NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

Quality in Sport. eISSN 2450-3118.

Journal Home Page https://apcz.umk.pl/QS/index

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PONIEWOZIK Paweł, PERNAL Maja, MIODUSZEWSKA Joanna, ROT Paweł, PONIEWOZIK Piotr, DZIUBA Natalia, SIM Aleksandra, ZUZAK Andrzej Paweł, GRABOWSKI Krzysztof, ROGUSKA Zofia. Postbiotics as Effective and Safe "Vaccines" Against Various Respiratory Diseases: Literature Review. Quality in Sport. 2026;54:70813. eISSN 2450-3118. https://doi.org/10.12775/QS.2026.54.70813

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
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The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 13.04.2026. Revised: 17.04.2026. Accepted: 17.04.2026. Published: 19.04.2026.

Postbiotics as Effective and Safe "Vaccines" Against Various Respiratory Diseases: Literature Review

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Abstract

Background: Respiratory diseases, including COPD, asthma, and allergic rhinitis, pose a significant health and economic burden, prompting the search for new preventive and therapeutic strategies. Increasing attention is paid to microbiome-based therapies and the gut-lung axis as targets for immunomodulatory interventions. Postbiotics - defined as non-viable microorganisms or their components that exert beneficial biological effects - have emerged as a promising area of research.

Aim of the study: This study presented the current state of knowledge regarding postbiotics and assessed their potential in the prevention and treatment of respiratory diseases, with particular emphasis on their mechanisms of action.

Methodology: The review was conducted using PubMed and supplementary Google Scholar. Studies from 2012 to 2026 were analyzed.

Results: Postbiotics demonstrate multiple mechanisms of action, including modulation of the immune response, regulation of cytokine production, influence on the Th1/Th2 balance, and enhancement of epithelial barrier integrity. Experimental and clinical evidence suggests that postbiotics may reduce the frequency and severity of infections, decrease exacerbations of chronic respiratory diseases, and support the treatment of atopic and neaplastic conditions. In addition, they have a favorable safety profile, potentially better than probiotics, especially in populations with compromised immunity.

Conclusion: Postbiotics represent a diverse and promising group of compounds with significant potential for both preventive and therapeutic applications in respiratory diseases. However, further well-designed, large-scale clinical trials are necessary to confirm their efficacy and safety.

Keywords: bacterial lysate, asthma, COPD, gut-lung axis, allergic rhinitis, respiratory tract infections

1. Introduction

Respiratory diseases place a massive burden on the healthcare system and are a significant factor in the deterioration of patients' health and quality of life. Data from 2021 show that COPD ranks sixth globally in terms of disability-adjusted life years lost (DALY) [1]. Furthermore, the disease is listed as the third leading cause of death [2]. Pulmonary diseases associated with atopy, i.e., asthma and allergic rhinitis, are characterized, similarly to COPD, by a chronic course and recurrent exacerbations over time. Given the widespread prevalence of respiratory diseases, there is a clear need to seek new, effective therapeutic options. Microbiome-based therapy appears promising. It involves modulating the immune system through the use of probiotics, prebiotics, synbiotics, or postbiotics. A key concept explaining how such oral therapies influence respiratory tract immunology is the gut-lung axis. Particular attention is paid to postbiotics, defined as non-viable components of microorganisms or metabolic products. They exert a beneficial biological effect on the host [3]. Unlike probiotics, postbiotics do not contain live bacteria, which increases their stability and safety, especially in immunocompromised individuals. Studies indicate that postbiotics can modulate the immune response by influencing immune cells, cytokine production, and the integrity of the epithelial barrier [4]. Recently, the impact of microbiota on the human body has garnered significant interest among researchers. Nevertheless, many mechanisms and interactions occurring between the microorganisms living in the human body and the body itself remain unclear. The aim of this study is to present the current state of knowledge on postbiotics and to assess their potential as innovative agents with vaccine-like effects in the prevention of respiratory tract diseases. Particular attention was given to mechanisms of action, results of experimental and clinical studies, and possible directions for further research.

2. Methodology

The literature search covered the years **2012–2026** and included PubMed and supplementary Google Scholar queries using combinations of terms such as *bacterial lysate*, *asthma*, *COPD*, *allergic rhinitis*, *gut–lung axis* and *respiratory tract disorders*. Studies were included if they addressed immunomodulatory effects of bacterial lysates in respiratory diseases and were peer-reviewed original articles, clinical trials, meta-analyses or reviews. Titles, abstracts, and full texts were screened to ensure relevance and methodological quality. The extracted findings were synthesized narratively to highlight mechanisms of action and clinical implications.

3. General characteristics of postbiotics

According to the 2019 ISAPP definition, postbiotics are substances containing non-viable microorganisms and/or their components, the administration of which benefits the host [3]. It is worth noting that in the human body (primarily the large intestine), postbiotics are biologically produced through bacterial lysis and the release of specific components. The components used in the laboratory production of postbiotics are mainly: short-chain fatty acids (SCFAs, e.g., butyrate), bacterial enzymes, peptides and proteins with immunomodulatory effects, cell wall fragments (e.g., lipopolysaccharides/LPS), and extracellular polysaccharides [4]. It is worth noting that bacterial lysate is not synonymous with a postbiotic. The difference compared to a postbiotic is that it does not need to have documented benefits for the host upon administration [3]. It is a term that more technically describes the technological process of processing bacterial cells.

