KAROŃ, Łukasz, ZYGMUNT, Anna, KAROŃ, Karolina, GRABOWSKI, Wojciech, PEDRYCZ, Daria, PEDRYCZ, Emilia, and DRAPAŁA, Grzegorz. Allergy Modulation: Exploring the Role of Prebiotics, Probiotics, and Synbiotics in Enhancing Health Outcomes – A Literature Review. 2024;31:55738. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.31.55738
https://apcz.umk.pl/QS/article/view/55738

The journal has had 20 points in Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's 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 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 20.10.2024. Revised: 21.10.2024. Accepted: 12.11.2024. Published: 12.11.2024.

Allergy Modulation: Exploring the Role of Prebiotics, Probiotics, and Synbiotics in Enhancing Health Outcomes - A Literature Review

Łukasz Karoń

Department of Pathology and Molecular Diagnostics,

Medical University of Silesia in Katowice

ORCID: 0009-0009-5083-8307

corresponding author: e-mail: lk12345@vp.pl

Anna Zygmunt

Department of Pathology and Molecular Diagnostics,

Medical University of Silesia in Katowice

ORCID: 0009-0002-5849-6347

Karolina Karoń

Municipal Hospital in Zabrze

ORCID: 0009-0005-0356-8907

Wojciech Grabowski
Municipal Hospital in Zabrze
ORCID: 0009-0006-9238-1411

Daria Pedrycz
Department of Family Medicine,
Medical University of Białystok
ORCID: 0009-0001-4988-5992

Emilia Pedrycz
Wojewodzki Szpital Zespolony w Kielcach
ORCID: 0009-0006-2751-2227

Grzegorz Drapała
Wojewodzki Szpital Zespolony w Kielcach
ORCID: 0009-0008-1492-1544

Abstract

This literature review explores the role of prebiotics, probiotics, and synbiotics in the prevention and management of allergic diseases, including eczema, asthma, allergic rhinitis, and food allergies. The review delves into the mechanisms by which these dietary interventions modulate the gut microbiome, influence immune system responses, and enhance the epithelial barrier. While prebiotics promote the growth of beneficial gut bacteria and the production of short-chain fatty acids, probiotics introduce live microorganisms that restore balance in the gut ecosystem. Synbiotics combine both approaches to synergistically improve gut health. Despite the promising potential of these interventions, the evidence remains mixed, with their efficacy varying across different allergic conditions. This review underscores the need for further research to clarify the effectiveness of prebiotics, probiotics, and synbiotics in allergy prevention and management, highlighting the complexities involved in translating these findings into clinical practice.

Keywords: allergic diseases, gut microbiota, probiotics, prebiotics, synbiotics, immune modulation

Introduction

The burgeoning prevalence of allergic diseases such as eczema, asthma, allergic rhinitis, and food allergies in contemporary society has intensified the pursuit for innovative and effective management strategies. Among such strategies is the exploration of dietary interventions, particularly the roles of prebiotics, probiotics, and synbiotics, in modulating the gut microbiome to bolster immune defense mechanisms against allergic reactions. This review delves into this triad of interventions, their definitions, implications, and the evidence from recent research on their efficacy against various allergic diseases.

Prebiotics are selectively fermented ingredients that cannot be digested by the host, designed to confer benefits primarily by stimulating the growth and/or activity of advantageous bacteria in the digestive system. These interventions aim at improving host health by enhancing the composition and functionality of the gut microbiota. Prebiotics, such as inulin, fructooligosaccharides (FOS), and galactooligosaccharides (GOS), specifically encourage the growth of beneficial bacterial species like bifidobacteria and lactobacilli (1).

Probiotics, on the other hand, consist of live microorganisms—predominantly bacteria, but also yeasts—that, when administered in adequate amounts, bestow a health benefit on the host. This approach directly introduces beneficial microbes into the gut ecosystem, with the objective of restoring the balance of the intestinal flora, thereby enhancing gut health and immune function (2).

Synbiotics represent a synergistic combination of probiotics and prebiotics. This concept capitalizes on the mutualistic relationship between prebiotics and probiotics, aiming to improve the survivability of beneficial microorganisms in the gastrointestinal tract and their overall efficacy in promoting host health. By simultaneously offering a conducive environment (through prebiotics) for the beneficial microbes (probiotics) to thrive, synbiotics underscore the potential of a combined approach to dietary modulation of the gut microbiome (3).

Despite the promising premise that modulating the gut microflora could prevent or ameliorate allergic diseases, the evidence remains mixed and segmented by the type of allergic condition. Some guidelines support the use of prebiotics, probiotics, and synbiotics in preventing conditions like atopic dermatitis, yet their efficacy in other allergic conditions, such as allergic rhinitis, asthma, and food allergies, is still under rigorous investigation (4).

As this review progresses, it will further explore the intricacies of employing prebiotics, probiotics, and synbiotics in the prevention and management of allergic diseases. We shall examine the nuances influencing their efficacy and discuss the emerging strategies that may

potentiate their allergy-preventive effects, lighting the path toward future evidence-based implementation.

