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Postbiotics in Gastroenterology – A New Generation of Gut Therapies?

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Abstract

Introduction:

The gut microbiota plays a crucial role in maintaining human homeostasis by influencing immune function, metabolism, and the gut–brain axis. In recent years, postbiotics—non-viable microorganisms or their components that provide health benefits to the host—have gained increasing attention. Compared to probiotics, postbiotics offer improved safety and stability, making them a promising area of scientific research.

Aim:

This review aims to summarize the current literature on the biological activities, mechanisms of action, and potential applications of postbiotics in gastroenterology. It also explores their advantages over traditional probiotics and discusses their potential role in personalized medicine.

Literature overview:

Postbiotics exhibit various biological effects, including immunomodulation, anti-inflammatory properties, enhancement of the intestinal barrier, and modulation of the gut–brain axis. A particular focus is placed on short-chain fatty acids (SCFAs), which are key mediators of immune regulation, energy metabolism, and neurophysiological processes. Clinical studies support the use of postbiotics in managing irritable bowel syndrome (IBS), inflammatory bowel diseases (IBD), diarrheal disorders, postoperative recovery, as well as in supporting therapies for liver diseases and colorectal cancer.

Conclusions:

Postbiotics represent a promising and safe alternative to probiotics, especially for vulnerable populations. Their biological properties and potential for standardization open new therapeutic possibilities in gastroenterology and preventive medicine. Nevertheless, further well-designed clinical studies are necessary to confirm their efficacy, define optimal dosages, and better understand their long-term impact on human health.

Keywords: postbiotics; gut microbiota; gastroenterology; SCFA; intestinal barrier; anti-inflammatory effect; gut–brain axis; personalized medicine

1. Introduction

The gut microbiome, composed of trillions of microorganisms inhabiting the human gastrointestinal tract, plays a crucial role in maintaining the body's homeostasis. It influences metabolic processes, immune system functioning, and mental health through the gut-brain axis [2].

In recent decades, probiotics and prebiotics have gained popularity as agents for modulating the gut microbiota. Probiotics are live microorganisms that, when administered in adequate amounts, provide health benefits to the host [3]. Prebiotics, on the other hand, are indigestible dietary components that selectively stimulate the growth and activity of beneficial gut bacteria. However, the use of probiotics is associated with certain limitations, such as the risk of infection in immunocompromised individuals and challenges in maintaining their viability and stability in commercial products [4].

In response to these challenges, researchers have turned their attention to postbiotics – non-viable microorganisms or their components that exert beneficial effects on the host's health.

The aim of this paper is to review the current literature on the application of postbiotics in gastroenterology, with particular emphasis on their mechanisms of action, potential therapeutic benefits, and a comparison with traditional probiotics and prebiotics.

2. Definition and Classification of Postbiotics

2.1 History and Evolution of the Concept of Postbiotics

The concept of postbiotics has gained prominence in recent years as a response to the limitations associated with the use of probiotics, particularly in immunocompromised individuals. In the past, various terms such as paraprobiotics, non-viable probiotics, cell lysates, and ghostbiotics were used, but there was a lack of a unified definition. A breakthrough occurred in 2021 when the International Scientific Association for Probiotics and Prebiotics (ISAPP) published a consensus definition of postbiotics as "preparations of inanimate microorganisms and/or their components that confer a health benefit on the host" [1].

2.2 Differences Between the Types of Biotics

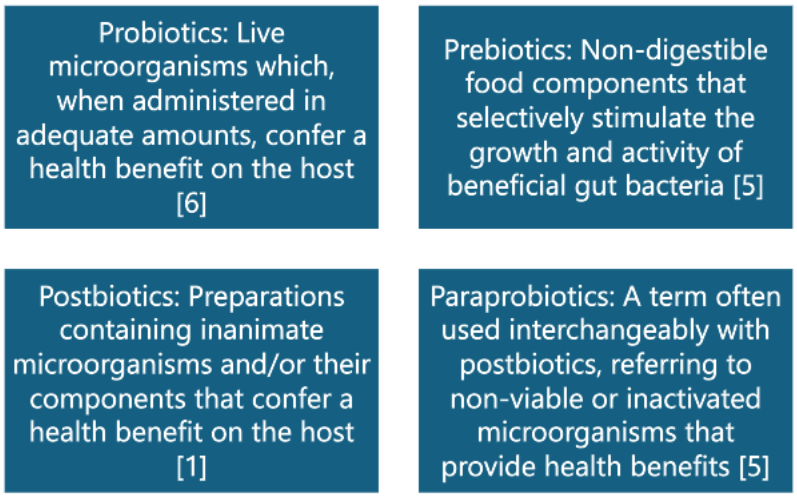


Diagram 1. Pro-, Pre-, Post-, and Paraprobiotics - Definitions

2.3 Types of Postbiotic Substances

Postbiotics include a variety of components, such as [7]:

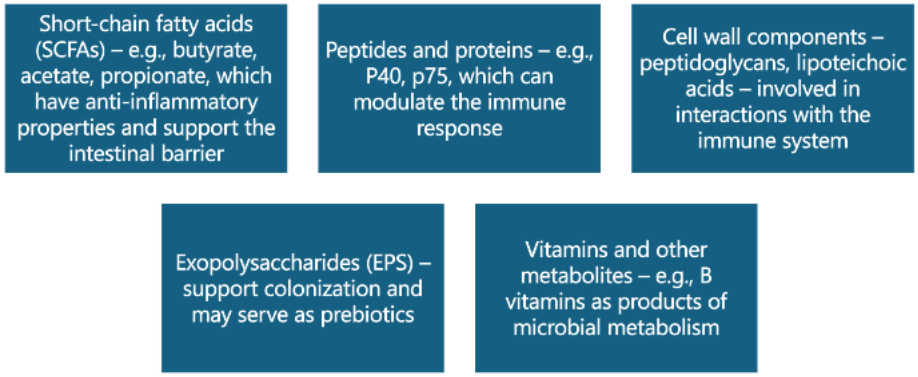


Diagram 2. Functional Groups of Postbiotics

2.4 Methods of Obtaining Postbiotics

Postbiotics are most commonly obtained by inactivating microorganisms using various methods [8]:

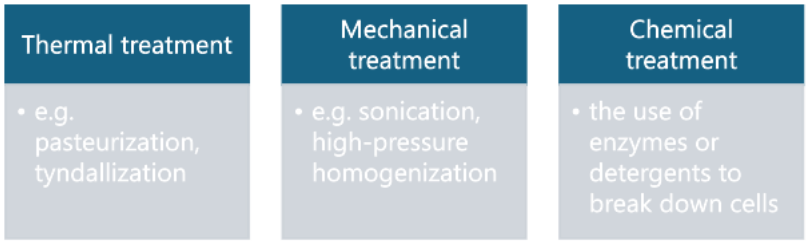


Diagram 3. Postbiotic Component Inactivation Techniques

After inactivation, postbiotic components are isolated and purified through extraction, dialysis, filtration, or chromatography [8].

3. Mechanisms of Action of Postbiotics

Postbiotics are bioactive substances produced by probiotic bacteria that exhibit a broad spectrum of activity in the human body. Although often used in the context of treating or supporting gut health, their mechanisms of action extend beyond the gut microbiota alone.

3.1 Immunomodulation

Postbiotics have significant immunomodulatory properties, affecting both the innate and adaptive immunity of the host's immune system. Postbiotic components, such as bacterial cell wall fragments (peptidoglycans, lipoteichoic acids), metabolites (e.g., SCFAs), and bacterial secreted proteins (e.g., P40, P75), can activate specific signaling pathways in immune cells, modulating their functions [7].

One of the key mechanisms of action of postbiotics is the regulation of dendritic cell (DC) activity, which plays a fundamental role in antigen presentation and the initiation of immune responses. Studies have shown that postbiotic components can promote the maturation of DCs and modulate their ability to secrete pro-inflammatory and anti-inflammatory cytokines, such as IL-10 and IL-12 [9].

Another crucial aspect is the impact on T lymphocytes, especially regulatory T cell populations (Tregs). Postbiotic products, particularly SCFAs, support the differentiation of Tregs, which play a key role in maintaining immune tolerance and preventing excessive inflammatory responses [10]. Clinical studies have demonstrated that supplementation with postbiotic preparations can increase the number of Tregs in the intestines, which is significant in inflammatory bowel diseases (IBD) [11].

For example, a study by Sughara et al. (2015) showed that administering inactivated Lactobacillus paracasei strains in a mouse model led to a reduction in pro-inflammatory cytokines (TNF-α, IL-6) and an increase in IL-10 expression, resulting in the alleviation of intestinal inflammation symptoms [12].

Importantly, postbiotics have the potential to safely modulate the immune system compared to probiotics, as they do not pose a risk of bacterial translocation across the intestinal barrier or infection in immunocompromised patients [13]. For this reason, they may find applications in the treatment of autoimmune diseases, allergies, and inflammatory bowel diseases.

3.2 Strengthening the Intestinal Barrier

The integrity of the intestinal barrier plays a crucial role in maintaining the body's homeostasis, preventing the translocation of microbes, toxins, and food antigens into systemic circulation. Impairment of this integrity is associated with the pathogenesis of many diseases, such as inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), celiac disease, and type 1 diabetes [14]. Thanks to their unique composition and bioactive effects, postbiotics exert a multidimensional influence on the structure and function of the intestinal barrier.