The microorganisms most commonly used to produce postbiotics are *Streptococcus pneumoniae, Haemophilus influenzae, Moraxella catarrhalis, Streptococcus pyogenes, Streptococcus viridans, Staphylococcus aureus, Klebsiella pneumoniae, and Klebsiella ozaenae* [5]. Suitable bacterial strains must be selected and cultured under specific standardized conditions. The bacteria are then inactivated using various techniques, such as heat treatment, ultrasound, or high pressure [6]. Controlled cell lysis is often used to release immunogenic molecules. The final stage involves purifying the sample, determining the dose, and formulating the preparation. Postbiotics can be divided into monovalent and polyvalent preparations. The former contains the lysate of a single microorganism, while the latter contains several in various quantitative ratios [7].

For example, in a study assessing the effect of postbiotics on the course of recurrent pharyngotonsillitis, Rebolledo et al. used a preparation containing S. pneumoniae, H. influenzae, S. pyogenes, and M. catarrhalis in a ratio of 20/20/40/20%, respectively. In the case of recurrent acute otitis media (AOM), this ratio was 40/30/15/15% [8]. Differences in postbiotic production also include the process of obtaining bacterial lysate itself. Mechanical or chemical methods are most used. Ferrare et al. compared the efficacy of a polyvalent mechanical bacterial lysate (PMBL) in stimulating an immune response with that of a polyvalent alkaline bacterial lysate (PABL) as a chemical method. The study results showed no significant differences [9] Another form of postbiotic proposed by researchers is bacterial extracellular vesicles (EVs). These are structures produced by bacteria, surrounded by a cell membrane, which contain, among other things, proteins, lipids, LPS, and nucleic acids. They can activate pattern recognition receptors, potentially leading to immunomodulation [10], [11], [12].

The oral route is considered the primary, most common, and best-understood route of postbiotic administration [6], [13]. Sublingual administration, like intranasal administration, acts directly on the mucosa, which is rich in immune cells, and may be associated with a stronger immune response [9], [11], [14].

4. The immunomodulatory mechanism of individual postbiotics

The effect of postbiotics on the immune system is multifaceted and requires a thorough examination of how they regulate it. The remainder of this article will describe the most well-established immunomodulatory interactions of specific postbiotics.

Heat-killed *Caulobacter crescentus* (HKCC)

In the study by Werellagama et al., a bacterial strain of *Caulobacter crescentus* that had been killed at a temperature of 80°C was analyzed. The activation of innate lymphoid cells (ILCs) was identified as the central mechanism of action of HKCC. These cells play a key role in regulating the body’s early inflammatory response. It is worth noting that HKCC activates ILCs in a balanced manner—one that does not lead to a pathological immune cell reaction. HKCC limits excessive infiltration of neutrophils and CD11b+, Ly6G+ myeloid cells, whose accumulation is associated with increased bacterial load in the lungs. The postbiotic's effect on the immune system's humoral response has also been shown. HKCC causes an increase in systemic IgG and mucosal IgA concentrations without anti-HKCC antibody levels. Additionally, it is emphasized that more than 21 days of HKCC administration induces the development of long-term trained immunity, covering both bacterial and viral infections, thanks to an action based on pathogen-associated molecular patterns (PAMPs) [15].

Polivalent mechanical bacterial lysate (PMBL)

At the cellular level, PMBL exerts an immunomodulatory effect on the innate and adaptive immune systems, including NK cells, leading to their functional activation. This activation is associated with an increase in the number of NK cells and enhanced secretion of interferon gamma (IFN-γ), a key effector cytokine and surrogate marker of NK cell activity. Clinical evidence indicates that administration of PMBL significantly increases IFN-γ levels in the body, reflecting enhanced NK cell function. In summary, these results indicate that PMBL enhances the innate immune response by strengthening IFN-γ-dependent, NK-cell-mediated mechanisms, thereby improving the host's defense against recurrent infections [16].

It is worth noting that through the regulation of IFN-γ, the ratio of Th1 to Th2 lymphocytes shifts in favor of Th1. This is important in the context of atopic diseases, where Th2 cells predominate [9]. Studies have shown that IFN-α levels in patients receiving PMBL with recurrent respiratory tract infections (RRTI) increase more significantly than in the control group. This results in an increase in the number of NK cells [16]

PMBL also inhibits the excessive activation of ILCs with γδT and iNKT receptors, which have been shown to be associated with a more severe course of allergic rhinitis [17]. Bartkowiak-Emeryk et al. demonstrated that, among other things, significantly increased levels of Treg lymphocytes in the study group, compared with a decrease in the control group[18] Additionally, PMBL strengthens the immunity of the respiratory tract mucosa by increasing local IgA production and modulating cytokine expression, which improves barrier function and limits allergen penetration [18]

Interestingly, it has been shown that the immune protection against pneumococcal pneumonia induced by bacterial lysate does not require neutrophil recruitment, IL-17A, or activation of the Caspase-1 pathway [9].

Bacterial extracellular vesicles (BEVs)

BEVs are actively internalized by pulmonary macrophages. Following TLR4 receptor activation, there is sustained phosphorylation of MAP kinases, followed by the transcription factor NF-κB. This leads to increased synthesis of nitric oxide (NO). At the tissue level, EVs stimulate airway epithelial cells to express proteins associated with oxidative stress and inflammation (including the production of chemokine CXCL8). This, in turn, drives the recruitment of immune cells to the lungs, including neutrophils, CD11b+ dendritic cells, γδ T cells, and NK cells. Razim et al. emphasize that BEVs exhibit adjuvant activity and may be incorporated into intranasal vaccines [11].

