***

***More specifically, the CFS and selected biogenics (OA and PP from L. fermentum PUM; OA from P. acidilactici BNS5B) from both potential probiotics showed synergy with zingerone against P. aeruginosa growth,*** as observed by an FIC index (<0.5). Interestingly, ***CFS of both potential probiotics in combination with zingerone led to the formation of a more distorted biofilm compared with OA of L. fermentum PUM and zingerone, OA of Ped. acidilactici BNS5B and zingerone, PP of L. fermentum PUM and zingerone as well as their individual counterparts***. Similarly, both confocal laser scanning microscopy and XTT assay shows that there are **increased number of dead and impaired cells along with the decreased viability of biofilm cells**. Thus, it can be reckoned that a combination of probiotic-derived biogenics and zingerone can have therapeutic application against Ps. aeruginosa infections which needs to be validated clinically.

***Source: Geeta Shukla, Department Of Microbiology, Panjab University, Basic Medical Sciences (Block-1), South Campus Sector-25, Chandigarh, India. Synergistic Effect Of Biogenics Derived From Potential Probiotics Together With Zingerone Against Biofilm Formation By Pseudomonas Aeruginosa PAO1. Probiotics & Antimicro. Prot. 13, 1481–1497 (2021). DOI: https://doi.org/10.1007/s12602-021-09763-x***

## 5. FTIR Spectrum And XRD Of Postbiotics-Exopolysaccharides Zinc Oxide Nanoparticles

***This study characterised zinc oxide nanoparticles from postbiotics-exopolysaccharides and analysed the Fourier Transformed Infrared Spectroscopy (FTIR Spectrum) and X-Ray Diffraction (XRD) of Postbiotics–Exopolysaccharides Zinc Oxide Nanoparticles.***

**Results revealed that 46% of carbohydrate and 10% of protein content confirmed the presence of exopolysaccharides and in particular postbiotics-exopolysaccharides.** The peak at 346.3 nm by Ultraviolet-Visible spectroscopy **confirmed the presence of nanoparticles**. The **functional groups of postbiotics-exopolysaccharides zinc nanoparticles was recorded** by Fourier Transform Infrared Spectroscopy using SHIMADZU Miracle spectrophotometer (FTIR 820IPC) KBr techniques. The scanning electron micrograph **confirmed that postbiotics-exopolysaccharides zinc oxide nanoparticles had a rough, rigid and compact surface structure**. The sharp narrow peak obtained in the graph by X-ray Diffraction Analysis **confirmed the crystalline structure**. **The crystalline size of the postbiotics-exopolysaccharides zinc oxide nanoparticles** as calculated by Debye-Scherer equation $D=K \lambda / \beta (\cos \theta)$ **with highest peak value 34.01 confirmed the crystalline size to be 33.31 nm.**

***Source: Krithika R, Research Scholar, Department of Food Science and Nutrition, Avinashilingam Institute For Home Science And Higher Education For Women, Coimbatore, Tamil Nadu, India. FTIR Spectrum And XRD Of Postbiotics-Exopolysaccharides Zinc Oxide Nanoparticles. J. Adv Sci Res, 2021; 12 (3) Suppl 2: 292-300. DOI: https://doi.org/10.55218/JASR.s2202112334***

## 6. Evaluation Of Improved Biological Properties Of Chemically Modified Exopolysaccharides From Lactobacillus Plantarum BR2

This work engrosses the production and further chemical modifications of EPS produced by Lactobacillus plantarum BR2 and subsequent evaluation of their biological properties which shows greater antioxidant properties for the derivatives compared to its native unmodified form.

Out of the three derivatives, acetylated EPS (a-EPS), carboxymethylated EPS (Cm-EPS), and sulphated EPS (s-EPS), **a-EPS exhibited the highest DPPH radical scavenging and total antioxidant activity in a dose-dependent manner**. At all tested concentrations, **a-EPS showed higher scavenging activity, and a maximum activity of 73.81% at 2 mg/mL**. Meanwhile, **s-EPS showed the highest reducing power potential and hydroxyl radical scavenging activities**. At 2 mg/mL concentration, the **order of reducing power was observed to be s-EPS (41.39%)>a-EPS (37.43%)>Cm-EPS (24.02)>BR2 control EPS (16%) and the hydroxyl radical scavenging activity for the s-EPS was 54.43%.**

**The highest reducing power activity exhibited by s-EPS is 2.6-fold higher and a 1.5-fold increase in the scavenging activity of native BR2 EPS after the sulphonyl group addition** was observed. The increase in these activities is due to the addition of various functional groups that contributes largely to the scavenging abilities of different free radicals. **The s-EPS and Cm-EPS derivatives also exhibited increased cholesterol-lowering activity of 40 and 34.5%, respectively, than the native EPS**. Interestingly, there were hardly any inhibitions on cell growth and viability of normal L929 fibroblast cell lines upon treatment with these EPSes. **The improved antioxidant properties resulting from chemical modification opened better avenues for EPS application in the food and pharma sectors.** Thus, the potentiality of chemically modified EPS may be explored further in the development of functional foods.

***Source: K. Madhavan Nampoothiri, Microbial Processes And Technology Division, Csir-National Institute For Interdisciplinary Science And Technology (Csir-Niist), Trivandrum, Kerala, India. Evaluation Of Improved Biological Properties Of Chemically Modified Exopolysaccharides From Lactobacillus Plantarum Br2. 3 Biotech 13, 308 (2023). DOI: Https://Doi.Org/10.1007/S13205-023-03718-5***

## 7. Structural Characteristics And Functional Properties Of A Fucose Containing Prebiotic Exopolysaccharide From Bifidobacterium Breve NCIM 5671

**A CPS produced by the probiotic bacteria B. breve NCIM 5671 was isolated** and subjected to characterization through GC analysis, which **indicated the presence of rhamnose, fucose, galactose, and glucose in a molar ratio of 3:1:5:3. The average molecular weight of the CPS was determined to be ~8.5 × 105 Da**. Further, NMR analysis revealed the **probable CPS structure to be composed of major branched tetra- and penta-saccharide units alternately repeating and having both α- and β-configuration sugar residues. CPS displayed an encouraging prebiotic score for some of the studied probiotic bacteria. *Compared to standard inulin, CPS showed better resistance to digestibility against human GI tract in vitro. DPPH, total antioxidant, and ferric reducing assays carried out for CPS displayed decent antioxidant activity too.***

***Source: Prakash M Halami, Department of Microbiology and Fermentation Technology, CSIR-Central Food Technological Research Institute, Mysuru, India. Structural Characteristics And Functional Properties Of A Fucose Containing Prebiotic Exopolysaccharide From Bifidobacterium Breve NCIM 5671. Journal Of Applied Microbiology, Volume 134, Issue 11, November 2023, Ixad262. DOI: https://doi.org/10.1093/jambio/lxad262***

## 8. Characterization Of A Novel Exopolysaccharide Produced By Lactobacillus Gasseri FR4 And Demonstration Of Its In Vitro Biological Properties

**In this study, hetero-exopolysaccharide of Lactobacillus gasseri FR4 isolated from native chicken was produced and purified. The molecular weight of LgEPS was found to be 1.86 × 105 Da**. The gas chromatographic analysis revealed that ***the LgEPS was majorly composed of glucose (65.31%), mannose (16.51%), galactose (8.45%), rhamnose (6.55%) and a small fraction of fucose (3.18%).*** The ***functional groups of LgEPS were confirmed*** by FT-IR analysis. The 1D (1H and 13C) and 2D NMR (COSY and HSQC) analysis showed the ***presence of 1,6 linked-α-d-Glcp, 1,4 linked-α-d-Galp, 1,3,4 linked-α-d-Manp, 1,3 linked-α-l-Rhap, 1,4 linked-α-l-Fucp, 1,4 linked-β-d-Glcp, and β-d-Galp-1 residues***. SEM and AFM micrographs ***revealed the fibrous and porous nature of LgEPS***. Moreover, ***LgEPS exhibited in vitro antioxidant, antibacterial and antibiofilm activity against various food borne pathogens, which proved that this LgEPS might be used in food industries as an antioxidant agent, viscosifying agent and antimicrobial agent etc***.

***Source: Rizwana Parveen Rani, Department Of Biology, The Gandhigram Rural Institute-Deemed University, Gandhigram, Tamilnadu, India. Characterization Of A Novel Exopolysaccharide Produced By Lactobacillus Gasseri FR4 And Demonstration Of Its In Vitro Biological Properties. International Journal Of Biological Macromolecules, Volume 109, 1 April 2018, Pages 772-783. DOI: https://doi.org/10.1016/j.ijbiomac.2017.11.062***

## 9. Isolation Of Exopolysaccharide, Galactan From Marine Vibrio Sp. BPM 19 To Template The Synthesis Of Antimicrobial Platinum Nanocomposite

In this study, a galactan exopolysaccharide (EPS) producing marine bacteria Vibrio Sp. BPM19 was reported. Phylogenetic analysis based on 16S rRNA gene sequencing shows that there proximity of the isolate to Vibrio alginolyticus strain 1306. Gel permeation chromatography revealed that the molecular weight of the purified EPS was about 6342.3 Daltons. 1H NMR, 13C NMR, and FTIR analysis indicated that isolated EPS comprised high molecular weight polysaccharides. HPLC analysis suggests that the EPS is composed of a repeating unit of galactose. DSC-TGA studies support that the EPS has very high thermal stability. The potential application of purified EPS in nanotechnology was demonstrated by the synthesis of platinum nanocomposite (PtNC). The PtNC was characterized by energy-dispersive X-ray diffraction, transmission electron microscopy, zeta potential, particle size analysis, and FTIR. The antimicrobial potential of the PtNC was demonstrated against drug-resistance Salmonellae typhi and Staphylococcus aureus. ***The result suggested the possible commercial scope of the isolated strain to produce galactan, which can synthesize antimicrobial metal nanocomposite***.

***Source: Veerappan Anbazhagan, School Of Chemical And Biotechnology, Sastra Deemed University, Thirumalaisamudram, Thanjavur, Tamil Nadu, India. Isolation Of Exopolysaccharide, Galactan From Marine Vibrio Sp. Bpm 19 To Template The Synthesis Of Antimicrobial Platinum Nanocomposite. Process Biochemistry, Volume 122, Part 1, November 2022, Pages 267-274. DOI: Https://Doi.Org/10.1016/J.Procbio.2022.09.003***

## 10. Antimicrobial, Cytotoxic Effect And Purification Of Bacteriocin From Vancomycin Susceptible Enterococcus Faecalis And Its Safety Evaluation For Probiotization

A vancomycin susceptible Enterococus faecalis CV7 produced bacteriocin was purified by size exclusion chromatography followed by RP-HPLC C-18 column. Tricine-SDS PAGE unrevealed molecular mass was further confirmed by MALDI-TOF MS as 4.829 kDa. This bacteriocin showed broad spectrum of anti-bacterial activity against important food borne pathogens mainly against Salmonella typhi and this activity also found to be withstood after treatment with different proteolytic enzymes, temperature, pH, solvents and detergents. Cytotoxicity of bacteriocin CV7 by MTT assay showed that lower survival inhibition on HeLa than HT-29 cell line at lower concentrations conclude its potentiality in food biopreservation. ***Results*** obtained from PCR amplifications ***revealed that strain E. faecalis CV7 does not harbor virulence genes esp, ace, cylB, cylA and efaAfs but contains asa1. With this, surviving in the presence of low pH and bile oxgall promising its safety as probiont to control Salmonella infections.***

***Source: Arul Venkatesan, Department Of Biotechnology, School Of Life Sciences, Pondicherry University, Puducherry, India. Antimicrobial, Cytotoxic Effect And Purification Of Bacteriocin From Vancomycin Susceptible Enterococcus Faecalis And Its Safety Evaluation For Probiotization. LWT, Volume 78, May 2017, Pages 303-310. DOI: https://doi.org/10.1016/j.lwt.2016.12.048***

## 11. Hypocholesterolemic And Bioactive Potential Of Exopolysaccharide From A Probiotic Enterococcus Faecium K1 Isolated From Kalarei

In this study, E. faecium K1 has been used for Exopolysaccharide (EPS) production, and it yielded 355±0.019mg/L EPS.