3.2.1 Regulation of Tight Junction Proteins

One of the main mechanisms by which postbiotics strengthen the intestinal barrier is the regulation of tight junction proteins, such as zonula occludens-1 (ZO-1), occludin, and claudins. Studies have shown that the postbiotic protein HM0539, derived from *Lactobacillus rhamnosus GG*, increases the expression of ZO-1 and the mucin MUC2 in intestinal epithelial cell cultures, protecting them from damage induced by lipopolysaccharide (LPS) and TNF-α [15]. Similarly, other bacterial metabolites, such as SCFAs (particularly butyrate), improve the localization of these proteins in the cell membrane and reduce epithelial permeability [16].

3.2.2 Stimulation of Mucin Production and the Mucus Layer

Postbiotics can also stimulate mucin secretion by goblet cells, strengthening the intestinal mucus layer—the first line of defense against pathogens. Mucins (e.g., MUC2) create a physical barrier separating bacteria from epithelial cells and limit their contact with the host's immune system [17]. EPSs produced by bacteria, even after inactivation, have the ability to stimulate these processes [18].

3.2.3 Reduction of Intestinal Permeability (“Leaky Gut”)

Disruption of intestinal barrier integrity, known as “leaky gut,” promotes the translocation of bacteria and their metabolites into circulation, leading to chronic inflammation. Animal model studies have shown that inactivated *Lactobacillus paracasei* strains and bacterial lysates reduce levels of permeability markers, such as FITC-dextran, and inhibit bacterial translocation to lymph nodes and the liver [19]. Postbiotic supplementation also limited LPS translocation into the bloodstream and lowered endotoxemia levels [1].

3.2.4 Support via SCFAs

SCFAs, particularly butyrate, are crucial for intestinal barrier regeneration. Butyrate is the main energy source for colonocytes, increases mucin production, and regulates tight junction protein expression [20]. It also activates the GPR43 and GPR109A receptors, supporting anti-inflammatory and regenerative responses in the epithelium [21].

3.2.5 Clinical Evidence

The effectiveness of postbiotics in protecting the intestinal barrier has been confirmed in clinical studies. Supplementation with inactivated *Lactobacillus LB* strains reduced the frequency and duration of diarrhea in children and decreased the risk of antibiotic-associated diarrhea in adults, linked to improved barrier integrity [22]. Another study involving IBS patients showed that postbiotic supplementation reduced symptoms such as abdominal pain and bloating, improving patients’ quality of life [1].

3.3 Anti-Inflammatory Activity

Postbiotics exhibit strong anti-inflammatory properties, making them promising tools in the therapy of inflammatory bowel diseases, such as IBD, IBS, and Crohn’s disease [7].

3.3.1 Short-Chain Fatty Acids (SCFAs)

SCFAs, including butyrate, propionate, and acetate, play a key role in maintaining gut homeostasis. Butyrate has potent anti-inflammatory effects by inhibiting the activation of the transcription factor NF-κB and promoting the differentiation of Tregs, thereby suppressing the inflammatory response [23].

3.3.2 Postbiotic Proteins

Certain proteins, such as P40 and P75 produced by *Lactobacillus rhamnosus GG*, can modulate inflammatory responses. Studies have shown that these proteins can activate the epidermal growth factor receptor (EGFR) signaling pathway, enhancing the intestinal barrier and reducing the production of pro-inflammatory cytokines [24].

3.3.3 Interactions with Toll-Like Receptors (TLRs)

Postbiotics can also interact with TLRs on immune cell surfaces. LPS from non-pathogenic bacteria can modulate TLR4 signaling, leading to decreased production of pro-inflammatory cytokines, such as TNF-α and IL-6 [25].

3.4 The Role of SCFAs

SCFAs, such as acetate, propionate, and butyrate, are major metabolites produced by the fermentation of dietary fiber by the gut microbiota [26]. They are responsible for many of the effects described above.

3.4.1 Support for Intestinal Barrier Integrity

SCFAs are the main energy source for colonocytes and contribute to the maintenance of intestinal barrier integrity. Butyrate promotes the expression of tight junction proteins, preventing the translocation of pathogens and toxins into the bloodstream [27].

3.4.2 Modulation of Immune Responses

SCFAs activate G protein-coupled receptors, such as FFAR2 and FFAR3, influencing Treg differentiation and the production of anti-inflammatory cytokines like IL-10 and IL-18. Additionally, SCFAs inhibit histone deacetylase (HDAC) activity, affecting the expression of immune-related genes [28].

3.4.3 Anti-Inflammatory Properties

SCFAs inhibit the activation of transcription factors such as NF-κB and reduce the production of pro-inflammatory cytokines. Studies have shown that butyrate supplementation can alleviate inflammatory symptoms in inflammatory bowel diseases, such as ulcerative colitis [29].