5. Comparison of postbiotics and probiotics

The scientific literature emphasizes that postbiotics and probiotics differ not only in their mechanism of action, but above all in their safety profile and stability. This is important for their clinical applications. Postbiotics, as metabolically inactive products or fragments of bacterial cells, carry no risk of causing severe infection, which—though rare—has been reported with probiotics in immunocompromised patients [19], [20]. The absence of live microorganisms also eliminates the possibility of horizontal transfer of antibiotic resistance genes, which is one of the key safety limitations of probiotics [19], [21]. Studies on the stability of preparations have shown that postbiotics are highly resistant to changes in temperature, pH, and storage conditions, which facilitates their standardization and ensures the reproducibility of their biological effect [19]. Probiotics, as live cultures, require controlled transport and storage conditions, and their mechanism of action depends on competition with pathogens and their ability to colonize [19], [22] These differences also translate into the frequency of adverse effects: postbiotics exhibit a very low side-effect profile, while probiotics may cause temporary intestinal discomfort and, in specific cases, more serious complications [20], [23] A summary of these characteristics suggests that postbiotics represent a promising, more predictable, and safer alternative to probiotics, particularly in high-risk populations, while maintaining a beneficial effect on the immune response and host homeostasis. This information is presented in Table 1

Kryterium	**Postbiotyki** (nieaktywne produkty lub fragmenty bakterii)	**Probiotyki** (żywe mikroorganizmy)
Ryzyko ciężkiej infekcji	Brak ryzyka infekcji, ponieważ preparat nie zawiera żywych bakterii[19].	Niewielkie, ale istniejące ryzyko bakteriemii lub fungemii u osób z immunosupresją [20].
Transfer genów oporności na antybiotyki	Niemożliwy – brak żywych komórek zdolnych do wymiany materiału genetycznego [19].	Możliwy w warunkach sprzyjających horyzontalnemu transferowi genów [21]
Częstość działań niepożądanych	Zwykle bardzo niska; działania uboczne ograniczają się do łagodnych reakcji [19].	Zwykle niska, ale możliwe wzdęcia, dyskomfort jelitowy, rzadko poważniejsze reakcje [20], [23].
Stabilność preparatu	Bardzo wysoka – odporność na temperaturę, pH i warunki przechowywania [19].	Niższa – żywe kultury wymagają odpowiednich warunków transportu i przechowywania [19].
Mechanizm działania	Oparty na metabolitach, fragmentach komórkowych i modulacji immunologicznej [19].	Oparty na kolonizacji, konkurencji z patogenami i modulacji mikrobiomu[22].
Możliwość stosowania u pacjentów wysokiego ryzyka	Bezpieczne u noworodków, wcześniaków, osób z immunosupresją [19].	Wymaga ostrożności u pacjentów z obniżoną odpornością [20], [23].

Powtarzalność efektu biologicznego	Wysoka – brak zmienności wynikającej z przeżywalności bakterii [19].	Zmienna – zależy od żywotności szczepu, dawki i warunków środowiskowych [22]
Regulacje i standaryzacja	Łatwiejsza standaryzacja składu i działania [19].	Trudniejsza – żywe szczepy mogą różnić się między seriami preparatu. [23]

Table 1. Comparison of the characteristics of postbiotics and probiotics.

6. The Use of Postbiotics in Specific Diseases

Asthma

Asthma is a chronic inflammatory disease of the respiratory system classified as an atopic disease. It most commonly presents with wheezing, shortness of breath, and coughing, and is characterized by fluctuations in the severity of these symptoms over time [24] Asthma is one of the most common respiratory diseases, with 3,340 cases per 100,000 people reported in 2021 [25]. It is worth noting that despite the availability of many effective drug classes for the treatment of asthma, the disease remains a significant clinical problem, especially in regions with increasing exposure to environmental factors [26] Postbiotics appear to be a promising therapeutic option with increasingly strong scientific evidence [27].

In a study by Bartkowiak-Emeryk et al., the efficacy of postbiotic therapy with PMBL was investigated. The study group consisted of 21 children diagnosed with asthma. It was demonstrated that using PMBL for 10 days a month over a 3-month period leads to significant changes in the lymphocyte profile, which may provide evidence of the immunomodulatory effect of the postbiotic during asthma. [18] Chinese researchers conducted a cohort study using PBL on 795 patients. A significant reduction in the incidence of asthma exacerbations was observed, and consequently, a reduced need for beta-2-adrenergic agonists or glucocorticosteroids [28]. A meta-analysis of 36 clinical trials (involving a total of 1,551 patients in the study group) demonstrated that treatment with the bacterial lysate OM-85 resulted in a 24% improvement in asthma control and lung function compared to the control group. It is worth noting that better results were observed in the pediatric group [29]. Christopoulou et al. conducted a retrospective study of 137 patients with moderate to severe asthma. Patients were administered OM-85 for 12 months. The study results showed that patients using OM-85 experienced a marked reduction in the number of symptomatic asthma episodes, as well as a significant decrease in the frequency of asthma exacerbations (by 71%). It is worth noting that OM-85 therapy led to a reduction in the number of glucocorticosteroid courses and the need for antibiotics [30].