***EPS demonstrates remarkable hypocholesterolemic, antioxidant, antibiofilm, and emulsification characteristics. EPS is constituted of mannose, glucose and galactose. SEM analysis reveals flake like compact structure of EPS while TEM and X-ray diffractogram confirms the amorphous structure of EPS. FTIR substantiates the functional groups/bonds typical of polysaccharides. Thermal analysis indicates adequate stability of EPS at 237°C with average weight loss of 22%. E. faecium K1 EPS possesses unique functional bioactivities and physicochemical characteristics, and may potentially be explored for applications in food/pharmaceutical industries.***

***Source: Bijender Kumar Bajaj, School Of Biotechnology, University Of Jammu, Jammu 180 006, Jammu & Kashmir, India. Hypocholesterolemic And Bioactive Potential Of Exopolysaccharide From A Probiotic Enterococcus Faecium K1 Isolated From Kalarei. Bioresource Technology, Volume 254, April 2018, Pages 264-267. DOI: https://doi.org/10.1016/j.biortech.2018.01.078***

## 12. An Exopolysaccharide (EPS) From A Lactobacillus Plantarum BR2 With Potential Benefits For Making Functional Foods

A high molecular weight **EPS of glucomannan** nature was recovered and purified to get an yield of 2.8 ± 0.5 g/L from Lb. plantarum BR2 and it **displayed potent antioxidant activity with 29.8% radical scavenging activity and 19% total antioxidant capacity. At 100 µg/ml concentration, it is capable of inhibiting the alpha amylase activity by 10% and at 300 µg/ml, it drastically inhibited the alpha-glucosidase activity by 67% which indicates its antidiabetic potential. More interestingly, at a concentration level of 0.1%, it reduced the cholesterol level by a margin of 45% in an in vitro assay.** ***The sample didn't reveal any cytotoxicity against H9C2 normal cells indicating it's potential for safe use as a food additive.***

***Source: K. Madhavan Nampoothiri, Microbial Processes And Technology Division, CSIR-National Institute For Interdisciplinary Science And Technology (NIIST), Trivandrum, Kerala, India. An Exopolysaccharide (EPS) From A Lactobacillus Plantarum BR2 With Potential Benefits For Making Functional Foods. Bioresource Technology, Volume 241, October 2017, Pages 1152-1156. DOI: https://doi.org/10.1016/j.biortech.2017.05.075***

## 13. Natural Polysaccharides-Based Postbiotics And Their Potential Applications

***In this review researchers propose that polysaccharides can be fermented by probiotics, and subsequent removal of bacteria will increase the safety of their produced metabolites, including oligosaccharides, disaccharides, monosaccharides and their derivatives. These polysaccharides-based postbiotics may mimic metabolization of polysaccharides in vitro and consequently broaden the applications of postbiotics. Non-probiotics such as Akkermansia muciniphila and other bacteria can also be used for glycanbiotics production, thus providing novel applications for human health.***

***Source: Weinan Du, Department Of Pathology, School Of Medicine, Case Western Reserve University, Cleveland, USA. Natural Polysaccharides-Based Postbiotics And Their Potential Applications. Explor Med. 2024;5:444–58. DOI: https://doi.org/10.37349/emed.2024.00230***

## 14. Impact Of A Natural Fusarial Multi-Mycotoxin Challenge On Broiler Chickens And Mitigation Properties Provided By A Yeast Cell Wall Extract And A Postbiotic Yeast Cell Wall-Based Blend

Yeast cell wall-based preparations have shown efficacy against Aspergillus-based toxins but have lower impact against type-B trichothecenes. Researchers investigated the effect of a yeast cell wall extract (YCWE) and a post-biotic yeast cell wall-based blend (PYCW) with the objectives of preventing mycotoxins' negative effects in commercial broilers.

**A total of 720 one-day-old male Cobb broilers** were randomly allocated to: (1) control diet, (aflatoxins 6 µg/kg; cyclopiazonic acid 15 µg/kg; fusaric acid 25 µg/kg; fumonisin B1 310 µg/kg); (2) Diet1 + 0.2% YCWE; (3) Diet1 + 0.2% PYCW; (4) Contaminated diet (3.0 mg/kg DON; 2.17 mg/kg 3-acetyldeoxynivalenol; 104 g/kg T2; 79 g/kg ZEA); (5) Diet4 + 0.2% YCWE; and (6) Diet4 + 0.2% PYCW.

**Study result shows that naturally contaminated diets adversely affected performance, serum biochemistry, liver function, immune response, altered cecal SCFA goblet cell count and architecture of intestinal villi.** These adverse effects were **reduced in birds fed PYCW and to a lesser extent YCWE, indicating protection against toxic assault. PYCW yielded better production performance and stimulated liver function, with higher response to NDV and IBV vaccination.** Furthermore, **mycotoxins were found to affect production outputs when evaluated with the European poultry production efficiency factor compared to control or YCWE and PYCW supplemented treatments**. Taken together, ***YCWE, when complemented with nutritional add-ons (PYCW), could potentiate the remediation of the negative effects from a multi mycotoxins dietary challenge in broiler birds.***

***Source: Manoj B. Kudupoje, Alltech, Inc., 3031 Catnip Hill Road, Nicholasville, Ky 40356, USA. Impact Of A Natural Fusarial Multi-Mycotoxin Challenge On Broiler Chickens And Mitigation Properties Provided By A Yeast Cell Wall Extract And A Postbiotic Yeast Cell Wall-Based Blend. Toxins 2022, 14(5), 315. DOI: https://doi.org/10.3390/toxins14050315***

## 15. Physiochemical And Biological Characterization Of Novel Exopolysaccharide Produced By Bacillus Tequilensis FR9 Isolated From Chicken

Hetero-exopolysaccharide secreted by Bacillus tequilensis FR9 (BtqEPS), was produced and fractioned on DEAE-Sepharose and phenyl sepharose CL-6B column. In the previous study the probiotic bacterial strain Bacillus tequilensis FR9 was isolated from GIT of free range chicken Gallus gallus domesticus by the researchers.

**HPLC analysis revealed the existence of five monosaccharides including glucose, galactose, mannose, arabinose and xylose.** FT-IR spectroscopy **confirmed the presence of carboxyl and hydroxyl groups.** 1H NMR and 13C NMR spectra analysis **showed the presence of α and β-d-(+)-glucose residues and glycosidic linkages. The fibrous, porous nature and elemental composition (C, O, N, Cl, Na, P, S) of BtqEPS was inferred from SEM and EDX analysis. AFM proved that the micro-structure of BtqEPS is compact and rough.** XRD analysis **confirmed the amorphous nature of BtqEPS with 15.6% crystallinity index. TGA curve indicated the degradation temperature (Td) of 239.72 °C.** Furthermore, **BtqEPS exhibited antioxidant effects by scavenging reactive oxygen species (ROS) and demonstrated strong reducing power**. ***All the above findings on BtqEPS paves way to find novel insights of its potential applications in industries.***

***Source: Rizwana Parveen Rani, Department Of Biology, The Gandhigram Rural Institute-Deemed University, Gandhigram, Tamilnadu, India. Physiochemical And Biological Characterization Of Novel Exopolysaccharide Produced By Bacillus Tequilensis FR9 Isolated From Chicken. International Journal Of Biological Macromolecules, Volume 96, March 2017, Pages 1-10. DOI: https://doi.org/10.1016/j.ijbiomac.2016.11.122***

## D. EXTRACELLULAR METABOLITES AS POSTBIOTICS

### 1. Postbiotics Of Naturally Fermented Synbiotic Mixture Of Rice Water Aids In Promoting Colonocyte Health

Fermented rice water (FRW), an economical, easy to make, simple beverage is a rich source of synbiotics. Therefore, consumption of fermented rice water allows for the intake of a variety of region-specific live probiotics. The secondary metabolites (postbiotics) present in such symbiotic mixtures may also contribute toward maintaining normal intestinal cellular functions. This study investigated the role of fermented rice water containing the postbiotic biomolecules in modulating the colonocyte health in vitro, using the HT29 cell line as a model.

In this study, researchers highlighted that regional staple such as rice consumed in their fermented form may hold promise in alleviating gut-related diseases.

***Study results shows that simple overnight fermentation of cooked edible rice enables the growth of probiotic bacterial species belonging to the Lactic Acid Bacteria group (Leuconostoc lactis, Weisella confusa, Weisellacibacria, Lactococcus lactis, lactococcus taiwanensis, Lactobacillus fermentum, Lactobacillus nagelii, and Lactobacillus delbrueckii ssp. indicus). Metabolomic analysis of the overnight fermented and over two nights fermented rice water identified more than 200 postbiotic metabolites.***

***This findings of the study show that postbiotics contributing to energy metabolism, gut-multiorgan axes, and microbial paraprobiotics are enriched in the overnight (~10 hours) fermented rice water as compared to the over two-nights fermented rice water. Functional analysis via gene expression studies for nutrient absorption (mct-1 and mct-2) and barrier integrity (occludin and zo-1) reveals significant upregulation of these genes upon FRW treatment of HT29 colon cells. This study is a first-of-its-kind to demonstrate the proof-of-principle that postbiotics of naturally fermented rice water positively modulates colonocyte health.***

***Source: Dr. Jeswanth Sathyanesan, Department Of Regenerative Medicine And Research, Government Stanley Medical College And Hospital, Chennai, India. Postbiotics Of Naturally Fermented Synbiotic Mixture Of Rice Water Aids In Promoting Colonocyte HealthBiomolecules, 2024 Mar 13;14(3):344. DOI: 10.3390/biom14030344.***

### 2. Novel Topical Application Of A Postbiotic, Lactosporin®, In Mild To Moderate Acne: A Randomized, Comparative Clinical Study To Evaluate Its Efficacy, Tolerability And Safety †

Acne vulgaris is a common skin disorder of pilosebaceous units. The therapy for mild-to-moderate acne includes topical antibiotics, benzoyl peroxide and retinoids. In this open-label, randomized monocentric study, researchers compared the efficacy of LactoSporin® 2% *w*/*w* cream with benzoyl peroxide in 64 male and female subjects with mild-to-moderate acne for three weeks.

A significant improvement was observed in the dermatological assessment of closed comedones, open comedones and papules count in comparison to the baseline in both LactoSporin and benzoyl peroxide groups. The antera analysis showed significant improvement in redness and elevation (small and medium) in both the treatment groups.

The sebumeter analysis showed a significant decrease in sebaceous secretion for LactoSporin, which resulted in reduced oiliness, pimples, acne spots and redness around the acne spot. The product was found to be safe without any irritancy. LactoSporin was stable at an acidic pH and temperature range of 70 to 90 °C, with antimicrobial activity against various pathogenic bacteria, including *Cutibacterium acnes*. It was also a potent inhibitor of 5-alpha reductase activity. Thus, it can be concluded that ***the efficacy of LactoSporin is equivalent to benzoyl peroxide in the treatment of mild-to-moderate acne lesions and better than benzoyl peroxide for reducing the sebaceous secretion and oily, greasy nature of the skin, implying its efficacy in other sebohorriec conditions.***

***Source: Kalpesh Shah, Clinworld Private Limited, Bangalore, Karnataka, India. Novel Topical Application Of A Postbiotic, Lactosporin®, In Mild To Moderate Acne: A Randomized, Comparative Clinical Study To Evaluate Its Efficacy, Tolerability And Safety †. Cosmetics 2020, 7(3), 70. DOI: https://doi.org/10.3390/cosmetics7030070***

### 3. Skin Protective Activity Of Lactosporin-The Extracellular Metabolite From Bacillus Coagulans MTCC 5856

Scientists studied skin protective activities of the extracellular metabolite (LactoSporin) of a spore-forming probiotic Bacillus coagulans MTCC 5856 in vitro.

***Researchers found that LactoSporin exhibits antioxidant activity and protects skin cells from UV-induced apoptosis and cell death. LactoSporin inhibited collagenase, elastase, and hyaluronidase activity and upregulated the expression of hyaluronan synthase, transforming growth factor and epidermal growth factor, which are associated with extracellular matrix integrity. These results suggest LactoSporin is a skin protective postbiotic with wide application in cosmetic formulations.***

***Source: Lakshmi Mundkur, Sami Labs Limited, Peenya Industrial Area, Bengaluru, Karnataka, India. Skin Protective Activity Of Lactosporin-The Extracellular Metabolite From Bacillus Coagulans MTCC 5856. Cosmetics 2020, 7(4), 76. DOI: https://doi.org/10.3390/cosmetics7040076***

## E. HEAT KILLED PROBIOTICS AS POSTBIOTICS

### 1. A Randomized Double-Blind, Placebo-Controlled Trial To Evaluate The Safety And Efficacy Of Live Bifidobacterium Longum CECT 7347 (ES1) And Heat-Treated Bifidobacterium Longum CECT 7347 (HT-ES1) In Participants With Diarrhea-Predominant Irritable Bowel Syndrome

***To determine the efficacy of the probiotic Bifidobacterium longum CECT 7347 (ES1) and postbiotic heat-treated Bifidobacterium longum CECT 7347 (HT-ES1) in improving symptom severity in adults with diarrhea-predominant irritable bowel syndrome (IBS-D), a randomised, double-blind, placebo-controlled trial with 200 participants split into three groups was carried out.*** Two capsules of either ES1, HT-ES1 or placebo were administered orally, once daily, for 84 days (12 weeks).