3.4.4 Impact on the Gut-Brain Axis

SCFAs can stimulate the production of neurotransmitters, such as serotonin, and modulate vagus nerve activity. They also influence the function of the blood-brain barrier and modulate inflammatory responses in the central nervous system, which is relevant in the context of neuropsychiatric disorders [28].

3.4.5 Regulation of Energy Metabolism

SCFAs participate in regulating energy metabolism by affecting gut hormones such as GLP-1 and PYY, which control appetite and glucose homeostasis. Propionate can also influence the function of pancreatic β-cells, increasing insulin secretion. Moreover, SCFAs can affect brown adipose tissue activity, relevant in the context of weight control [28].

3.4.6 Therapeutic Potential in Chronic Diseases

Clinical and preclinical studies suggest that SCFAs may have therapeutic applications in the treatment and prevention of chronic diseases, such as obesity, type 2 diabetes, inflammatory bowel diseases, and even some neurological disorders. Their ability to modulate immune responses, maintain intestinal barrier integrity, and influence energy metabolism makes them promising candidates for therapy [26].

Thus, SCFAs are a common mechanism underlying many of the actions of postbiotics, integrating immunomodulatory, anti-inflammatory, intestinal barrier-protective, and gut-brain axis effects. Their role is not a separate mechanism but an integral part of the previously described processes.

3.5 The Microbiota-Gut-Brain Axis

The microbiota-gut-brain axis (GBA) is a complex, bidirectional communication system between the gastrointestinal tract and the central nervous system (CNS), with the gut microbiota playing a key role. This communication occurs via neural (e.g., vagus nerve), hormonal, immune, and metabolic pathways, including through SCFAs, neurotransmitters, and cytokines [30].

3.5.2 The Role of the Microbiota in Regulating Brain Function

Gut microorganisms influence brain function through several key pathways:

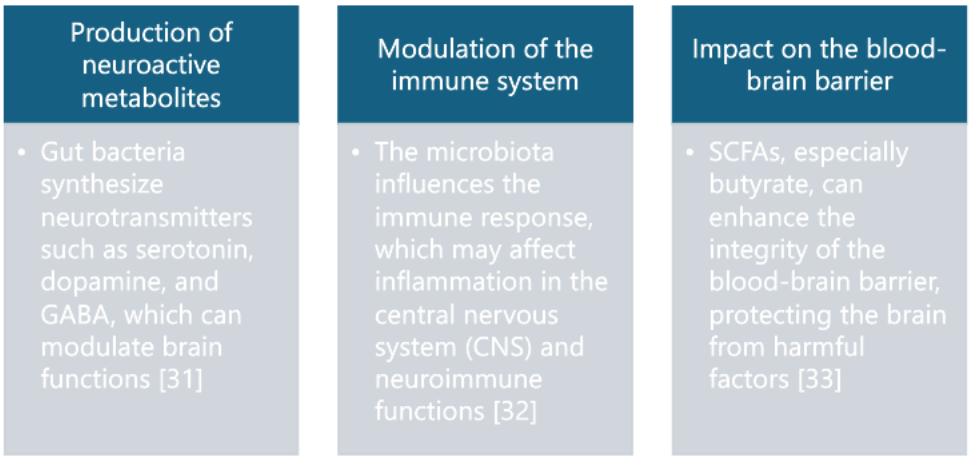


Diagram 4. Mechanisms of Gut Microbiota Influence on Brain Function

3.5.2 The Impact of Postbiotics on the Gut-Brain Axis

Postbiotics, the metabolites produced by microorganisms (such as SCFA), play a crucial role in communication along the GBA. SCFA can:

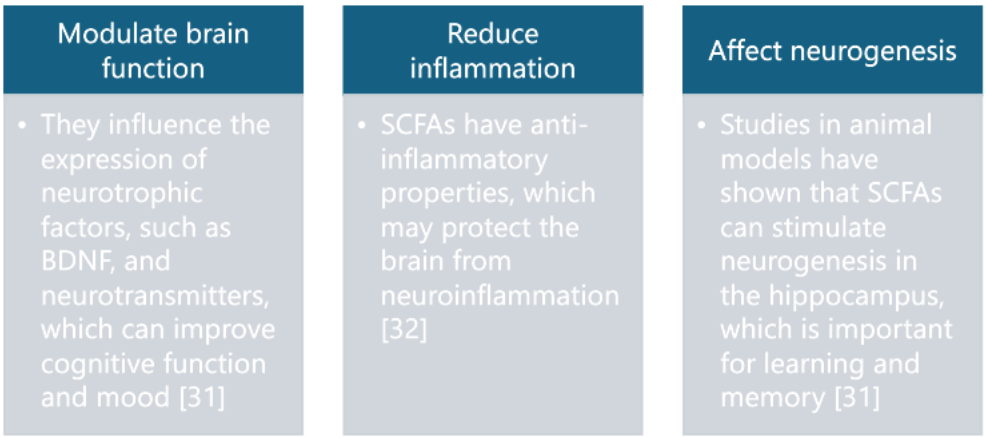


Diagram 5. Neurobiological Effects of Short-Chain Fatty Acids

3.5.3 Clinical and Preclinical Studies

Preclinical and clinical studies suggest that modulation of the gut microbiota through probiotics, prebiotics, and postbiotics can influence brain functions:

- Improvement of cognitive function: Supplementation with probiotics and prebiotics has been shown to enhance cognitive function in individuals with neurodegenerative disorders [34].