Allergic rhinitis

Allergic rhinitis (AR) is a common inflammatory condition of the nasal mucosa classified as an atopic disease. AR is characterized primarily by sneezing, watery discharge, itching, and a sensation of nasal congestion. Etiologically, it is an IgE-mediated reaction to environmental allergens such as plant pollen, house dust mites, or animal dander. Consequently, a common seasonal pattern of symptoms is a distinguishing feature [31]. It is estimated that the condition affects 10 to 20% of the population in the U.S. and Europe [32]

Clinical studies indicate that bacterial lysates may play a significant role as an adjunct therapy for AR. They reduce the severity of symptoms and, consequently, the need for antiallergic medications [5], [33]. Janeczek et al. conducted a study on a group of 50 pediatric patients with seasonal allergic rhinitis (SAR). A significant improvement in symptoms was demonstrated on the TNSS (Total Nasal Symptom Score) and VAS (Visual Analog Scale) [17] Interestingly, in a study of a pediatric group, *S. aureus* colonization was identified in the nasopharynx in as many as 42% of children with S. aureus-associated rhinitis, suggesting nasopharyngeal dysbiosis as a potential pathogenic factor of the disease. However, it is worth noting that no effect of postbiotics (PMBL) on *S. aureus* carriage rates was demonstrated. [34]

Chronic obstructive pulmonary disease (COPD)

As mentioned, COPD poses a significant problem for patients and a challenge for healthcare systems. Its etiology is multifactorial but smoking and exposure to air pollution—including particulate matter—play a key role, accounting for over 40% of the global disease burden [1]. It is estimated that the prevalence of COPD in the population over 40 years of age is approximately 10–12%, although these figures vary regionally and depend on the diagnostic criteria used [35]. The disease leads to chronic airflow limitation in the airways due to persistent inflammation involving the lung parenchyma and peripheral airways, resulting in irreversible and progressive obstruction. These changes are associated with an increased number of macrophages, neutrophils, and T lymphocytes, as well as heightened oxidative stress, which further exacerbates damage to lung structures[36]. Excessive mucus production is also a significant component of the clinical picture; it increases the risk of exacerbations and impairs lung function, and its presence is one of the main factors affecting patients' quality of life [37]. Treatment includes both pharmacological therapies aimed at reducing inflammation and improving airway patency, as well as non-pharmacological interventions, including respiratory rehabilitation and strategies to limit exposure to harmful factors, which can slow disease progression and reduce the burden of the disease [36]. It is worth noting, however, that the availability of medications used in COPD treatment is insufficient in some regions [38].

A meta-analysis was conducted including 13 scientific studies and a total of 1,366 patients in the group receiving OM-85. The study group showed a significantly lower number of exacerbations and days requiring antibiotic therapy. A negative cost-effectiveness ratio was also demonstrated, indicating that postbiotics may yield savings for the healthcare system [39]. Choi et al. conducted a study on a group of 238 adult patients with COPD. The study group was also administered the bacterial lysate OM-85. The study results indicate that the use of OM-85 led to a reduction in the risk of moderate and moderate-to-severe exacerbations. The therapy also resulted in an overall reduction in the frequency of these episodes, suggesting stabilization of the disease course in treated patients. Furthermore, a prolongation of the time to the first moderate exacerbation was observed [40]. It should be emphasized that many studies exhibit methodological variability, and their results should be interpreted with some caution. Nevertheless, they show a consistent trend supporting the efficacy of PBL in the treatment of COPD [41].

Infectious lung diseases (pneumococcal, tuberculosis, RSV, coronavirus)

For recurrent respiratory tract infections (RRTI), there is fairly convincing evidence supporting postbiotic therapy's efficacy. It has been demonstrated that postbiotics reduce the frequency, duration, and severity of these infections in both children and adults [42] However, it is worth highlighting several recent studies examining the effects of postbiotics in specific microbial-etiology diseases.

Ferrara et al. demonstrated that PBL stimulates different immunomodulatory mechanisms than conjugate pneumococcal vaccination. Therefore, their administration during the vaccination period could be considered to enhance protective effects [9] Additionally, it has been shown that some postbiotics may act similarly to vaccine adjuvants and enhance their effects [42], [43].

Werrellagama et al. observed in an animal model study that administration of HKCC strongly activates innate immune mechanisms. Furthermore, the group of mice receiving HKCC demonstrated a lower bacterial load of *Mycobacterium avium* and lower viral loads of influenza and SARS-CoV-2. Importantly, HKCC administration alone limited the proliferation of *M. tuberculosis bacilli*, and the addition of an antituberculosis drug (isoniazid) resulted in an even stronger therapeutic effect [15].

In another animal model study, the efficacy of OM-85 administration in respiratory syncytial virus (RSV) infection was evaluated. Antunes et al. demonstrated significant inhibition of viral replication and a reduction in perivascular and peribronchial inflammation in the lungs of mice treated with OM-85. The full effect was achieved after four doses of bacterial lysate. The authors highlight the potential role of PBL in viral diseases for which effective drugs or vaccines are lacking [44].

Many researchers suggest that PBL enhances the antiviral immune response, including, among others, against COVID-19 [15], [45]. However, the potential supportive role of PBL in long-COVID-19 is also significant. This is a syndrome of symptoms persisting for at least 3 months after the acute phase of SARS-CoV-2 infection, which can affect multiple body systems. Intestinal dysbiosis has been frequently observed during COVID-19[46]. The occurrence of neurological symptoms during long-COVID may be caused by abnormalities in the composition and quantity of the gut microbiota, in accordance with the “gut-brain” axis mechanism [47] Given the beneficial effects of postbiotics on the gut microbiota and their immunomodulatory action, their administration may alleviate chronic long-COVID symptoms such as fatigue, cognitive impairments, or gastrointestinal problems [48].