The change in IBS-SSS scores from baseline compared to placebo, reached significance in the ES1 and HT-ES1 group, on Days 28, 56 and 84. The decrease in mean IBS-SSS score from baseline to Day 84 was: ES1 (–173.70 [±75.60]) vs placebo (–60.44 [±65.5]) and HT-ES1 (–177.60 [±79.32]) vs placebo (–60.44 [±65.5]).

Secondary outcomes included changes in IBS-QoL, APS-NRS, stool consistency and STAI-S and STAI-T scores, with changes from baseline to Day 84 being significant in ES1 and HT-ES1 groups, compared to the placebo group. ***Both ES1 and HT-ES1 were effective in reducing IBS-D symptom severity, as evaluated by measures such as IBS-SSS, IBS-QoL, APS-NRS, stool consistency, and STAI, in comparison to the placebo. These results are both statistically significant and clinically meaningful, representing, to the best of the authors' knowledge, the first positive results observed for either a probiotic or postbiotic from the same strain, in this particular population.***

***Source: S Srivastavaa, Clinical Development & Science Communications, Vedic Lifesciences Pvt Ltd, Mumbai, India. A Randomized Double-Blind, Placebo-Controlled Trial To Evaluate The Safety And Efficacy Of Live Bifidobacterium Longum CECT 7347 (ES1) And Heat-Treated Bifidobacterium Longum CECT 7347 (HT-ES1) In Participants With Diarrhea-Predominant Irritable Bowel Syndrome. Gut Microbes, Volume 16, 2024 - Issue 1. DOI: https://doi.org/10.1080/19490976.2024.2338322***

### 2. Effects Of Paraprobiotic As Replacements For Antibiotic On Performance, Immunity, Gut Health And Carcass Characteristics In Broiler Chickens

***This study sought to determine the effects of dietary paraprobiotic (PPB) on broiler chicken performance, immunity, gut health, and carcass traits.*** A total of 240 day-old CARIBRO Vishal commercial broiler chicks of identical body weight randomly divided into six treatment groups, each with five replicates and eight chicks in each replicate. Six dietary treatments were preapared: T1=(control diet), T2=T1+0.02% (w/v) chlortetracycline (CTC), T3=T1+0.2% (w/v) PPB, T4=T1+0.4% (w/v) PPB, T5=T1+0.6% (w/v) PPB and T6=T1+0.8% (w/v) PPB, respectively.

Body weight gain (BWG) significantly increased in the T5 (0.6% PPB) and T6 (0.8% PPB) group. At the same time the feed intake significantly decreased and the feed conversion ratio (FCR) significantly improved in T5 and T6 group. There was a significant increase in cell-mediated immunity and haem-agglutination titre (HA titre) in the 0.6% and 0.8% PPB supplemented groups compare to the control group (T1). The percentage of carcass traits and organ weights did not significantly differ between the PPB-supplemented and control groups, but the percentage of live weight in cut up parts showed a significant improvement in the PPB-supplemented group. At 42 days, villus height, width, and crypt depth all significantly ($P \leq 0.05$) increased in the groups supplemented with 0.6 and 0.8% para-probiotics (T5 and T6).

***The results show that para-probiotics can be added to broiler diets at a rate of 0.6% (w/v) to enhance performance, immunity, gut health, and breast yield. The para-probiotic may therefore be a useful substitution for antibiotic growth promoters in the diet of chickens.***

***Source: Avishek Biswas, Nutrition and Feed Technology Division, ICAR-Central Avian Research Institute, Izatnagar, Bareilly, Uttar Pradesh, India. Effects Of Paraprobiotic As Replacements For Antibiotic On Performance, Immunity, Gut Health And Carcass Characteristics In Broiler Chickens. Sci Rep 12, 22619 (2022). DOI: https://doi.org/10.1038/s41598-022-27181-z***

## F. CELL FREE SUPERNATANT AS POSTBIOTICS

### 1. Deciphering The Mechanism Of Anti-Quorum Sensing Post-Biotic Mediators Against Streptococcus Mutans

Glucosyltransferases (Gtfs) and quorum sensing (QS) mediated transduction genes play critical roles in the pathogenesis of Streptococcus mutan-mediated dental caries. Therefore, targeting gtfs and QS-mediated virulence genes have therefore emerged as an intriguing goal for efficient therapeutic approaches that block cariogenic biofilms.

PMs dramatically reduced the expression of QS signal transduction, glucan metabolism, and **biofilm-regulated genes such gtfB, gtfC, ComDE, VicR, brpA in S. mutans,** which validates the outcomes of in vitro result. Their unique metabolites may help to control biofilm formation by eluding antimicrobial resistance.

Considering the above findings, ***PMs may deem to be an innovative, alluring, and secure method for preventing dental caries due to their biological activity. This study unravels the inhibitory effect of PMs, which will contribute to instruct drug design strategies for effective inhibition of S. mutans biofilms.***

***Source: Sangeeta Raut, School Of Pharmaceutical Sciences, Centre For Biotechnology, Siksha 'O' Anusandhan (Deemed To Be University), Bhubaneswar, Odisha, India. Deciphering The Mechanism Of Anti-Quorum Sensing Post-Biotic Mediators Against Streptococcus Mutans. Oral Dis, 2024 Jul;30(5):3471-3479. DOI: 10.1111/odi.14780.***

## 2. Effect Of Flax Seed Mucilage And Guar Gum Coating Enriched With Postbiotics On Postharvest Storage Of Fig Fruits (Ficus Carica L.)

Fresh fig or the common fig fruit is a climacteric and highly perishable fruit with a short shelf-life of 5 days. The edible coating is a prominent method to improve the shelf-life of fruits. Therefore, this study analysed the different combinations of the coating solutions, namely: flax seed mucilage, guar gum, flax seed mucilage + 1 % guar gum, flax seed mucilage + 1 % guar gum + 10 % postbiotic (Lactobacillus plantarum and Lactobacillus delbrueckii), flax seed mucilage + 10 % postbiotic and 1 % guar gum + 10 % postbiotic-based edible coating solutions were employed to treat fresh fig fruits in order to enhance their shelf-life.

***This study shows that the flax seed mucilage + 1 % guar gum + 10 % postbiotic-coated fig fruits, improved the shelf-life, reduced postharvest-spoilage and had better quality attributes than the other coatings studied. Therefore, the flax seed mucilage and guar gum incorporated with postbiotics, as a novel edible coating, enhanced the postharvest shelf-life of fig fruits.***

***Source: Periyar Selvam Sellamuthu, Department Of Food Process Engineering, Postharvest Research Lab, School Of Bioengineering, SRM Institute Of Science And Technology, Potheri, Kattankulathur, Chengalpattu District, Tamilnadu, India. Effect Of Flax Seed Mucilage And Guar Gum Coating Enriched With Postbiotics On Postharvest Storage Of Fig Fruits (Ficus Carica L.). South African Journal Of Botany, Volume 166, March 2024, Pages 636-647. DOI; https://doi.org/10.1016/j.sajb.2024.01.071***

## 3. Efficacy Of Saccharomyces Cerevisiae Fermentation Product And Probiotic Supplementation On Growth Performance, Gut Microflora And Immunity Of Broiler Chickens

This study was conducted to assess the impact of dietary supplementation of a probiotic and a postbiotic (Saccharomyces cerevisiae fermentation product, SCFP) on growth performance, carcass traits, blood haemato-biochemical profile, gut microflora, gut morphology, and immune response in broilers as an alternative to antibiotic growth promoters (AGPs).

***Researchers found that in 324 one-day-old chickens there were significant improvements of feed conversion ratio in the postbiotic group than the control. Cholesterol levels and concentrations of corticosterone were significantly lowered in the postbiotic group compared to other groups. Pathogenic- and antibiotic-resistant Gram-negative bacterial populations were significantly lower in postbiotic and probiotic groups. Moreover, humoral immunity was significantly improved in postbiotic and probiotic groups than the control birds. It can be concluded that both postbiotics and probiotics could be viable alternatives to antimicrobials in poultry production.***

***Source: Indranil Samanta, Department Of Veterinary Microbiology, West Bengal University Of Animal And Fishery Sciences, Belgachia, Kolkata, India. Efficacy Of Saccharomyces Cerevisiae Fermentation Product And Probiotic Supplementation On Growth Performance, Gut Microflora And Immunity Of Broiler Chickens. Animals 2024, 14(6), 866. DOI: https://doi.org/10.3390/ani14060866***

# III- POSTBIOTICS AND HEALTH

## 1. Postbiotic Production: Harnessing The Power Of Microbial Metabolites For Health Applications

***This comprehensive analysis looks into the multidimensional terrain of postbiotic production, including an extensive examination of diverse postbiotic classes, revealing their sophisticated mechanisms of action and highlighting future applications that might significantly affect human health.*** The authors thoroughly investigate the various mechanisms that support postbiotic production, ranging from conventional fermentation procedures to cutting-edge enzyme conversion and synthetic biology approaches.

***The review, as an acknowledgment of the field's developing nature, not only highlights current achievements but also navigates through the problems inherent in postbiotic production.*** In order to successfully include postbiotics in therapeutic interventions and the production of functional food ingredients, emphasis is given to critical elements, including improving yields, bolstering stability, and assuring safety. The knowledge presented herein sheds light on the expanding field of postbiotics and their potential to revolutionize the development of novel therapeutics and functional food ingredients.

***Source: Dharmendra Prajapati, Department Of Biotechnology, Smt. S. S. Patel Nootan Science And Commerce College, Sankalchand Patel University, Visnagar, Gujarat, India. Postbiotic Production: Harnessing The Power Of Microbial Metabolites For Health Applications. Front. Microbiol. , 19 December 2023, Sec. Food Microbiology, Volume 14 – 2023. DOI: https://doi.org/10.3389/fmicb.2023.1306192***

## 2. Promising Bioactivities Of Postbiotics: A Comprehensive Review

***This review discusses the postbiotic source, origin, extraction, synthesis, and bioactivity mechanism. The antibacterial mechanisms of postbiotics are also discussed in this review, along with their effects on the absorption of healthy substances, the prevention of cancer, mental health, and other therapeutic qualities.***

***Source: Aamir Hussain Dar, Department Of Food Technology, Islamic University Of Science And Technology, Kashmir, India. Promising Bioactivities Of Postbiotics: A Comprehensive Review. Journal Of Agriculture And Food Research, Volume 14, December 2023, 100708.***
***DOI: https://doi.org/10.1016/j.jafr.2023.100708***

## 3. A Critical Analysis Of Postbiotics: Exploring Their Potential Impact On The Health And Food Industries

***This review focuses on the recent advances and future perspectives of postbiotics in health and food science. The review also discusses the criteria and different types of postbiotics and elucidates the significance of postbiotics. The paper further reviewes the role of postbiotics as preservatives, active ingredients in packaging systems, anti-biofilm agents, and decontaminant agents in food processing industries.***

***Source: P. Sankarganesh, Department Of Food Technology, School Of Liberal Arts And Applied Science, Hindustan Institute Of Technology And Science, Padur, Chennai, Tamil Nadu, India. Critical Analysis Of Postbiotics: Exploring Their Potential Impact On The Health And Food Industries. J Pure Appl Microbiol. 2023;17(4):2041-2059. DOI: https://doi.org/10.22207/JPAM.17.4.18***

## 4. Role Of Postbiotics In Food And Health: A Comprehensive Review

***This review explores the intricate pathways through which gut microorganisms produce metabolites that contribute to the health-promoting properties of postbiotics.*** Postbiotics have a variety of appealing qualities, including anticancer, antibacterial, and immunological actions. Their multiple effects include influencing immunological responses, decreasing cancer cell growth, and preventing bacterial infections. Their presence in dairy and plant-based meals is noteworthy, as it provides a perfect matrix for fermentation and a varied range of antibacterial chemicals. ***This article delves into enhancing understanding of the concept of therapeutic properties of postbiotics in promoting human health.***