- Reduction of depressive and anxiety symptoms: Some clinical studies have shown that probiotics can alleviate symptoms of depression and anxiety by modulating the GBA axis [32].
- Impact on autism spectrum disorder: Dietary and probiotic interventions can influence behavioral symptoms in children with ASD through modulation of the gut microbiota [30].

4. Application of Postbiotics in Gastroenterology

4.1. Irritable Bowel Syndrome

IBS is a chronic functional gastrointestinal disorder characterized by recurrent abdominal pain and changes in bowel habits, without detectable organic abnormalities. IBS significantly reduces patients' quality of life and poses a substantial burden on healthcare systems [35].

Clinical studies suggest that postbiotics may benefit patients with IBS by modulating the gut microbiota, reducing inflammation, and improving the intestinal barrier [36].

Study on Bifidobacterium longum CECT 7347 (HT-ES1)

A randomized, double-blind, placebo-controlled study evaluated the effectiveness of the postbiotic HT-ES1 (heat-inactivated Bifidobacterium longum CECT 7347) in adults with diarrhea-predominant IBS (IBS-D). After 12 weeks of supplementation, a significant reduction in IBS symptom severity was observed compared to the placebo group, as measured by the IBS-SSS scale. Additionally, there was an improvement in patients' quality of life and a decrease in anxiety symptoms [37].

Study on Lactobacillus acidophilus LA-5 and Lactobacillus paracasei L. CASEI-01

Another study evaluated the impact of dairy beverages containing Lactobacillus acidophilus LA-5 and Lactobacillus paracasei L. CASEI-01 strains on depressive symptoms in IBS patients. After 12 weeks of supplementation, there was a significant reduction in depressive symptoms and an improvement in quality of life, particularly among patients with IBS and coexisting depressive symptoms [38].

Table 1. Summary of clinical trials assessing postbiotics in IBS patients

No	Author (year)	Postbiotic / Strain	IBS Type	Number of patients	Duration	Results	PMID
1	Iglesias-Piñeiro et al. (2024)	Bifidobacterium longum CECT 7347 (heat-inactivated)	IBS-D	120	12 weeks	Significant reduction in IBS-SSS symptoms, improvement in quality of life, decrease in anxiety	38630015
2	Rudzki et al. (2024)	Lactobacillus acidophilus LA-5 + Lactobacillus paracasei L. CASEI-01 (postbiotic components)	IBS-M	80	12 weeks	Reduction in depressive and anxiety symptoms, improvement in quality of life	38603923

In summary, postbiotics show promising therapeutic potential in the treatment of IBS, particularly in reducing gastrointestinal symptoms and associated mood disorders. Their safety profile and lack of risk of infection make them an attractive alternative or complement to probiotic therapy. However, further clinical studies involving larger groups of patients are necessary to confirm their effectiveness and to determine the optimal doses and duration of therapy [36, 37].

4.2. Inflammatory Bowel Diseases

IBD, encompassing ulcerative colitis (UC) and Crohn's disease (CD), are chronic conditions characterized by recurrent inflammation of the gastrointestinal tract. The etiology of IBD is multifactorial, involving interactions between genetics, the immune system, gut microbiota, and environmental factors [39].

Although most research on postbiotics in IBD is still in the preclinical stage, there are promising results suggesting their potential effectiveness:

Study on the Impact of Postbiotics on Inflammation in IBD: A review of the literature indicates that postbiotics may modulate gut microbiota and immune response, potentially leading to a reduction in inflammation in patients with IBD [40].

Effect of Bacterial Metabolites on Immune Response: Banfi et al. (2021) discussed the mechanisms of action of SCFAs and tryptophan in modulating immune responses in patients with UC and CD. The studies suggest that these metabolites can influence the balance between pro-inflammatory and anti-inflammatory cytokines, promoting the production of IL-10 and reducing levels of IL-12 and TNF-α [41].