Oncological diseases

Cancer is a major issue facing modern medicine. Recent epidemiological analyses indicate that 10.4 million deaths from cancer were recorded in 2023 [49]. Research suggests that postbiotics may be effective in preventing the progression of cancer and in its treatment. It is worth mentioning the first “anti-cancer vaccine,” consisting of bacterial lysates, namely the Coley vaccine. It was used in the treatment of sarcomas, cancers, lymphomas, melanomas, and myelomas. Bacterial lysates such as BCG (*M. bovis*), heat-killed *Mycobacterium indicus pranii*, and *M. obuense* have shown promising results in the treatment of bladder cancer, non-small cell lung cancer (NSCLC), and melanoma [42].

Sun et al. conducted a retrospective study involving 72 patients with chronic bronchitis in the study group, in whom a total of 93 high-risk pulmonary nodules were diagnosed. Patients were administered OM-85, and the nodules were monitored via chest CT scans. In the study group, only 30.1% of nodules showed an increase in clinical malignancy (according to RECIST criteria), whereas in the control group, the percentage was 45.0%. It is worth noting that the study utilized three assessment methods: AI-risk (assessment of lesion progression using an artificial intelligence model), nodule volume, and RECIST criteria [50].

Otolaryngological disorders

Ear, nose, and throat (ENT) infections in children are one of the most common reasons for doctor visits and hospitalizations. This is due to the immaturity of both the immune system and the anatomy of the throat, Eustachian tube, and paranasal sinuses [51]. It is estimated that up to 18% of children aged 1 to 4 years will experience ENT infections [52].

In their study of 57 pediatric patients with recurrent ENT, Rebolledo et al. examined the efficacy of administering a polyvalent bacterial lysate for the prevention and/or treatment of acute episodes of otitis media (AOM) and pharyngotonsillitis (PT). After 6 months of using PBL with a specific percentage composition, it was shown that the average number of episodes was reduced by 74.7%, and school absenteeism was reduced by 99.5%. Additionally, it was observed that when an episode of the disease did occur, its course was significantly milder, and no adverse reactions were reported [8].

7. Conclusion

Postbiotics have been shown to broadly regulate both innate and adaptive immune mechanisms. Among other effects, they lead to the activation of NK cells, increased local IgA production, and a shift in the Th1/Th2 lymphocyte ratio in favor of Th1 cells, which is particularly important in alleviating the course of atopic diseases. Additionally, they promote long-term immune training. Due to the absence of live microorganisms, postbiotics have a much better safety profile than probiotics. They eliminate the risk of severe systemic infections (e.g., sepsis) and the transfer of antibiotic resistance genes, allowing for their safe use in immunocompromised patients.

In summary, the use of postbiotics translates into significant clinical benefits, including a reduction in the frequency and severity of asthma and COPD exacerbations. This results in a reduced need for glucocorticosteroids, bronchodilators, or antibiotics. Their efficacy in alleviating the symptoms of allergic rhinitis has also been demonstrated. Postbiotics effectively reduce the frequency, duration, and severity of recurrent respiratory tract infections (RRTI) and otolaryngological infections (e.g., acute otitis media), particularly in the pediatric population. Many scientific findings report on the potential use of probiotics as vaccine adjuvants to enhance their efficacy. However, it is necessary to conduct more research, especially to prove the effectiveness of postbiotics in the prevention and treatment of cancer.

Disclosure:

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All authors have read and agreed with the published version of the manuscript.

Funding statement:

No external funding was received to perform this review.

Institutional Review Board Statement:

Not applicable

Informed Consent Statement:

Not applicable

Data Availability Statement:

Not applicable

Conflict of Interest Statement:

The authors declare no conflict of interest.

References:

[1] Z. Cao *et al.*, "Burden of chronic obstructive pulmonary disease and its attributable risk factors in 204 countries and territories, 1990–2021: results from the Global Burden of Disease Study 2021," *BMJ Public Health*, vol. 4, no. 1, p. e002489, Jan. 2026, doi: 10.1136/bmjph-2024-002489. https://doi.org/10.1136/bmjph-2024-002489.

[2] S. Chen *et al.*, "The global economic burden of chronic obstructive pulmonary disease for 204 countries and territories in 2020-50: a health-augmented macroeconomic

modelling study.," *Lancet Glob. Health*, vol. 11, no. 8, pp. e1183–e1193, Aug. 2023, doi: 10.1016/S2214-109X(23)00217-6. https://doi.org/10.1016/S2214-109X(23)00217-6.

[3] S. Salminen *et al.*, "The International Scientific Association of Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of postbiotics," Sep. 01, 2021, *Nature Research*. doi: 10.1038/s41575-021-00440-6. https://doi.org/10.1038/s41575-021-00440-6.

[4] J. E. Aguilar-Toalá *et al.*, "Postbiotics: An evolving term within the functional foods field," *Trends Food Sci. Technol.*, vol. 75, pp. 105–114, May 2018, doi: 10.1016/j.tifs.2018.03.009. https://doi.org/10.1016/j.tifs.2018.03.009.

[5] A. Kaczynska, M. Klosinska, P. Chmiel, K. Janeczek, and A. Emeryk, "The Crosstalk between the Gut Microbiota Composition and the Clinical Course of Allergic Rhinitis: The Use of Probiotics, Prebiotics and Bacterial Lysates in the Treatment of Allergic Rhinitis.," *Nutrients*, vol. 14, no. 20, Oct. 2022, doi: 10.3390/nu14204328. https://doi.org/10.3390/nu14204328.