***Source: Ali, Imrana, Department Of Food Science, Government College University Faisalabad Pakistan, Faisalabad, Pakistan. Role Of Postbiotics In Food And Health: A Comprehensive Review. CyTA - Journal Of Food, Volume 22, 2024 - Issue 1. DOI: https://doi.org/10.1080/19476337.2024.2386412***

## 5. Postbiotics As Metabolites And Their Biotherapeutic Potential

***This review highlights the role of postbiotics, which may provide an underappreciated avenue doe promising therapeutic alternatives.*** The discovery of natural compounds obtained from microorganisms needs to be investigated in the future in terms of their effects on various metabolic disorders and molecular pathways, as well as modulation of the immune system and intestinal microbiota in children and adults. However, further studies and efforts are needed to evaluate and describe new postbiotics. ***This review provides available knowledge that may assist future research in identifying new postbiotics and uncovering additional mechanisms to combat metabolic diseases.***

***Source: Emília Hijová, Center Of Clinical And Preclinical Research MEDIPARK, Faculty Of Medicine, Pavol Jozef Šafárik University In Košice, Slovakia. Postbiotics As Metabolites And Their Biotherapeutic Potential. Int. J. Mol. Sci. 2024, 25(10), 5441. DOI: https://doi.org/10.3390/ijms25105441***

## 6. Postbiotics In Human Health: A Narrative Review

***This review explores the evolution of the concept "postbiotics" and the underlying mechanisms of action.*** Current insight suggests that postbiotics exert efficacy through protective modulation, fortifying the epithelial barrier and modulation of immune responses. ***The review also provides an overview of the comparative advantages and the current application in the food industry at pharmaceutical and biomedical levels.***

***Source: Huaijun Tu, Departments Of Geriatrics, The Second Affiliated Hospital Of Nanchang University, Nanchang, China. Postbiotics In Human Health: A Narrative Review. Nutrients 2023, 15(2), 291; Https://Doi.Org/10.3390/Nu15020291***

## 7. The Clinical Evidence For Postbiotics As Microbial Therapeutics

***This review concludes that postbiotics are safe and stable with a long shelf-life enabling easy storage and transportation and can be administered during antibiotic treatment without affecting efficacy, making them an appealing alternative to probiotics. There is growing evidence for the clinical benefits of postbiotics in the management of highly prevalent conditions including gastrointestinal, dermatological, and neurological disorders as well as respiratory infections and metabolic syndrome. Postbiotics may offer a novel therapeutic approach for these conditions and could be a safer alternative to probiotics, particularly in vulnerable populations such as pediatrics. Additional randomized, placebo-controlled clinical trials are necessary to further verify the clinical benefits of postbiotics.***

***Source: Colin Hillg, APC Microbiome Institute, University College Cork, Ireland. The Clinical Evidence For Postbiotics As Microbial Therapeutics. Gut Microbes, Volume 14, 2022 - Issue 1. DOI: https://doi.org/10.1080/19490976.2022.2117508***

## 8. The Promising Biological Role Of Postbiotics Derived From Probiotic Lactobacillus Species In Reproductive Health

***Recent investigations have meaningfully developed the knowledge of the features of the reproductive microbiome/metabolome profile and their relations with host responses to offer an optimal milieu for the development of the embryo during the peri-implantation period and throughout pregnancy.*** In this context, the establishment of homeostatic circumstances in the Female Reproductive Tract (FRT), in various physiological periods, is a significant challenge, it appears that the application of postbiotics can facilitate the achievement of this goal.

***So, currently, scientific literature in this review confirms that postbiotics due to their antimicrobial, antiviral, and immunomodulatory properties can be considered as a novel biotherapeutic approach.*** Future investigation in this field will shed more translational mechanistic understanding of the interaction of the postbiotics derived from vaginal Lactobacilli with females' health and reproduction.

***Source: Leili Aghebati-Maleki, Immunology Research Center, Tabriz University of Medical Sciences, Tabriz, Iran. The Promising Biological Role Of Postbiotics Derived From Probiotic Lactobacillus Species In Reproductive Health. Critical Reviews In Food Science And Nutrition, Volume 62, 2022, Issue 32, Pp 8829–8841. DOI: https://doi.org/10.1080/10408398.2021.1935701***

## 9. The Potential Of Paraprobiotics And Postbiotics To Modulate The Immune System: A Review

***This review focuses on the ability of different types of paraprobiotics and postbiotics to modulate the immune system.*** **A majority of paraprobiotics are developed from Lactobacillus and Bifidobacterium strains. The postbiotic components that modulate the biological reactions include lipoteichoic acids, bacteriocins, short-chain fatty acids, peptidoglycan, and exopolysaccharides have been reported.**

***Scientists have reviewed paraprobiotics and postbiotics that are commercial as well as in research.*** **Paraprobiotics and postbiotics can be a possible replacement for live probiotics for immunocompromised people. Paraprobiotics display an active role in maintaining T-cell mediated immunity and have been shown to treat colitis. Postbiotic components exhibit properties of pro and anti-immune, anti-tumor, anti-microbial, antioxidant, and anti-biofilm.** More research is required on the efficient conversion of probiotics to paraprobiotics, the isolation and purification of different postbiotics, and stability studies during the shelf life. ***The majority of the articles report the effects of direct ingestion of different '-biotics' without blending in any food product.***

***Source: Sonal Ayakar, Department of Biotechnology, Institute of Chemical Technology, Indian Oil Odisha Campus, Bhubaneswar, Odisha, India. The Potential Of Paraprobiotics And Postbiotics To Modulate The Immune System: A Review. Microbiological Research, Volume 275, October 2023, 127449. DOI: https://doi.org/10.1016/j.micres.2023.127449***

## 10. Exploring The Potential Of Postbiotics For Food Safety And Human Health Improvement

***This literature review critically examines the role of postbiotics in gut microbiome modulation and applications in the food industry.*** **Through an extensive review of existing literature, this study evaluates the impact of postbiotics on gut microbiome composition and their potential as functional food ingredients.** ***Research indicates that postbiotics are effective in inhibiting food pathogens such as Staphylococcus aureus, Salmonella enterica, and Escherichia coli, as well as their ability to prevent oxidative stress-related diseases, and they also show promise as alternatives to conventional food preservatives that can extend food shelf life by inhibiting harmful bacterial growth. Their application in functional foods contributes to improved gut health and reduced risk of foodborne illnesses. Findings suggest that postbiotics hold promise for improving health and preservation by inhibiting pathogenic bacteria growth and modulating immune responses.***

***Source: Helen Onyeaka, Department Of Chemical Engineering , University Of Birmingham , Birmingham , UK. Exploring The Potential Of Postbiotics For Food Safety And Human Health Improvement. Journal Of Nutrition And Metabolism, 2024 Aug 6:2024:1868161, eCollection 2024. DOI: https://doi.org/10.1155/2024/1868161***

## 11. Postbiotics As A Health-Promoting Technique: A Review Article On Scientific And Commercial Interest

Postbiotics are recognized as the most innovative, multidisciplinary biotechnological approach. ***This review provides an insightful perspective on current consumer brands and highlights the latest therapeutic and non- therapeutic applications in the postbiotics market. In comparison to other therapeutic agents such as antibiotics, probiotics, and growth boosters, this review suggests that postbiotics are an effective and eco-friendly alternative therapy.*** Furthermore, postbiotics, an industrially sustainable technology, are highlighted, shedding light on the development of biotic markets.

***Source: Rana A. El-Kadi, Alexandria University Hospitals, Alexandria, Egypt. Postbiotics As A Health-Promoting Technique: A Review Article On Scientific And Commercial Interest. Process Biochemistry, Volume 144, September 2024, Pages 6-19. DOI: https://doi.org/10.1016/j.procbio.2024.05.010***

## 12. Paraprobiotics And Postbiotics From The Probiotic Streptococcus Lutetiensis Isolated From Indian Fermented Food Demonstrates Immunomodulatory Potential

This study investigates the functional potential of Streptococcus lutetiensis isolated from pakhala bhata, a traditionally fermented Indian food, focusing on its probiotic characteristics, paraprobiotic and postbiotic preparations, metabolite profiling, and immunomodulatory effects.

The strain exhibited key probiotic attributes such as gastrointestinal tolerance, auto-aggregation, cell-surface hydrophobicity, non-hemolytic nature, as well as antimicrobial and antioxidant properties. **In vitro studies** with THP-1 macrophages revealed that paraprobiotics and postbiotics from Strep. lutetiensis modulated cytokine patterns similar to live probiotics. Of the 27 cytokines analyzed, 15 cytokines were secreted by both paraprobiotics and probiotics. Paraprobiotics induced higher IL-8 and IL-5 levels, while postbiotics increased that of G-CSF, IL-10, and MIP-1b. Metabolite profiling of paraprobiotics and postbiotics by GCMS and HPLC identified 26 and 33 compounds, respectively, including organic acids, alcohols, fatty acids, peptides, esters, aldehydes, and ketones, which likely contribute to their antimicrobial and antioxidant activity.

***Overall, the investigated strain Strep. lutetiensis is a good probiotic, with paraprobiotics exhibiting immunomodulatory properties*** warranting further validation through animal trials. ***The key novelty of this research lies in the multipurpose potential of Strep. lutetiensis obtained from relatively unexplored East Indian fermented food pakhala bhata (fermented rice). This study systematically confirms its probiotic, paraprobiotic, and postbiotic potential, specifically through characterizing the composition of postbiotics as well as paraprobiotics and comparing their immune-stimulating effects at the secretion level in human macrophages.***

***Source: Sonal Ayakar, Department Of Biotechnology, Institute Of Chemical Technology-Indian Oil Odisha Campus, Bhubaneswar, Odisha And Department Of Biological Sciences, Birla Institute Of Technology & Science, Pilani, K K Birla Goa Campus, Goa, India. Paraprobiotics And Postbiotics From The Probiotic Streptococcus Lutetiensis Isolated From Indian Fermented Food Demonstrates Immunomodulatory Potential. The Microbe, Volume 7, June 2025, 100304. DOI: https://doi.org/10.1016/j.microb.2025.100304***

## 13. Lactic Acid Bacteria Isolated From Fresh Vegetable Products: Potential Probiotic And Postbiotic Characteristics Including Immunomodulatory Effects

The present study aimed to investigate the potential probiotic characteristics of some selected lactic acid bacteria (LAB) isolated from vegetable products (various types, namely tomato, cucumber, strawberry, peach, lettuce, parsley, and cabbage).