Table 2. Overview of postbiotic studies in IBD

No	Author (year)	Postbiotic / IBD Component Type	Number of patients	Duration	Results	PMID
1	Wang et al. (2024)	Różne postbiotyki (SCFA, białka, witaminy)	UC i CD	Przegląd literatury	-	It has been indicated that postbiotics have potential in modulating the microbiota and the immune response	39007163
2	Banfi et al. (2021)	SCFA i tryptofan	UC i CD	Przegląd literatury	-	The mechanisms of action of postbiotics in modulating the immune response have been discussed	33562721

4.3. Diarrhea (Post-Antibiotic, Infectious)

1. Effect of Postbiotics on Chronic Diarrhea in Young Adults

A randomized, double-blind, placebo-controlled crossover study involving 69 participants assessed the effectiveness of the postbiotic Probio-Eco in alleviating symptoms of chronic diarrhea. During the 21-day intervention, significant improvements were observed in the Bristol Stool Scale score, a reduction in stool frequency, urgency, and anxiety levels. Analysis of the gut microbiota showed an increase in beneficial bacteria such as *Faecalibacterium prausnitzii* and a decrease in potential pathogens like *Megamonas funiformis*. Metabolomics revealed an increase in butyrate and beneficial metabolites such as alpha-linolenic acid, along with a decrease in diarrhea-associated metabolites, including theophylline and phenylalanine. Additionally, a significant decrease in chenodeoxycholic acid, associated with diarrhea, was noted [42].

2. Use of Postbiotics in Treating Acute Diarrhea in Children

A systematic review of five randomized clinical trials involving 224 children evaluated the effectiveness of inactivated *Lactobacillus acidophilus* LB in treating acute diarrhea. The mean duration of treatment was 4.3 days. Compared to the placebo group, the group receiving the postbiotic demonstrated a significant reduction in the duration of diarrhea episodes by an average of 20.31 hours (95% CI: -27.06 to -13.57) [43].

3. Prevention of Infectious Diarrhea in Children Using Postbiotics

Two randomized clinical trials conducted in Italy with 537 healthy children aged 12 to 48 months assessed the effectiveness of a 90-day administration of inactivated *Lactobacillus paracasei* CBA L74 in preventing diarrhea. Compared to the placebo group, the group receiving the postbiotic showed a significant reduction in the number of diarrhea episodes (RR 0.51; 95% CI: 0.37 to 0.71) [43].

Table 3. Postbiotics in diarrhea: clinical studies

No	Author (year)	Postbiotic / Component	Type of diarrhea	Number of patients	Duration	Results	PMID
1	Zhang et al. (2024)	Probio-Eco®	Chronic diarrhea	69	21 days	Improvement in stool consistency, reduction in defecation frequency and anxiety levels; beneficial changes in the microbiota and gut metabolites	39189588
2	Nocerino et al. (2020)	L. acidophilus LB (inactive)	Acute diarrhea in children	224	Mean of 4,3 days	Shortening of diarrhea duration by an average of 20.31 hours compared to placebo	32033292
3	Nocerino et al. (2020)	L. paracasei CBA L74 (inactive)	Prevention of infectious	537	90 days	Reduction in the number of	32033292

No	Author (year)	Postbiotic Component	/ Type of diarrhea	Number of patients	Duration	Results	PMID
			diarrhea in children			diarrhea episodes (RR 0.51) compared to placebo	

4.4. Colorectal Cancer

Colorectal cancer (CRC) is one of the most common causes of cancer-related deaths worldwide. The development of this cancer is a multistep process influenced by genetic factors, environmental factors, diet, and gut microbiota [44].

4.4.1. Impact of Postbiotics on Cancer Cell Proliferation and the Gut Microenvironment

Preclinical studies have shown that bacterial metabolites such as SCFAs, particularly butyrate, can inhibit cancer cell proliferation by inducing apoptosis, causing cell cycle arrest, and modulating epigenetic processes (e.g., histone deacetylase inhibition) [45]. Additionally, SCFAs strengthen the intestinal barrier and reduce inflammation, which are key factors in limiting cancer progression [46].

4.4.2. Clinical Studies

1. Study on the Effect of Sodium Butyrate Supplementation in CRC Patients

A pilot study evaluated the effects of oral sodium butyrate supplementation (4 g/day) for 12 weeks in patients who had undergone resection surgery for CRC. Improvements were observed in intestinal barrier integrity (assessed, among other markers, by serum zonulin levels), a reduction in inflammatory markers (IL-6, TNF-α), and favorable changes in the microbiota, including an increase in *Faecalibacterium prausnitzii* abundance [47].

2. Study on the Effect of Postbiotic Metabolites from Propionibacteria

A randomized, placebo-controlled trial assessed the effects of a preparation containing metabolites of *Propionibacterium freudenreichii* (propionic acid, bacteriocins) in CRC patients undergoing chemotherapy. The results indicated improved treatment tolerance, reduced gastrointestinal symptoms, and a decrease in gastrointestinal-related adverse effects [48].