[6] G. Vinderola, M. E. Sanders, S. Salminen, and H. Szajewska, "Postbiotics: The concept and their use in healthy populations," *Front. Nutr.*, vol. 9, Dec. 2022, doi: 10.3389/fnut.2022.1002213. https://doi.org/10.3389/fnut.2022.1002213

[7] A. Kumar, K. M. Green, and M. Rawat, "A Comprehensive Overview of Postbiotics with a Special Focus on Discovery Techniques and Clinical Applications," Sep. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/foods13182937. https://doi.org/10.3390/foods13182937

[8] L. Rebolledo *et al.*, "Bacterial immunotherapy is highly effective in reducing recurrent upper respiratory tract infections in children: a prospective observational study," *European Archives of Oto-Rhino-Laryngology*, vol. 280, no. 10, pp. 4519–4530, Oct. 2023, doi: 10.1007/s00405-023-08035-4. https://doi.org/10.1007/s00405-023-08035-4

[9] F. Ferrara, A. Rial, N. Suárez, and J. A. Chabalgoity, "Polyvalent Bacterial Lysate Protects Against Pneumonia Independently of Neutrophils, IL-17A or Caspase-1 Activation," *Front. Immunol.*, vol. 12, Apr. 2021, doi: 10.3389/fimmu.2021.562244. https://doi.org/10.3389/fimmu.2021.562244

[10] Humaira, I. Ahmad, H. A. Shakir, M. Khan, M. Franco, and M. Irfan, "Bacterial Extracellular Vesicles: Potential Therapeutic Applications, Challenges, and Future Prospects.," *J. Basic Microbiol.*, vol. 64, no. 10, p. e2400221, Oct. 2024, doi: 10.1002/jobm.202400221. https://doi.org/10.1002/jobm.202400221

[11] A. Razim *et al.*, "Bacterial extracellular vesicles as intranasal postbiotics: Detailed characterization and interaction with airway cells," *J. Extracell. Vesicles*, vol. 13, no. 10, Oct. 2024, doi: 10.1002/jev2.70004. https://doi.org/10.1002/jev2.70004

[12] L. M. Muñoz-Echeverri, S. Benavides-López, O. Geiger, M. A. Trujillo-Roldán, and N. A. Valdez-Cruz, "Bacterial extracellular vesicles: biotechnological perspective for enhanced productivity.," *World J. Microbiol. Biotechnol.*, vol. 40, no. 6, p. 174, Apr. 2024, doi: 10.1007/s11274-024-03963-7. https://doi.org/10.1007/s11274-024-03963-7

[13] C. A. M. Wegh, S. Y. Geerlings, J. Knol, G. Roeselers, and C. Belzer, "Postbiotics and their potential applications in early life nutrition and beyond," Oct. 01, 2019, *MDPI AG*. doi: 10.3390/ijms20194673. https://doi.org/10.3390/ijms20194673

[14] F. Braido *et al.*, "Sublingually administered bacterial lysates: rationale, mechanisms of action and clinical outcomes," 2024, *Bioexcel Publishing LTD*. doi: 10.7573/dic.2024-1-5. https://doi.org/10.7573/dic.2024-1-5

[15] S. Werellagama *et al.*, "Host-directed broad-spectrum immunotherapeutic strategy for respiratory infections: Heat-killed Caulobacter crescentus (HKCC) as an innate-immune based biotherapeutic/postbiotic," *PLoS Pathog.*, vol. 22, no. 2 February, Feb. 2026, doi: 10.1371/journal.ppat.1013994. https://doi.org/10.1371/journal.ppat.1013994

[16] Y. K. Lee, J. H. Haam, E. Suh, S. H. Cho, and Y. S. Kim, "A Case-Control Study on the Changes in Natural Killer Cell Activity following Administration of Polyvalent Mechanical Bacterial Lysate in Korean Adults with Recurrent Respiratory Tract Infection," *J. Clin. Med.*, vol. 11, no. 11, Jun. 2022, doi: 10.3390/jcm11113014. https://doi.org/10.3390/jcm11113014

[17] K. Janeczek *et al.*, "Effect of immunostimulation with bacterial lysate on the clinical course of allergic rhinitis and the level of γδT, iNKT and cytotoxic T cells in children sensitized to grass pollen allergens: A randomized controlled trial," *Front. Immunol.*, vol. 14, Jan. 2023, doi: 10.3389/fimmu.2023.1073788. https://doi.org/10.3389/fimmu.2023.1073788

[18] M. Bartkowiak-Emeryk, A. Emeryk, J. Roliński, E. Wawryk-Gawda, and E. Markut-Miotła, "Impact of Polyvalent Mechanical Bacterial Lysate on lymphocyte number and activity in asthmatic children: a randomized controlled trial," *Allergy, Asthma and Clinical Immunology*, vol. 17, no. 1, Dec. 2021, doi: 10.1186/s13223-020-00503-4. https://doi.org/10.1186/s13223-020-00503-4

[19] X. Chen, C. Yuan, J. He, W. Li, and C. Liao, “Current research status and trends in the bioactivity of postbiotics,” 2025, *Frontiers Media SA*. doi: 10.3389/frfst.2025.1692683. https://doi.org/10.3389/frfst.2025.1692683