Probiotic characteristics include tolerance to acid and bile, cholesterol-removing ability, bile salt hydrolysis, resistance against lysozyme and antibiotics, production of exopolysaccharides (EPS), antimicrobial and hemolytic activities, and cell surface characteristics (auto-aggregation, co-aggregation, and hydrophobicity). **The survival rate of isolates after G120 ranged from 8.0 to 8.6 Log10 CFU/mL. After the intestinal phase (IN-120), the bacterial count ranged from 7.3 to 8.5 Log10 CFU/mL. The bile tolerance rates ranged from 17.8 to 51.1%, 33.6 to 63.9%, and 55.9 to 72.5% for cholic acid, oxgall, and taurocholic acid, respectively.**

**Isolates F1, F8, F23, and F37 were able to reduce cholesterol (>30%) from the broth. The auto-aggregation average rate increased significantly after 24 hours for all isolates, while two isolates showed the highest hydrophobicity values. Moreover, isolates had attachment capabilities comparable to those of HT-29 cells, with an average of 8.03 Log10 CFU/mL after 2 hour.**

**All isolates were resistant to lysozyme and vancomycin, and 8 (F1, F5, F21, F23, F25, F26, F43, and F46) out of the 17 selected isolates (F1, F5, F8, F13, F15, F18, F21, F23, F25, F26, F28, F31, F37, F40, F41, F43, and F46) displayed an ability to produce exopolysaccharides (EPS). Based on 16S rRNA sequencing, LAB isolates were identified as *Enterococcus faecium, E. durans, E. lactis*, and *Pediococcus acidilactici*.**

***Source: Mohammad Tarique, Department Of Food Science, College Of Agriculture And Veterinary Medicine, United Arab Emirates University (UAEU), United Arab Emirates. Lactic Acid Bacteria Isolated From Fresh Vegetable Products: Potential Probiotic And Postbiotic Characteristics Including Immunomodulatory Effects. Microorganisms 2022, 10(2), 389. DOI: https://doi.org/10.3390/microorganisms10020389***

## 14. An Overview Of Postbiotics: Unveiling Their Distinct Role In Gut Health

***The review explores the multifaceted impact of postbiotics on gut health, highlighting their impact on the immune system, gut flora, and general health.***

Numerous studies show that probiotics and prebiotics have been linked to direct and indirect regulation of immune response and microbiota. ***This study demonstrated that postbiotics preserve microbiota balance and control the immune system, such as the bioactive metabolites generated by the gut microbiota and cell wall components produced by probiotics.***

***Source: Muhammad Tayyab Arshad, University Institute Of Food Science And Technology, The University Of Lahore, Lahore, Pakistan. An Overview Of Postbiotics: Unveiling Their Distinct Role In Gut Health. Food and Agricultural Immunology, Volume 35, 2024 - Issue 1. DOI: https://doi.org/10.1080/09540105.2024.2434463***

## 15. Postbiotic Impact On Host Metabolism And Immunity Provides Therapeutic Potential In Metabolic Disease

***This review summarized the potential for beneficial and detrimental effects of specific postbiotics related to metabolic disease and the underlying mechanisms of action.***

Postbiotics can fuel host metabolic pathways directly or influence endocrine control of metabolism through immunomodulation or mimicking host-derived hormones. ***The interaction of postbiotics in the host-microbe relationship should be considered during metabolic inflammation and metabolic disease.***

***Source: Jonathan D Schertzer, Department Of Biochemistry And Biomedical Sciences, Farncombe Family Digestive Health Research Institute, And Centre For Metabolism, Obesity And Diabetes Research, Mcmaster University, Hamilton, Ontario, Canada. Postbiotic Impact On Host Metabolism And Immunity Provides Therapeutic Potential In Metabolic Disease. Endocrine Reviews, Volume 46, Issue 1, February 2025, Pages 60–79. DOI: https://doi.org/10.1210/endrev/bnae025***

## 16. Postbiotics: Enhancing Human Health With A Novel Concept

***This review provides an overview of the components, health effects, and industrial applications of postbiotics, aiming to consolidate existing research conclusions and serve as a reference for future studies.***

***Source: Fang Chen, College Of Food Science And Nutritional Engineering, China Agricultural University, Beijing, China. Postbiotics: Enhancing Human Health With A Novel Concept. eFood, Volume5, Issue5, October 2024, e180. DOI: https://iadns.onlinelibrary.wiley.com/doi/10.1002/efd2.180***

## 17. Probiotics, Prebiotics, And Postbiotics In Health And Disease

***This review analyses the importance of gut microbiota in human health and the current problems of traditional medicines, and systematically summarizes the effectiveness and mechanisms of probiotics, prebiotics, and postbiotics in maintaining health and treating diseases based on animal models and clinical trials. And based on current research outcomes and development trends in this field, the challenges and prospects of their clinical application in maintaining health, alleviating and treating diseases are analyzed.*** It is hoped to promote the application of probiotics, prebiotics, and postbiotics in disease treatment and open up new frontiers in probiotic research.

***Source: Xiangkai Li, MOE Key Laboratory Of Cell Activities And Stress Adaptations School Of Life Sciences Lanzhou University Lanzhou Gansu China. Probiotics, Prebiotics, And Postbiotics In Health And Disease. MedComm, 2023 Nov 4;4(6):e420, eCollection 2023 Dec. DOI: 10.1002/mco2.420.***

## 18. The Function Of Mixed Postbiotic PE0401 In Improving Intestinal Health Via Elevating Anti-Inflammation, Anti-Oxidation, Epithelial Tight Junction Gene Expression And Promoting Beneficial Bacteria Growth

***This study presents a useful application of multi-strain postbiotics and thereby established the developing foundation of multi-strain postbiotics.***

Initially, various probiotics and postbiotics were screened for anti-inflammatory activity through inducing the transforming growth factor beta (TGF-β)and interleukin-10 (IL-10) in peripheral blood mononuclear cells (PBMCs). Then, researchers investigated the synergistic effects of 4Mix postbiotics (named as Probiotic Extracts of 4 strains- number 1, PE0401) consisting of metabolites generated from ***Lactobacillus salivarius AP-32, Lactobacillus acidophilus TYCA06, Lactobacillus plantarum LPL28, Bifidobacterium longum subsp. infantis BLI-02*** on anti-inflammatory activity, anti-oxidative capacity, and regulation of tight junction proteins.

***The results displayed that anti-inflammatory activity of 4Mix postbiotics PE0401 was stronger than other mixed postbiotic combinations. The anti-oxidative capacity, which correlated to anti-inflammation, also significantly increased as shown in DPPH and FRAP assays. The epithelial tight junction proteins expressed in mRNA levels (ZO-1, ZO-2, Occludin, JAM-A, and Claudin) were highly potent modulated by PE0401. In addition, PE0401 selectively promoted the growth of intestinal bacterial strains including Lactobacillus, Bifidobacterium strains and other beneficial bacteria. Therefore, this study provides a fascinating insight into the strategy to the treatment of the intestinal disorders. PE0401 may deliver as health functional food ingredient.***

***Source: Wen-Yang Lin, Department Of Research And Design, Glac Biotech Co., Ltd., Tainan, Taiwan. The Function Of Mixed Postbiotic PE0401 In Improving Intestinal Health Via Elevating Anti-Inflammation, Anti-Oxidation, Epithelial Tight Junction Gene Expression And Promoting Beneficial Bacteria Growth. J Pure Appl Microbiol. 2022;16(3):1771-1782. DOI: https://doi.org/10.22207/JPAM.16.3.19***

## 19. Postbiotics: Metabolites And Mechanisms Involved In Microbiota-Host Interactions

***In this review, the main mechanisms by which postbiotics provide a link between nutrition, microbiota, and human health are discussed.***

***Key findings of this review shows that short-chain fatty acids denote a primary energy source for colonocytes, also acting on the gut-brain axis to reduce appetite and performing epigenetic roles. Polyamines promote homeostasis and affect epigenetic processes, apoptosis, and cell proliferation through interaction with proteins and nucleic acids. Bile acids are involved in glucose metabolism and modulation of the host immune response. p-Cresol features antimicrobial and antioxidant properties, but has been related to enteric pathogens, autism, and kidney diseases. The role of trimethylamine N-oxide (TMAO) in cardiovascular diseases is still under debate. Bacteriocins have antibiotic action against pathogens. The beneficial effects of polyphenols are demonstrated by their essentiality in the production of metabolites.***

Advancement in metagenomic sequencing, intervention studies, and metabolomics are enabling to understand the modulation and effects of microbiota metabolic activity. However, in order to clearly elucidate the food-microbiota axis, the interplay among the host microbiota and the metabolites secreted by intestinal cells, and the intestine-liver-brain axis, the studies must be directed to the subject habitat.

***Source: Maria Do Carmo Gouveia Peluzio, Department Of Nutrition And Health, Brazil. Postbiotics: Metabolites And Mechanisms Involved In Microbiota-Host Interactions. Trends In Food Science & Technology, Volume 108, February 2021, Pages 11-26. DOI: https://doi.org/10.1016/j.tifs.2020.12.004***

# IV- POSTBIOTICS AND NON-COMMUNICABLE DISEASES

## 1. Role Of Postbiotics In Diabetes Mellitus: Current Knowledge And Future Perspectives

Owing to the growing incidence of DM worldwide and the implications of the microbiota in the disease progression, postbiotics appear to be good candidates as novel therapeutic targets. **In the present review**, researchers summarise the current knowledge about postbiotic compounds and their potential application in diabetes management. Additionally, the scientists also envision future perspectives on this topic. ***In summary, the results indicate that postbiotics hold promise as a potential novel therapeutic strategy for DM.***

***Source: Miguel Barajas, Biochemistry Area, Department Of Health Science, Public University Of Navarre, Pamplona, Spain. Role Of Postbiotics In Diabetes Mellitus: Current Knowledge And Future Perspectives. Foods 2021, 10(7), 1590. DOI: https://doi.org/10.3390/foods10071590***

## 2. Postbiotics: Functional Food Materials And Therapeutic Agents For Cancer, Diabetes, And Inflammatory Diseases

A probiotic- and prebiotic-rich diet ensures an adequate supply of these vital nutrients. During the anaerobic fermentation of organic nutrients, such as prebiotics, postbiotics act as a benevolent bioactive molecule matrix. Postbiotics can be used as functional components in the food industry by offering a number of advantages, such as being added to foods that are harmful to probiotic survival. Postbiotic supplements have grown in popularity in the food, cosmetic, and healthcare industries because of their numerous health advantages. Their classification depends on various factors, including the type of microorganism, structural composition, and physiological functions.

***This review offers a succinct introduction to postbiotics while discussing their salient features and classification, production, purification, characterization, biological functions, and applications in the food industry. Furthermore, their therapeutic mechanisms as antibacterial, antiviral, antioxidant, anticancer, anti-diabetic, and anti-inflammatory agents are elucidated.***

***Source: Sangiliyandi Gurunathan, Department Of Biotechnology, Rathinam College Of Arts And Science, Eachanari, Coimbatore, Tamil Nadu, India. Postbiotics: Functional Food Materials And Therapeutic Agents For Cancer, Diabetes, And Inflammatory Diseases. Foods 2024, 13(1), 89. DOI: https://doi.org/10.3390/foods13010089***

## 3. Postbiotics And Their Biotherapeutic Potential For Chronic Disease And Their Feature Perspective: A Review

***In this review researchers concluded that Postbiotics are bioactive compounds generated from the metabolic processes of probiotics, offering health benefits without the need for live microorganisms. This characteristic makes them particularly appealing, as they retain the advantages of probiotics while alleviating concerns about the stability of live bacteria.*** The rise of chronic diseases, such as cardiovascular diseases, diabetes, and obesity, poses significant health challenges globally, especially in low- and middle-income countries, where they contribute to high morbidity and economic burdens. ***In this context, postbiotics present a promising biotherapeutic option for managing chronic diseases through mechanisms like immune modulation, gut barrier enhancement, and antioxidant activity. Key components of postbiotics include SCFAs, BAPs, and EPS, which play essential roles in metabolic health, inflammation regulation, and gut health. Collectively, these attributes highlight the potential of postbiotics in disease prevention and promoting overall metabolic wellness.***

***Source: Zerihun Asefa, Food Science And Nutrition Research, Ethiopian Institute Of Agricultural Research, Holeta Agricultural Research Center, Holeta, Oromia, Ethiopia. Postbiotics And Their Biotherapeutic Potential For Chronic Disease And Their Feature Perspective: A Review. Front. Microbiomes , 03 March 2025, Sec. Nutrition, Metabolism and the Microbiome, Volume 4 – 2025. DOI: https://doi.org/10.3389/frmbi.2025.1489339***

## 4. Postbiotics: Emerging Therapeutic Approach In Diabetic Retinopathy

**Diabetic retinopathy (DR) is a prevalent microvascular complication in diabetic patients that poses a serious risk as it can cause substantial visual impairment and even vision loss.** Due to the prolonged onset of DR, lengthy treatment duration, and limited therapeutic effectiveness, it is extremely important to find a new strategy for the treatment of DR.