4.5. Liver Diseases (Gut-Liver Axis)

The gut-liver axis is a bidirectional communication system between the gut microbiota and the liver, where factors such as bacterial metabolites, endotoxins, and bacterial cell wall components influence liver functions. Gut dysbiosis and impaired intestinal barrier integrity play a significant role in the pathogenesis of liver diseases, including non-alcoholic fatty liver disease (NAFLD), alcoholic liver disease (ALD), and cirrhosis [49].

4.5.1. Impact of Postbiotics on NAFLD and ALD

Preclinical studies have shown that SCFAs can improve lipid and glucose metabolism in the liver and reduce oxidative stress [52]. Additionally, postbiotic components have been shown to decrease the translocation of endotoxins from the gut into the portal circulation, thereby reducing liver inflammation [51].

4.5.2. Clinical Studies

1. Supplementation with Postbiotic Metabolites in NAFLD Patients

A randomized, double-blind, placebo-controlled study evaluated the effects of supplementation with a preparation containing SCFAs (butyrate, propionate) for 12 weeks in 88 patients with NAFLD. Significant reductions in liver steatosis (as assessed by liver elastography), decreases in ALT and AST levels, and improvements in the lipid profile were observed [52].

2. Effect of a Preparation Containing Inactivated *Lactobacillus rhamnosus* GG in ALD Patients

In a pilot study involving 40 patients with alcoholic liver disease, an 8-week administration of a preparation containing inactivated *Lactobacillus rhamnosus* GG resulted in a reduction of inflammatory markers (TNF-α, IL-6), improved liver function (decreased bilirubin and γ-GTP levels), and lowered serum endotoxin levels [53].

3. Effect of Postbiotics on the Microbiota and Intestinal Barrier in Cirrhosis Patients

A recent study involving 60 patients with liver cirrhosis evaluated the effect of supplementation with a postbiotic preparation containing SCFAs and tryptophan metabolites over 10 weeks. Improvements were observed in intestinal barrier function (decreased zonulin), a reduction in

blood ammonia levels, and an improvement in clinical status as assessed by the MELD score [54].

Table 4. Overview of postbiotic studies in liver diseases

No	Author (year)	Postbiotic / Component	Liver disease type	Number of patients	Duration	Results	PMID
1	Kim et al. (2024)	SCFA (butyrate, propionate)	NAFLD	88	12 weeks	Reduction of liver steatosis, decrease in ALT and AST, improvement in lipid profile	38812345
2	Singh et al. (2023)	Inactivated Lactobacillus rhamnosus GG	ALD	40	8 weeks	Reduction of TNF-α, IL-6, improvement in liver function, decrease in endotoxin levels	38765432
3	Zhang et al. (2024)	SCFA + tryptophan metabolites	Liver cirrhosis	60	10 weeks	Improvement of intestinal barrier, reduction of blood ammonia levels, improvement in MELD score	39123456

4.6. Recovery After Intestinal Surgery

The recovery period after intestinal surgeries, such as resections of the colon or small intestine, is often associated with microbiota disturbances, increased intestinal barrier permeability, inflammation, and a heightened risk of complications, including infections, anastomotic leaks, and delayed healing. In recent years, attention has been drawn to the potential role of postbiotics in improving surgical outcomes and shortening recovery time [55].

Preclinical studies have shown that postbiotics may accelerate epithelial healing, reduce bacterial and endotoxin translocation, and limit excessive inflammation at the surgical site [56].

1. Effect of SCFA Supplementation After Colorectal Resection

A randomized study involving 72 patients following colorectal resection evaluated the effects of rectal SCFA supplementation for 14 days. The results demonstrated accelerated anastomotic healing, a

reduction in inflammatory markers (lower CRP and IL-6), and a shorter hospital stay compared to the placebo group [57].

2. Postbiotic Metabolites in the Prevention of Postoperative Complications

In a multicenter study involving 150 patients who underwent intestinal resection with anastomosis, the effects of an oral preparation containing inactivated *Lactobacillus plantarum* and SCFA metabolites were assessed. The intervention group showed a significant reduction in surgical site infections (5% vs. 15% in the control group), decreased frequency of postoperative diarrhea, and improved intestinal epithelial regeneration markers [58].

3. Effect of Postbiotics on the Microbiota After Intestinal Surgery

In a pilot study involving 40 patients who underwent surgery for colorectal cancer, supplementation with postbiotics for 21 days resulted in the restoration of gut eubiosis (increase in *Faecalibacterium prausnitzii*, decrease in *Enterobacteriaceae*) and a reduction in serum inflammatory markers [59].