[20] D. Merenstein *et al.*, “Emerging issues in probiotic safety: 2023 perspectives,” 2023, *Taylor and Francis Ltd.* doi: 10.1080/19490976.2023.2185034. https://doi.org/10.1080/19490976.2023.2185034

[21] H. Szajewska *et al.*, “Antibiotic-perturbed microbiota and the role of probiotics.,” *Nat. Rev. Gastroenterol. Hepatol.*, vol. 22, no. 3, pp. 155–172, Mar. 2025, doi: 10.1038/s41575-024-01023-x. https://doi.org/10.1038/s41575-024-01023-x

[22] S. Smolinska, F.-D. Popescu, and M. Zemelka-Wiacek, “A Review of the Influence of Prebiotics, Probiotics, Synbiotics, and Postbiotics on the Human Gut Microbiome and Intestinal Integrity.,” *J. Clin. Med.*, vol. 14, no. 11, May 2025, doi: 10.3390/jcm14113673. https://doi.org/10.3390/jcm14113673

[23] A. Vitiello, M. Boccellino, and A. Zovi, “Probiotics and postbiotics to counter antimicrobial resistant infections, an editorial,” *European Journal of Clinical Microbiology and Infectious Diseases*, Mar. 2025, doi: 10.1007/s10096-025-05371-7. https://doi.org/10.1007/s10096-025-05371-7

[24] C. Porsbjerg, E. Melén, L. Lehtimäki, and D. Shaw, “Asthma,” *The Lancet*, vol. 401, no. 10379, pp. 858–873, Mar. 2023, doi: 10.1016/S0140-6736(22)02125-0. https://doi.org/10.1016/S0140-6736(22)02125-0

[25] L. Yuan *et al.*, “Global, regional, national burden of asthma from 1990 to 2021, with projections of incidence to 2050: a systematic analysis of the global burden of disease study 2021,” *EClinicalMedicine*, vol. 80, Feb. 2025, doi: 10.1016/j.eclinm.2024.103051. https://doi.org/10.1016/j.eclinm.2024.103051

[26] E. Garcia and F. Gilliland, “Moving beyond medication: Assessment and interventions on environmental and social determinants are needed to reduce severe asthma,” Feb. 01, 2022, *Elsevier Inc.* doi: 10.1016/j.jaci.2021.12.760. https://doi.org/10.1016/j.jaci.2021.12.760

[27] K. Węgrzyn, A. Jasińska, K. Janeczek, and W. Feleszko, “The Role of Postbiotics in Asthma Treatment,” Aug. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/microorganisms12081642. https://doi.org/10.3390/microorganisms12081642

[28] L. Li *et al.*, “Effectiveness of polyvalent bacterial lysate for pediatric asthma control: a retrospective propensity score-matched cohort study,” *Transl. Pediatr.*, vol. 11, no. 10, pp. 1697–1703, Oct. 2022, doi: 10.21037/tp-22-489. https://doi.org/10.21037/tp-22-489

[29] S. Yao, R. Qin, X. Song, L. He, X. Lin, and J. Li, “Bacterial lysate add-on therapy in adult and childhood asthma: a systematic review and meta-analysis,” *J. Thorac. Dis.*, vol. 15, no. 6, pp. 3143–3157, Jun. 2023, doi: 10.21037/jtd-22-1469. https://doi.org/10.21037/jtd-22-1469

[30] M. E. Christopoulou *et al.*, “Oral Bacterial Lysate OM-85 Prevents Respiratory Tract Infections in Asthma: The OMRIA RWE Study,” *J. Asthma Allergy*, vol. 18, pp. 891–902, 2025, doi: 10.2147/JAA.S517194. https://doi.org/10.2147/JAA.S517194

[31] S. M. Nur Husna, H. T. T. Tan, N. Md Shukri, N. S. Mohd Ashari, and K. K. Wong, “Allergic Rhinitis: A Clinical and Pathophysiological Overview,” Apr. 07, 2022, *Frontiers Media S.A.* doi: 10.3389/fmed.2022.874114. https://doi.org/10.3389/fmed.2022.874114

[32] T. Ozdoganoglu and M. Songu, “The burden of allergic rhinitis and asthma,” 2012. doi: 10.1177/1753465811431975. https://doi.org/10.1177/1753465811431975

[33] K. Janeczek, A. Kaczyńska, A. Emeryk, and C. Cingi, “Perspectives for the Use of Bacterial Lysates for the Treatment of Allergic Rhinitis: A Systematic Review,” 2022, *Dove Medical Press Ltd*. doi: 10.2147/JAA.S360828. https://doi.org/10.2147/JAA.S360828

[34] K. Janeczek, A. Emeryk, Ł. Zimmer, E. Poleszak, and M. Ordak, “Nasal carriage of Staphylococcus aureus in children with grass pollen-induced allergic rhinitis and the effect of polyvalent mechanical bacterial lysate immunostimulation on carriage status: A randomized controlled trial,” *Immun. Inflamm. Dis.*, vol. 10, no. 3, Mar. 2022, doi: 10.1002/iid3.584. https://doi.org/10.1002/iid3.584

[35] M. M. de Oca *et al.*, “The global burden of COPD: epidemiology and effect of prevention strategies,” Aug. 01, 2025, *Elsevier Ltd*. doi: 10.1016/S2213-2600(24)00339-4. https://doi.org/10.1016/S2213-2600(24)00339-4