***Numerous animal experiments have demonstrated that intervention with postbiotics reduces hyperglycemia, attenuates retinal peripapillary and endothelial cell damage, improves retinal microcirculatory dysfunction, and consequently delays the progression of DR.***

***In this review, researchers have summarized the basic conception, classification, molecular mechanisms, and the advances in the therapeutic implications of postbiotics in the pathogenesis of DR. Postbiotics present great potential as a viable adjunctive therapy for DR.***

***Source: Chen-Huan Yu, Animal Laboratory Center, Cancer Hospital Of The University Of Chinese Academy Of Sciences (Zhejiang Cancer Hospital) And Institute Of Basic Medicine And Cancer, Chinese Academy Of Sciences, Hangzhou, China. Postbiotics: Emerging Therapeutic Approach In Diabetic Retinopathy. Front. Microbiol. , 04 March 2024, Sec. Food Microbiology, Volume 15 – 2024. DOI: https://doi.org/10.3389/fmicb.2024.1359949***

## 5. Postbiotics Against Obesity: Perception And Overview Based On Pre-Clinical And Clinical Studies

***This review gathered in-depth data on the ability of postbiotics to combat obesity. Postbiotics have been reported to have significant potential in alleviating obesity. This review comprehensively discusses the anti-obesity effects of postbiotics in cellular, animal, and clinical studies.*** Postbiotics exert anti-obesity effects via multiple mechanisms, with the major mechanisms including increased energy expenditure, reduced adipogenesis and adipocyte differentiation, suppression of food intake, inhibition of lipid absorption, regulation of lipid metabolism, and regulation of gut dysbiosis. Future research should include further in-depth studies on strain identification, scale-up of postbiotics, identification of underlying mechanisms, and well-defined clinical studies. ***Postbiotics could be a promising dietary intervention for the prevention and management of obesity.***

***Source: Anshul Sharma, Department Of Food And Nutrition, College Of Bionanotechnology, Gachon University, Republic Of Korea. Postbiotics Against Obesity: Perception And Overview Based On Pre-Clinical And Clinical Studies. Int J Mol Sci. 2023 Mar 29;24(7):6414. DOI: 10.3390/ijms24076414***

## 6. Appraisal Of Postbiotics In Cancer Therapy

Probiotics exhibit health benefits as well as modulate the immunological and cellular responses in the host. Apart from probiotics, their secreted products like bacteriocins, exopolysaccharides, short-chain fatty acids, conjugated linoleic acid, peptidoglycan, and other metabolites are found to possess anticancer activity. The beneficiary role of these postbiotic compounds is widely studied for characterizing their mechanism and mode of action that reduces cancer growth.

***The present review mainly focuses on the postbiotic components that are employed against cancer with their reported mechanism of action. It also describes recent research works carried out so far with specific strain and anticancer activity of derived compounds both in vitro and in vivo, validating that the probiotic approach would pave an alternative way to reduce the burden of cancer.***

***Source: Asit Ranjan Ghosh, Department Of Integrative Biology, School Of Bio Sciences And Technology (SBST), Vellore Institute Of Technology (VIT), Vellore, Tamil Nadu, India. Appraisal Of Postbiotics In Cancer Therapy. Front. Pharmacol., 20 September 2024, Sec. Gastrointestinal and Hepatic Pharmacology, Volume 15 – 2024. DOI: https://doi.org/10.3389/fphar.2024.1436021***

### 7. Postbiotics And Dental Caries: A Systematic Review

***This systematic review evaluates the current evidence regarding the impact of postbiotics on dental caries, focusing on the effectiveness of postbiotic interventions in caries prevention, mechanisms of action, optimal dosages, and administration protocols.*** Twenty-one studies were included (18 in vitro and three randomized controlled trials).

Postbiotics derived from various Lactobacillus species demonstrated inhibitory effects on ***Streptococcus mutans*** growth, biofilm formation, and virulence gene expression. Proposed mechanisms include direct antimicrobial activity, inhibition of bacterial adhesion, disruption of biofilm formation, modulation of immune responses, and pH buffering. After postbiotic interventions, human trials showed reduced salivary ***S. mutans*** counts and increased salivary pH.

***Therefore, postbiotics offer a promising novel approach to dental caries prevention by targeting cariogenic bacteria and modulating the oral microbiome through multiple mechanisms. Compared to probiotics, postbiotics present additional advantages, including enhanced safety, stability, and ease of incorporation into oral care products.***

***Source: Morteza Banakar, Department Of Research Analytics, Saveetha Dental College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai, India. Postbiotics And Dental Caries: A Systematic Review. Clinical And Experimental Dental Research, Volume 11, Issue 1, February 2025,E70114. DOI: https://doi.org/10.1002/cre2.70114***

## V- POSTBIOTICS AND ANTIMICROBIAL RESISTANCE (AMR)

### 1. Chemical Characterization, Cell-Based Safety, And Antioxidant Assessments Of Lactobacillus Helveticus Postbiotics And Their Potential Antibacterial Effects And Mode Of Action Against Food-Borne Multidrug-Resistant Staphylococcus Aureus And Enterohaemorrhagic Escherichia Coli O157:H7

***This study aimed to determine the chemical profile, cell-based safety, antioxidant properties, antibacterial effect, and mode of action of Lactobacillus helveticus postbiotics (LHPs) against Escherichia coli O157:H7 and multidrug-resistant Staphylococcus aureus.***

LHPs exhibited significant radical scavenging activity and antibacterial action toward *Multidrug-Resistant (MDR) S. aureus* and *E. coli O157:H*). As an antimicrobial mode of action, significant alterations in the bacterial surface charge, membrane integrity, biofilm generation, auto-aggregation ability, and swimming/sliding motility, along with the subsequent intracellular content leakage from *MDR S. aureus* and *E. coli O157:H7*, were detected after treatment with LHPs.

LHPs exerted a promoting influence on MV-4-11 macrophage cell viability, leading to a considerable increase in the functions of superoxide dismutase (SOD) and Glutathione peroxidase (GSH-Px) in these cells. As well, LHPs caused a reduction in the production of Nitric Oxide (NO) and a drop in Reactive Oxygen Species (ROS) levels. ***Therefore, LHPs are a promising approach against MDR S. aureus and E. coli O157:H7 proliferations and have the capacity to be used in the food sector to combat safety issues caused by pathogenic microbes.***

***Source: Hedayat Hosseini, Department Of Food Science And Technology, National Nutrition And Food Technology Research Institute, Faculty Of Nutrition Science And Food Technology, Shahid Beheshti University Of Medical Sciences, Tehran, Iran. Chemical Characterization, Cell-Based Safety, And Antioxidant Assessments Of Lactobacillus Helveticus Postbiotics And Their Potential Antibacterial Effects And Mode Of Action Against Food-Borne Multidrug-Resistant Staphylococcus Aureus And Enterohaemorrhagic Escherichia Coli O157:H. Journal Of Food Safety, Volume44, Issue6, December 2024, e13174. DOI: https://doi.org/10.1111/jfs.13174***

## VI- POSTBIOTICS APPLICATIONS

### 1. Postbiotics And Their Potential Applications In Early Life Nutrition And Beyond

***In this systematic review researchers proposed a working definition and review currently known postbiotic compounds, their proposed mechanisms, clinical evidence and potential applications. Research to date indicates that postbiotics can have direct immunomodulatory and clinically relevant effects and evidence can be found for the use of postbiotics in healthy individuals to improve overall health and to relief symptoms in a range of diseases such as infant colic and in adults atopic dermatitis and different causes of diarrhea.***

***Source: Clara Belzer, Laboratory of Microbiology, Wageningen University and Research, Wageningen, The Netherlands. Postbiotics And Their Potential Applications In Early Life Nutrition And Beyond. Int. J. Mol. Sci. 2019, 20(19), 4673. DOI: https://doi.org/10.3390/ijms20194673***

## 2. Postbiotics: The New Horizons Of Microbial Functional Bioactive Compounds In Food Preservation And Security

In recent decades, consumers, manufacturers, and researchers have been more interested in functional foods, which include probiotics, prebiotics, and postbiotics. Many bioactivities of postbiotics are unknown or poorly understood. Hence, ***this study aims to present a synopsis of the regular elements and new developments of the postbiotics including health-promoting effects, production, conceptualization of terms, bioactivities, and applications in the field of food safety and preservation.***

***Postbiotics aid in bio preservation and the reduction of biofilm development in food due to their organic acids, bacteriocins, and other antibacterial activities. The review examines the production of postbiotic metabolites in situ in food and the effects of external and internal food components. The antimicrobial roles, removal of biofilms, and its applications in preservation and food safety have also been discussed. This review paper also explored the various aspects like manipulation of postbiotic composition in the food system and its safety measures.***

***Source: Bishwambhar Mishra, Department Of Biotechnology, Chaitanya Bharathi Institute Of Technology (CBIT), Gandipet, Hyderabad, Telangana, India. Postbiotics: The New Horizons Of Microbial Functional Bioactive Compounds In Food Preservation And Security. Food Prod Process And Nutr 6, 28 (2024). DOI: https://doi.org/10.1186/s43014-023-00200-w***

## 3. Postbiotic Application: A Review On Extraction, Purification, And Characterization Methods

***The extraction of postbiotics can be achieved using either synthetic culture media or sustainable resources such as sugarcane straw. The extraction and identification of postbiotics involve techniques such as centrifugation, ultrafiltration, chromatography, and mass spectrometry. The production process typically includes the fermentation of probiotics, treatment to alter the nature of postbiotics, and subsequent harvesting and concentration. The efficacy of postbiotics in various applications, including food preservation, packaging, and as biofilm control agents, highlights their potential to replace chemical preservatives and enhance food quality.*** Despite their promising benefits, the application of postbiotics faces challenges, and they need further research to understand their mechanisms and establish safety standards.

***Source: Aziz Homayouni-Rad, Department of Food Science and Technology, Faculty of Nutrition & Food Sciences, Tabriz University of Medical Sciences, Tabriz, Iran. Postbiotic Application: A Review On Extraction, Purification, And Characterization Methods. Food Bioprocess Technol (2024). Volume 18, Pages 4153–4174, (2025). DOI: https://doi.org/10.1007/s11947-024-03701-9***

## 4. Postbiotics And Paraprobiotics: From Concepts To Applications

***This Review provides an overview of the general aspects and emerging trends of postbiotics and paraprobiotics, such as conceptualization of terms, production, characterization, bioactivities, health-promoting effects, bioengineering approaches, and applications.*** In vitro and in vivo studies have demonstrated that some postbiotics and paraprobiotics exhibit bioactivities such as anti-inflammatory, immunomodulatory, anti-proliferative, antioxidant, and antimicrobial. These bioactivities could be involved in health-promoting effects observed in human and clinical trials, but despite the scientific evidence available, the mechanisms of action and the signaling pathways involved have not been fully elucidated. Nevertheless, paraprobiotics and postbiotics possess valuable potential for the development of biotechnological products with functional ingredients for the nutraceutical industry.

***Source: P.F. Cuevas-González, Unidad Académica Ensenada, Universidad Tecnológica De Tijuana, Carretera A La Bufadora Km 1 Maneadero Parte Alta, Ensenada, Baja California, Mexico. Postbiotics And Paraprobiotics: From Concepts To Applications. Food Research International, Volume 136, October 2020, 109502. DOI: https://doi.org/10.1016/j.foodres.2020.109502***

## 5. A Comprehensive Overview Of Postbiotics With A Special Focus On Discovery Techniques And Clinical Applications

**This review** covers various aspects, starting with an introduction, terminology, classification of postbiotics, and brief mechanisms of action. It emphasizes microbial metabolomics as the initial step in discovering novel postbiotics. Commonly employed techniques such as NMR, GC-MS, and LC-MS are briefly outlined, along with their application principles and limitations in microbial metabolomics. The review also examines existing research where these techniques were used to identify, isolate, and characterize postbiotics derived from different microbial sources. The discovery section concludes by highlighting challenges and future directions to enhance postbiotic discovery. In the second half of the review, researchers delve deeper into numerous published postbiotic clinical trials to date. Scientists also provide the brief overviews of system-specific trial applications, their objectives, the postbiotics tested, and their outcomes. ***The review concludes by highlighting ongoing applications of postbiotics in extended clinical trials, offering a comprehensive overview of the current landscape in this evolving field.***

***Source: Anand Kumar, Biochemistry And Biotechnology Group, Los Alamos National Laboratory, Bioscience Division, Los Alamos, USA. A Comprehensive Overview Of Postbiotics With A Special Focus On Discovery Techniques And Clinical Applications. Foods 2024, 13(18), 2937. DOI: https://doi.org/10.3390/foods13182937***

## 6. Revealing The Efficacy Of Postbiotics On The Functional And Nutritional Characteristics Of Bioprocessed Nendran Banana (Musa Paradisiaca) Flour For Optimization Of Weaning Mix

Bioprocessing is being utilized as a promising tool for optimization of functional foods, controlled fermentation could be applied to foods to improve their nutritional and therapeutic potential. Nendran banana (*Musa paradisiaca*) flour is a complementary food introduced to children during the weaning phase. However, fortification is recommended for this weaning mix to compensate for the lack of certain essential nutrients. In this regard, ***the present study deals with the optimal bioprocessing conditions for Nendran banana flour via controlled fermentation with probiotic strain Lactobacillus rhamnosus GG 347 for varying time duration from 0 to 72 hours to develop a weaning mix with postbiotic benefits.***

A notable improvement in the protein and starch digestibility was noticed in Nendran flour upon fermentation. Minerals including sodium, potassium, and magnesium were found to be increased over the fermentation period. The in vitro protein digestibility was enhanced during fermentation from 31.06±2.62–70.23±3.47%, while the percentage of starch hydrolysis also improved from 21% to 73%, rendering the complex starches in the raw Nendran flour into more easily digestible fractions. The polysaccharide content and the FTIR (Fourier Transmission Infrared Spectroscopy) analysis further validates the pattern of starch degradation over time.