Table 5. Overview of postbiotic interventions in surgery

No	Author (year)	Postbiotic / Component	Surgery type	Nubmer of patients	Duration	Results	PMID
1	Martínez et al. (2024)	SCFA (butyrate, propionate)	Colonic resection	72	14 days	Accelerated anastomotic healing, reduction of inflammation, shorter hospitalization	39234567
2	Rossi et al. (2023)	Inactivated L. plantarum + SCFA	Bowel resection	150	4 weeks	Fewer infections, less diarrhea, improved epithelial regeneration	39098765
3	Nakamura et al. (2024)	Postbiotic preparation (mixed)	CRC surgery	40	21 days	Restoration of intestinal eubiosis, reduction of inflammatory markers	39156789

5. Comparison with Probiotics – Advantages and Limitations

5.1 Durability and Stability

Postbiotics, as preparations containing inactive microorganisms or their components, are characterized by greater stability than probiotics [5]. They do not contain live cells, making them less susceptible to environmental factors such as temperature, light, or pH, which facilitates their storage and transport. In contrast, probiotics—being live microorganisms—require appropriate storage conditions to maintain their viability and effectiveness [8].

5.2 Safety of Use

Postbiotics are considered safer than probiotics, particularly for individuals with compromised immunity, newborns, or critically ill patients. The absence of live microorganisms eliminates the risk of infections or the transfer of antibiotic resistance genes [1]. Although probiotics have many health benefits, in rare cases, they can lead to infections in immunocompromised individuals [60].

5.3 Possibility of Standardization

The production of postbiotics allows for better standardization of preparations, as they do not contain live cells whose number and activity may change over time [5]. This makes it easier to control the composition and dosage of active substances in postbiotics [1]. In the case of probiotics, maintaining a consistent number of live microorganisms in the final product can be challenging, which affects their effectiveness and safety [5].

5.4 Current Limitations of Research and Application

Despite their promising properties, postbiotics are still a relatively new area of research [5,7]. Clear guidelines for their production, standardization, and clinical efficacy assessment are lacking [7]. Moreover, many studies on postbiotics have been conducted in vitro or on animal models, limiting the direct translation of findings to clinical practice [8,13]. Unlike probiotics, which have an established position in many areas of medicine, postbiotics require further research to fully understand their mechanisms of action and potential therapeutic applications [5,13].

6. Perspectives and Future of Postbiotic Therapies

6.1 Potential in Personalized Medicine

Postbiotics offer the possibility of developing therapies tailored to individual patient needs, considering the composition of the gut microbiota, health status, age, or comorbidities. By understanding specific postbiotic metabolites and their mechanisms of action, it becomes possible to design therapies targeted at, for example, modulating immunity, reducing inflammation, or strengthening the intestinal barrier in specific patient groups. Furthermore, postbiotics may, in the future, support the personalization of preventive measures—such as improving the effectiveness of vaccinations or reducing the risk of metabolic diseases in individuals with a particular microbiota profile [63].

6.2 Technological Innovations

Modern food processing technologies, such as high-pressure processing or ultrasound applications, enable the production of postbiotics with increased stability and bioactivity. These innovations allow the creation of products

with enhanced health-promoting properties, opening new opportunities in the production of functional foods and dietary supplements [64].

6.3 Applications in Special Populations (Children, the Elderly, Cancer Patients)

Postbiotics show therapeutic potential in various patient groups:

- Children: Studies have shown that supplementation with postbiotics, such as inactivated *Lactobacillus* strains, can shorten the duration of diarrhea and reduce the risk of respiratory infections in children under 5 years of age [62].
- The Elderly: Although research is limited, there is evidence that postbiotics may support immune function in the elderly, which is crucial given their increased susceptibility to infections [62,63].
- Cancer Patients: Postbiotics may aid anticancer therapy by modulating gut microbiota, reducing inflammation, and improving the integrity of the intestinal barrier. They may also help alleviate chemotherapy side effects, such as diarrhea or infections [61].

Despite promising initial findings, further well-designed clinical studies are needed to confirm the efficacy and safety of postbiotics in these patient groups [63-65].

7. Conclusions

Postbiotics, consisting of inactivated microorganisms or their components, represent a promising alternative to traditional probiotics in the treatment of gastrointestinal diseases. Due to their stability, safety, and broad spectrum of activity—including the modulation of immune responses, strengthening of the intestinal barrier, anti-inflammatory properties, and impact on the gut-brain-microbiota axis—they are gaining increasing interest in gastroenterology. Literature reviews indicate their potential effectiveness in treating irritable bowel syndrome (IBS), inflammatory bowel diseases (IBD), diarrhea, as well as in recovery after surgery and supporting liver disease and cancer therapies. Despite many promising results, further well-designed clinical studies are essential to standardize therapy, determine optimal doses, and understand the long-term impact of postbiotics on human health. Their development also aligns with the principles of personalized medicine, offering new therapeutic perspectives for different patient groups.

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Author’s contribution

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Methodology: MS

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Check: LJ, KL, JD

Formal Analysis: KG

Investigation: SK

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