[36] J. Xu, Q. Zeng, S. Li, Q. Su, and H. Fan, “Inflammation mechanism and research progress of COPD,” 2024, *Frontiers Media SA*. doi: 10.3389/fimmu.2024.1404615. https://doi.org/10.3389/fimmu.2024.1404615

[37] B. K. Shah, B. Singh, Y. Wang, S. Xie, and C. Wang, “Mucus Hypersecretion in Chronic Obstructive Pulmonary Disease and Its Treatment,” 2023, *Hindawi Limited*. doi: 10.1155/2023/8840594. https://doi.org/10.1155/2023/8840594

[38] D. Du *et al.*, “The availability of drugs for stable COPD treatment in China: a cross-sectional survey,” *NPJ Prim. Care Respir. Med.*, vol. 35, no. 1, Dec. 2025, doi: 10.1038/s41533-025-00413-1. https://doi.org/10.1038/s41533-025-00413-1

[39] G. Troiano, G. Messina, and N. Nante, “Bacterial lysates (OM-85 BV): A cost-effective proposal in order to contrast antibiotic resistance,” *J. Prev. Med. Hyg.*, vol. 62, no. 2, pp. E564–E573, Jul. 2021, doi: 10.15167/2421-4248/jpmh2021.62.2.1734. https://doi.org/10.15167/2421-4248/jpmh2021.62.2.1734

[40] J. Y. Choi, Y. B. Park, T. J. An, K. H. Yoo, and C. K. Rhee, “Effect of Broncho-Vaxom (OM-85) on the frequency of chronic obstructive pulmonary disease (COPD) exacerbations,” *BMC Pulm. Med.*, vol. 23, no. 1, Dec. 2023, doi: 10.1186/s12890-023-02665-4. https://doi.org/10.1186/s12890-023-02665-4

[41] M. Di Gioacchino, F. Santilli, and A. Pession, “Is There a Role for Immunostimulant Bacterial Lysates in the Management of Respiratory Tract Infection?,” Oct. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/biom14101249. https://doi.org/10.3390/biom14101249

[42] M. M. Rahman, I. D. Grice, G. C. Ulett, and M. Q. Wei, “Advances in Bacterial Lysate Immunotherapy for Infectious Diseases and Cancer,” 2024, *Hindawi Limited*. doi: 10.1155/2024/4312908. https://doi.org/10.1155/2024/4312908

[43] J. Żółkiewicz, A. Marzec, M. Ruszczyński, and W. Feleszko, “Postbiotics-A Step Beyond Pre- and Probiotics.,” *Nutrients*, vol. 12, no. 8, Jul. 2020, doi: 10.3390/nu12082189. https://doi.org/10.3390/nu12082189

[44] K. H. Antunes *et al.*, “Airway Administration of Bacterial Lysate OM-85 Protects Mice Against Respiratory Syncytial Virus Infection,” *Front. Immunol.*, vol. 13, May 2022, doi: 10.3389/fimmu.2022.867022. https://doi.org/10.3389/fimmu.2022.867022

[45] S. D. Todorov, J. R. Tagg, and I. V. Ivanova, “Could Probiotics and Postbiotics Function as ‘Silver Bullet’ in the Post-COVID-19 Era?,” Dec. 01, 2021, *Springer*. doi: 10.1007/s12602-021-09833-0. https://doi.org/10.1007/s12602-021-09833-0

[46] L. Lv *et al.*, “The faecal metabolome in COVID-19 patients is altered and associated with clinical features and gut microbes,” *Anal. Chim. Acta*, vol. 1152, Apr. 2021, doi: 10.1016/j.aca.2021.338267. https://doi.org/10.1016/j.aca.2021.338267

[47] S. M. Petrut, A. M. Bragaru, A. E. Munteanu, A. D. Moldovan, C. A. Moldovan, and E. Rusu, “Gut over Mind: Exploring the Powerful Gut–Brain Axis,” Mar. 01, 2025, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/nu17050842. https://doi.org/10.3390/nu17050842

[48] M. E. Jach *et al.*, “The Role of Probiotics and Their Postbiotic Metabolites in Post-COVID-19 Syndrome,” Oct. 01, 2025, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/molecules30204130. https://doi.org/10.3390/molecules30204130

[49] Q. Luo and D. P. Smith, “Global cancer burden: progress, projections, and challenges,” Oct. 11, 2025, *Elsevier B.V.* doi: 10.1016/S0140-6736(25)01570-3. https://doi.org/10.1016/S0140-6736(25)01570-3

[50] M. Sun *et al.*, “OM-85, a Bacterial Lysate, Reduces Pulmonary Nodule Malignant Probability: A Retrospective Study,” *Clinical Respiratory Journal*, vol. 19, no. 7, Jul. 2025, doi: 10.1111/crj.70109. https://doi.org/10.1111/crj.70109

[51] D. Srinivasan and K. Raja, “Common Ear, Nose, and Throat Disorders in Childhood,” in *Common Childhood Diseases - Diagnosis, Prevention and Management*, IntechOpen, 2024. doi: 10.5772/intechopen.1006071. https://doi.org/10.5772/intechopen.1006071

[52] W. Feleszko, M. Ruszczyński, and B. M. Zalewski, “Non-specific immune stimulation in respiratory tract infections. Separating the wheat from the chaff,” *Paediatr. Respir. Rev.*, vol. 15, no. 2, pp. 200–206, Jun. 2014, doi: 10.1016/j.prrv.2013.10.006. https://doi.org/10.1016/j.prrv.2013.10.006