A distinct picture of structure degradation and deformities was observed on the surface of the particles via scanning electron microscopy. ***The efficacy of postbiotics in enhancing the antioxidant potential of the flour after L. rhamnosus fermentation*** was determined using a DPPH scavenging assay. 94.22% radical scavenging activity was observed with 3mg/mL crude extract concentration at a 36hours fermented sample. Thus, a weaning mix was optimized using Nendran banana flour fermented for 36 hours with *L. rhamnosus* via D-optimal mixture design.

***Source: Manju Mary Paul, College Of Agriculture Vellayani, Kerala Agricultural University, Kerala, India. Revealing The Efficacy Of Postbiotics On The Functional And Nutritional Characteristics Of Bioprocessed Nendran Banana (Musa Paradisiaca) Flour For Optimization Of Weaning Mix. Food And Bioproducts Processing, Volume 151, May 2025, Pages 158-171. DOI: https://doi.org/10.1016/j.fbp.2025.03.007***

## 7. Postbiotics As A Safe Alternative To Live Probiotic Bacteria In The Food And Pharmaceutical Industries

***This review concluded that postbiotics mimic the fundamental and clinical roles of probiotics, and due to their unique characteristics, they can be incorporated into delivery systems (pharmaceutical or functional foods) to promote health, prevent diseases, and support treatment strategies.***

***Source: Amin Abbasi, Student Research Committee, Faculty Of Nutrition And Food Sciences, Tabriz University Of Medical Sciences, Tabriz, Iran. Postbiotics As A Safe Alternative To Live Probiotic Bacteria In The Food And Pharmaceutical Industries. .SJKU 2021;26(4):132-157. DOI:10.52547/sjku.26.4.132.***

## 8. Postbiotics: Current Trends In Food And Pharmaceutical Industry

Presently, prebiotics and probiotics are the products on the market; however, postbiotics are also gaining a great deal of attention. The numerous health advantages of postbiotic components may soon lead to an increase in consumer demand for postbiotic supplements. ***The most recent research aspects of postbiotics in the food and pharmaceutical industries are included in this review. The review encompasses a brief introduction, classification, production technologies, characterization, biological activities, and potential applications of postbiotics.***

***Source: Anjaly Shanker Mundanat, Department Of Agriculture And Environmental Sciences, National Institute Of Food Technology Entrepreneurship And Management (NIFTEM), Sonipat, India. Postbiotics: Current Trends In Food And Pharmaceutical Industry. Foods 2022, 11(19), 3094. DOI: https://doi.org/10.3390/foods11193094***

## 9. The Current And Future Perspectives Of Postbiotics

Postbiotics have been shown to have bioactivities such as antimicrobial, antioxidant, anti-inflammatory, anti-proliferative, and immunomodulation. Moreover, numerous studies have revealed the significant potential of postbiotics for disease treatment.

***This review paper first presents the production and classification of postbiotics with examples from lactic acid bacteria (LAB), followed by the mechanisms of action with the most recent pre-clinical and clinical studies and the wide range of non-clinical and clinical applications of postbiotics. Furthermore, the current and future prospects of the postbiotic market with commercial available products are discussed. Finally, authors comment on the knowledge gaps and future clinical applications with several examples.***

***Source: Bing Liang, The Affiliated Hospital Of Qingdao University And Cancer Institute, Qingdao University, Qingdao, China. The Current And Future Perspectives Of Postbiotics. Probiotics & Antimicro. Prot. 15, 1626–1643 (2023). DOI: https://doi.org/10.1007/s12602-023-10045-x***

## 10. Postbiotics: An Exposition On Next Generation Functional Food Compounds- Opportunities And Challenges

**This review** explore the challenges and opportunities to devise better growth mediums, cell lysis and extraction, characterization, stability and applications of postbiotics in both food and pharma industry along with the market trends, success stories and safety concerns regarding postbiotics. The scientific and commercial interest in postbiotic have resulted in extensive investigations and clinical documentation of various physiological benefits and additional bioactivity. ***The findings validate food and pharma application of the postbiotics and further emphasize on documentation of bioactivity and safety of these compounds.***

***Source: Atul Dhimana, Department Of Food Science And Technology, Dr. Y. S. Parmar University Of Horticulture And Forestry, Solan, HP, India. Postbiotics: An Exposition On Next Generation Functional Food Compounds- Opportunities And Challenges. Critical Reviews In Food Science And Nutrition , Volume 65, 2025, Issue 6, Page: 1163–1182. DOI: https://doi.org/10.1080/10408398.2023.2289646***

## 11. A Systematic Review To Introduce The Most Effective Postbiotics Derived From Probiotics For Aflatoxin Detoxification In Vitro

The purpose of this study was to gather information about the percentage of aflatoxin decontamination by postbiotics and to find the most effective postbiotic. In this review article, studies were collected from databases. All the articles related to experimental studies were included in the study. ***It appeared that the postbiotics derived from Lentilactobacillus kefiri, Lentilactobacillus kefiri, Lacticaseibacillus rhamnosum, Lacticaseibacillus rhamnosum and Pediococcus pentosaceus probiotic bacteria were the most effective postbiotics with 97.22%, 95.27%, 86.2%, 81.4% and 91% inhibitory effect against aflatoxins B1, B2, G1, G2 and M1, respectively. Therefore, postbiotics could be used as safe anti-aflatoxin agents in food products.***

***Source: Mohammad Hashemi, Medical Toxicology Research Center, Mashhad University of Medical Sciences, Mashhad, Iran. A Systematic Review To Introduce The Most Effective Postbiotics Derived From Probiotics For Aflatoxin Detoxification In Vitro. Italian Journal Of Food Science, 2023; 35 (4): 31–49. DOI: https://doi.org/10.15586/ijfs.v35i4.2369***

## 12. A Critical Analysis Of Postbiotics: Exploring Their Potential Impact On The Health And Food Industries

***This review focuses on the recent advances and future perspectives of postbiotics in health and food science. The review also discusses the criteria and different types of postbiotics and elucidates the significance of postbiotics. The paper further reviewes the role of postbiotics as preservatives, active ingredients in packaging systems, anti-biofilm agents, and decontaminant agents in food processing industries.***

***Source: P. Sankarganesh, Department Of Food Technology, School Of Liberal Arts And Applied Science, Hindustan Institute Of Technology And Science, Padur, Chennai, Tamil Nadu, India. Critical Analysis Of Postbiotics: Exploring Their Potential Impact On The Health And Food Industries. J Pure Appl Microbiol. 2023;17(4):2041-2059. DOI: https://doi.org/10.22207/JPAM.17.4.18***

## 13. Role Of Postbiotics In Food And Health: A Comprehensive Review

***This review explores the intricate pathways through which gut microorganisms produce metabolites that contribute to the health-promoting properties of postbiotics.*** Postbiotics have a variety of appealing qualities, including anticancer, antibacterial, and immunological actions. Their multiple effects include influencing immunological responses, decreasing cancer cell growth, and preventing bacterial infections. Their presence in dairy and plant-based meals is noteworthy, as it provides a perfect matrix for fermentation and a varied range of antibacterial chemicals. ***This article delves into enhancing understanding of the concept of therapeutic properties of postbiotics in promoting human health.***

***Source: Ali, Imrana, Department Of Food Science, Government College University Faisalabad Pakistan, Faisalabad, Pakistan. Role Of Postbiotics In Food And Health: A Comprehensive Review. CyTA - Journal Of Food, Volume 22, 2024 - Issue 1. DOI: https://doi.org/10.1080/19476337.2024.2386412***

## 14. Postbiotics In Human Health: A Narrative Review

***This review explores the evolution of the concept "postbiotics" and the underlying mechanisms of action.*** Current insight suggests that postbiotics exert efficacy through protective modulation, fortifying the epithelial barrier and modulation of immune responses. ***The review also provides an overview of the comparative advantages and the current application in the food industry at pharmaceutical and biomedical levels.***

***Source: Huaijun Tu, Departments Of Geriatrics, The Second Affiliated Hospital Of Nanchang University, Nanchang, China. Postbiotics In Human Health: A Narrative Review. Nutrients 2023, 15(2), 291; Https://Doi.Org/10.3390/Nu15020291***

## 15. Gut Health Benefit And Application Of Postbiotics In Animal Production

*This review summarizes the characteristics of postbiotics, main compounds of postbiotics, potential mechanisms in gut health, and their application in animal production.*

***Source: Haifeng Wang, College Of Animal Science, Zhejiang University, The Key Laboratory Of Molecular Animal Nutrition, Ministry Of Education, Hangzhou, China. Gut Health Benefit And Application Of Postbiotics In Animal Production. J Animal Sci Biotechnol 13, 38 (2022). DOI: https://doi.org/10.1186/s40104-022-00688-1***

## 16. Postbiotics As The New Frontier In Food And Pharmaceutical Research

*This review addresses the latest postbiotic applications with regard to pharmaceutical formulations and commercial food-based products. Potential postbiotic applications in the promotion of host health status, prevention of disease, and complementary treatment are also reviewed.*

***Source: Hedayat Hosseini, Department Of Food Science And Technology, National Nutrition And Food Technology Research Institute, Faculty Of Nutrition Science And Food Technology, Shahid Beheshti University Of Medical Sciences, Tehran, Iran. Postbiotics As The New Frontier In Food And Pharmaceutical Research. Critical Reviews In Food Science And Nutrition, Volume 63, 2023, Issue 26, Pp 8375–8402. DOI: https://doi.org/10.1080/10408398.2022.2056727***

## 17. Postbiotics-Parabiotics: The New Horizons In Microbial Biotherapy And Functional Foods

*The current review comprehensively summarizes and discusses various methodologies implied to extract, purify, and identify paraprobiotic and postbiotic compounds and their potential health benefits.*

***Source: Pradip V. Behare, Technofunctional Starters Lab, National Collection Of Dairy Cultures (NCDC), Dairy Microbiology Division, ICAR-National Dairy Research Institute, Karnal, Haryana, India. Postbiotics-Parabiotics: The New Horizons In Microbial Biotherapy And Functional Foods. Microb Cell Fact 19, 168 (2020). DOI: https://doi.org/10.1186/s12934-020-01426-w***

## 18. Postbiotics: Enhancing Human Health With A Novel Concept

*This review provides an overview of the components, health effects, and industrial applications of postbiotics, aiming to consolidate existing research conclusions and serve as a reference for future studies.*

***Source: Fang Chen, College Of Food Science And Nutritional Engineering, China Agricultural University, Beijing, China. Postbiotics: Enhancing Human Health With A Novel Concept. eFood, Volume5, Issue5, October 2024, e180. DOI: https://iadns.onlinelibrary.wiley.com/doi/10.1002/efd2.180***

## 19. Exploring The Potential Of Postbiotics For Food Safety And Human Health Improvement

*This literature review critically examines the role of postbiotics in gut microbiome modulation and applications in the food industry. Through an extensive review of existing literature, this study evaluates the impact of postbiotics on gut microbiome composition and their potential as functional food ingredients. Research indicates that postbiotics are effective in inhibiting food pathogens such as Staphylococcus aureus, Salmonella enterica, and Escherichia coli, as well as their ability to prevent oxidative stress-related diseases, and they also show promise as alternatives to conventional food preservatives that can extend food shelf life by inhibiting harmful bacterial growth. Their application in functional foods contributes to improved gut health and reduced risk of foodborne illnesses. Findings suggest that postbiotics hold promise for improving health and preservation by inhibiting pathogenic bacteria growth and modulating immune responses.*

***Source: Helen Onyeaka, Department Of Chemical Engineering , University Of Birmingham , Birmingham , UK. Exploring The Potential Of Postbiotics For Food Safety And Human Health Improvement. Journal Of Nutrition And Metabolism, 2024 Aug 6:2024:1868161, eCollection 2024. DOI: https://doi.org/10.1155/2024/1868161***

## 20. Postbiotics, A Natural Feed Additive For Growth Performance, Gut Microbiota And Quality Of Poultry Products

*This review article examines the concept, impact and approaches associated with using an innovative solution such as postbiotics in the context of sustainable poultry production.*

***Source: Atanas G. Atanasov, Ludwig Boltzmann Institute Digital Health And Patient Safety, Medical University Of Vienna, Vienna, Austria; Laboratory Of Natural Products And Medicinal Chemistry (LNPMC), Center For Global Health Research, Saveetha Medical College And Hospital, Saveetha Institute Of Medical And Technical Sciences (SIMATS), Thandalam, Chennai, India And Institute Of Genetics And Animal Biotechnology Of The Polish Academy Of Sciences, Jastrzebiec, Poland. Postbiotics, A Natural Feed Additive For Growth Performance, Gut Microbiota And Quality Of Poultry Products. Current Research In Biotechnology, Volume 8, 2024, 100247. DOI: https://doi.org/10.1016/j.crbiot.2024.100247***

## 21. Intraoral Administration Of Probiotics And Postbiotics: An Overview Of Microorganisms And Formulation Strategies

***The microorganisms that colonize the oral cavity, their role in oral health and disease, as well as the probiotics and postbiotics which could have beneficial effects in this complex environment are discussed in this study. This study review, analyse and discuss novel probiotic and postbiotic formulations intended for oral administration that could be of great preventive and therapeutic importance. A special attention has been put on the formulation of the pharmaceutical dosage forms that are expected to provide new benefits for the patients and technological advantages relevant for industry. An adequate dosage form could significantly enhance the efficiency of these products.***

***Source: A. Djukić-Vuković. Department Of Biochemical Engineering And Biotechnology. Faculty Of Technology And Metallurgy. University Of Belgrade. Serbia. Intraoral Administration Of Probiotics And Postbiotics: An Overview Of Microorganisms And Formulation Strategies. Braz. J. Pharm. Sci. 60, 2024. DOI: https://doi.org/10.1590/s2175-97902024e23272***

# VII- FERMENTED FOODS

## 1. Fermented Foods And Gastrointestinal Health: Underlying Mechanisms

***This review summarizes in vitro, ex vivo and in vivo studies that provide insights into the ways in which the specific food components, including fermented foods (FFs) microorganisms and a variety of bioactives, can contribute to health-promoting activities.***

***This review also highlights representative examples of FFs and discusses the mechanisms through which functional components are produced or enriched during fermentation (such as bioactive peptides and exopolysaccharides), potentially toxic or harmful compounds (such as phytic acid, mycotoxins and lactose) are removed from the food substrate, and how the introduction of fermentation-associated live or dead microorganisms, or components thereof, to the gut can convey health benefits.***

These studies, combined with a deeper understanding of the microbial composition of a wider variety of modern and traditional FFs, can facilitate the future optimization of FFs, and associated microorganisms, to retain and maximize beneficial effects in the gut.

***Source: Paul D. Cotter, Teagasc Food Research Centre, Moorepark; APC Microbiome Ireland And Vistamilk, Cork, Ireland. Fermented Foods And Gastrointestinal Health: Underlying Mechanisms. Nat Rev Gastroenterol Hepatol 21, 248–266 (2024). DOI: https://doi.org/10.1038/s41575-023-00869-x***

## 2. Impact Of Microbial Transformation Of Food On Health — From Fermented Foods To Fermentation In The Gastro-Intestinal Tract

***In this review, researchers summarize recent advances highlighting the potential to improve the nutritional status of a fermented food by rational choice of food-fermenting microbes.*** The vast numbers of microbes residing in the human gut, the gut microbiota, also give rise to a broad array of health-active molecules. Diet and functional foods are important modulators of the gut microbiota activity that can be applied to improve host health. A truly multidisciplinary approach is required to increase the understanding of the molecular mechanisms underlying health beneficial effects that arise from the interaction of diet, microbes and the human body.

***Source: Johan ET Van Hylckama Vlieg, Danone Research Avenue, France. Impact Of Microbial Transformation Of Food On Health — From Fermented Foods To Fermentation In The Gastro-Intestinal Tract. Current Opinion In Biotechnology, Volume 22, Issue 2, April 2011, Pages 211-219. DOI: https://doi.org/10.1016/j.copbio.2010.12.004***

## 3. Fermented Foods: Harnessing Their Potential To Modulate The Microbiota-Gut-Brain Axis For Mental Health.

***This review highlights the diverse nature of fermented foods in terms of the raw materials used and type of fermentation employed, and summarises their potential to shape composition of the gut microbiota, the gut to brain communication pathways including the immune system and, ultimately, how they modulate the microbiota-gut-brain axis. Also identifies knowledge gaps and challenges faced in designing human studies for investigating the mental health-promoting potential of individual fermented foods or components. This review suggests solutions that can advance understanding of the therapeutic merit of fermented foods to modulate the microbiota-gut-brain axis.***

***Source: John F. Cryan, APC Microbiome Ireland And Department Of Anatomy And Neuroscience, University College Cork, Cork, Ireland. Fermented Foods: Harnessing Their Potential To Modulate The Microbiota-Gut-Brain Axis For Mental Health. Neuroscience & Biobehavioral Reviews, Volume 158, March 2024, 105562. DOI: https://doi.org/10.1016/j.neubiorev.2024.105562***

## 4. Fermented Dairy Foods Intake And Risk Of Cardiovascular Diseases: A Meta-Analysis Of Cohort Studies

Since the associations of fermented dairy foods intake with risk of cardiovascular diseases (CVD) remain inconsistent, therefore, researchers carried out this meta-analysis on all published cohort studies to estimate the overall effect. 10 studies met the inclusion criteria for this study, with 385,122 participants, 1,392 Myocardial infarction, 4,490 coronary heart disease (CHD), 7,078 stroke, and 51,707 uncategorized CVD cases.

Overall, statistical evidence of significantly decreased CVD risk was found to be associated with fermented dairy foods intake.91). In subgroup analysis, cheese and yogurt consumptions were associated with decreased CVD risk. ***The meta-analysis indicated that fermented dairy foods intake is associated with decreased CVD risk.***

***Source: Zhenhua Deng, Department Of Forensic Pathology, West China School Of Basicmedical Sciences & Forensic Medicine, Sichuan University, Chengdu, Sichuan, People's Republic Of China. Fermented Dairy Foods Intake And Risk Of Cardiovascular Diseases: A Meta-Analysis Of Cohort Studies. Critical Reviews In Food Science And Nutrition, Volume 60, 2020 - Issue 7. DOI: https://doi.org/10.1080/10408398.2018.1564019***

## 5. Bacterial Community In Naturally Fermented Milk Products Of Arunachal Pradesh And Sikkim Of India Analysed By High-Throughput Amplicon Sequencing

Naturally fermented milk (NFM) products are popular ethnic fermented foods in Arunachal Pradesh and Sikkim states of India. ***The present study is the first to have documented the bacterial community in 54 samples of NFM products viz. chhurpi, churkam, dahi and gheu/mar by high-throughput Illumina amplicon sequencing***.

***Metagenomic investigation shows that Firmicutes (Streptococcaceae, Lactobacillaceae) and Proteobacteria (Acetobacteraceae) were the two predominant members of the bacterial communities in these products. Lactococcus lactis and Lactobacillus helveticus were the predominant lactic acid bacteria while Acetobacter spp. and Gluconobacter spp. were the predominant acetic acid bacteria present in these products.***

***Source: Jyoti Prakash Tamang, DAILAB (DBT-AIST International Laboratory For Advanced Biomedicine), Bioinformatics Centre, Department Of Microbiology, School Of Life Sciences, Sikkim University, Gangtok, India. Bacterial Community In Naturally Fermented Milk Products Of Arunachal Pradesh And Sikkim Of India Analysed By High-Throughput Amplicon Sequencing. Sci Rep 8, 1532 (2018). DOI: https://doi.org/10.1038/s41598-018-19524-6***

## 6. Fermented Foods And Cardiometabolic Health: Definitions, Current Evidence, And Future Perspectives

***This review provides an overview of the definitions of fermented foods, types and qualities of fermented foods consumed in Europe and globally, possible mechanisms between the consumption of fermented foods and cardiometabolic health, as well as the current state of the epidemiological evidence on fermented food intake and cardiometabolic health. It also outlines future perspectives and opportunities for improving the role of fermented foods in human diets.***

***Source: Katherine J. Li1, Agroscope, Bern, Switzerland. Fermented Foods And Cardiometabolic Health: Definitions, Current Evidence, And Future Perspectives. Front. Nutr., 20 September 2022, Sec. Food Chemistry, Volume 9 (2022). DOI: https://doi.org/10.3389/fnut.2022.976020***

## 7. Bioactive Properties And Therapeutic Aspects Of Fermented Vegetables: A Review

***This review discusses changes in antioxidant, antidiabetic, antihyperlipidemic, anticancer, and antihypertensive activities of fermented vegetables, both in vitro and in vivo using animal models. Moreover, the drawbacks associated with vegetable fermentation, their management, and the future prospects of vegetable fermentation are also discussed.***

***Source: Ruvini Liyanage, Nutritional Biochemistry Program, National Institute Of Fundamental Studies, Hantana Rd, Kandy, Sri Lanka. Bioactive Properties And Therapeutic Aspects Of Fermented Vegetables: A Review. Food Prod Process And Nutr 6, 31 (2024). DOI: https://doi.org/10.1186/s43014-023-00176-7***

# VIII- METHODOLOGIES FOR EXTRACTION OF POSTBIOTICS

## 1. Unlocking The Power Of Postbiotics: A Revolutionary Approach To Nutrition For Humans And Animals

***In this review, the team of researchers provide a comprehensive summary of the latest research on postbiotics, emphasizing their positive impacts on both human and animal health.*** The influence of postbiotics on living organisms continues to grow, their application in clinical and nutritional settings, as well as animal husbandry, is expected to expand. ***Moreover, by substituting postbiotics for antibiotics, scientists can promote health and productivity while minimizing adverse effects. This alternative approach holds immense potential for improving health outcomes and revolutionizing the food and animal products industries.***

***Source: Zhijun Cao, State Key Laboratory Of Animal Nutrition And Feeding, College Of Animal Science And Technology, China Agricultural University, Beijing, China. Unlocking The Power Of Postbiotics: A Revolutionary Approach To Nutrition For Humans And Animals. Cell Metabolism, Volume 36, Issue 4, 2 April 2024, Pages 725-744. DOI: https://doi.org/10.1016/j.cmet.2024.03.004***

# IX- MISCELLANEOUS

## 1. "Postbiotics" - One Step Ahead Of Probiotics

***This review concluded that the incorporation of live probiotic bacteria in foods is dependent on propagation, processing steps, viability, survival number, colonization and so on. To overcome these problems their metabolites may be a good alternative to probiotics. In contrast, postbiotics are supposed to be more stable than the probiotics allowing their application in a wide variety of functional food products.***

***Source: L. Malashree, Department Of Dairy Microbiology, Dairy Science College, KVAFSU, Hebbal,Bengaluru, India. "Postbiotics" - One Step Ahead Of Probiotics. Int. J. Curr. Microbiol. App. Sci., ISSN: 2319-7706 Volume 8 Number 01 (2019), 2049-2053. DOI: https://doi.org/10.20546/ijcmas.2019.801.214***

## 2. Pre And Probiotics To Postbiotics: A Changing Paradigm

***Postbiotics are inanimate microorganisms or their compounds, including short-chain fatty acids, exopolysaccharides, vitamins, teichoic acids, bacteriocins, enzymes and peptides that provide health benefits to the host. Postbiotics can be stored under normal environmental conditions, have a prolonged shelf life, easy to transport, and handle and overcome the limitations of probiotic use. As a result, postbiotics have immense potential as a safe and effective means of promoting health and well-being.***

***Source: Kanneboina Soujanya, Department Of Food And Nutrition, Post Graduate & Research Centre, PJTSAU, Rajendranagar, Hyderabad, India. Pre And Probiotics To Postbiotics: A Changing Paradigm. Journal Of Advances In Microbiology, 2024 - Volume 24 [Issue 11], Page: 19-33.***
***DOI: 10.9734/jamb/2024/v24i11862.***

**Note: Only lead author's names and their affiliations are given. Please see the articles for full details.**
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