Mechanisms of Microbial Modulation

The mechanisms by which prebiotics, probiotics, and synbiotics exert their health benefits are complex and interconnected, involving several critical pathways that impact gut health, immune function, and overall systemic balance. Prebiotics, as detailed by Brosseau et al., function primarily as fermentable substrates for specific beneficial gut bacteria, particularly bifidobacteria and lactobacilli. This fermentation process results in the production of short-chain fatty acids (SCFAs) such as butyrate, propionate, and acetate. These SCFAs are key players in enhancing the integrity of the epithelial barrier, which acts as the first line of defense against pathogens and allergens. By strengthening this barrier, prebiotics help prevent the translocation of harmful substances into the bloodstream, reducing the likelihood of immune system activation against harmless antigens, a process that is central to the development of allergic diseases.

Beyond their role in barrier function, SCFAs also modulate immune responses directly. They influence the activity of various immune cells, including T cells and dendritic cells, promoting a more tolerogenic immune environment. This modulation is crucial for preventing excessive inflammatory responses that are characteristic of allergic reactions. Prebiotics also exert direct effects on epithelial and immune cells, further enhancing their ability to promote immune tolerance. This dual action—both through the production of SCFAs and direct interaction with host cells—positions prebiotics as a potent tool in allergy prevention, particularly when introduced early in life to support the development of a balanced immune system.

Probiotics, which consist of live microorganisms, contribute to gut health by directly colonizing the intestinal tract and competing with pathogenic bacteria for resources and adhesion sites on the gut lining. This competitive exclusion helps maintain a balanced microbial ecosystem, which is essential for the proper functioning of the immune system. Probiotics also produce various bioactive compounds, including bacteriocins and other antimicrobial peptides, that further inhibit the growth of harmful bacteria. Moreover, probiotics interact with the host's immune cells, particularly in the gut-associated lymphoid tissue (GALT), where they can enhance the production of regulatory T cells (Tregs) and other anti-inflammatory mediators. These interactions help modulate the immune response, reducing the likelihood of allergic sensitization and promoting long-term immune tolerance.

Synbiotics, which combine prebiotics and probiotics, leverage the benefits of both components, creating a synergistic effect that enhances the survival, colonization, and activity of beneficial microbes in the gut. The prebiotic component provides a nutrient source that selectively feeds the probiotic organisms, ensuring their sustained presence and activity within the gut environment. This combination not only improves the gut microbial composition but also amplifies the immune-modulating effects of both prebiotics and probiotics. By fostering a more resilient gut microbiome and a robust immune system, synbiotics offer a powerful strategy for preventing and managing allergic diseases. They hold particular promise in the context of early-life interventions, where establishing a healthy gut microbiome can have long-lasting effects on immune function and disease susceptibility.

In summary, the mechanisms of action of prebiotics, probiotics, and synbiotics are deeply intertwined with gut microbiota dynamics, epithelial barrier function, and immune modulation. Through the production of SCFAs, direct interactions with immune cells, and the maintenance of a balanced gut ecosystem, these dietary interventions provide a comprehensive approach to enhancing immune tolerance and preventing allergic diseases. As research continues to uncover the complexities of these mechanisms, the potential for prebiotics, probiotics, and synbiotics to be integrated into clinical practice for allergy prevention and management becomes increasingly apparent, offering hope for more effective and personalized strategies in combating the growing prevalence of allergic conditions (5).

Atopic dermatitis

The impact of prebiotics, probiotics, and synbiotics on the prevention and treatment of eczema, also known as atopic dermatitis (AD), has been extensively studied, yielding a diverse array of findings that highlight both the potential benefits and inherent limitations of these interventions. Cuello-Garcia et al. (2017) explored the role of prebiotics in modulating immune responses, suggesting that their supplementation could be beneficial in preventing allergies, including eczema. Their study underscored the importance of early-life interventions in shaping immune development, potentially reducing the risk of allergic manifestations such as AD (1). However, Prescott and Björkstén (2007) provided a more cautious perspective, indicating that the data were insufficient to recommend probiotics as a standard therapy for allergic conditions, including atopic eczema. While some studies reviewed by them showed potential benefits in preventing eczema, they concluded that there was no clear evidence to support the preventive effects of probiotics on sensitization or other allergic diseases beyond eczema (6).

Forsberg et al. (2016) added to the discourse by discussing the World Allergy Organization's (WAO) conditional recommendation for the use of probiotics in the primary prevention of eczema. This recommendation was made with caution, given that it was based on very low-quality evidence and was accompanied by significant heterogeneity across studies. This variability in outcomes underscores the complexities involved in translating these findings into clinical practice (3). Makrgeorgou et al. (2018) further contributed to this complexity by suggesting that probiotics may not be effective in treating eczema. They pointed out significant gaps in the current evidence, particularly in terms of the consistency and robustness of the findings, which highlights the need for further research to clarify the potential role of probiotics in managing AD (7). In contrast, Dang et al. (2013) offered a more positive outlook through their meta-analysis, which concluded that the use of probiotics or synbiotics could reduce the incidence of eczema in infants under two years old. This effect was particularly noted with non-spore-forming strains of Lactobacilli and Bifidobacteria, although these benefits were not consistently accompanied by changes in systemic sensitization, indicating that the impact of probiotics might be more localized to skin manifestations rather than systemic allergic responses (4).

Eigenmann (2013) provided additional insights by reporting that combinations of probiotics and prebiotics, particularly when administered from late pregnancy through early infancy, appeared to be more effective in protecting infants from developing eczema than short-term administration of a single microorganism. This finding suggests that a multifaceted approach to gut microbiota modulation may offer enhanced protective benefits against AD (8). Savilahti (2011) similarly observed that synbiotics significantly reduced eczema incidence in infants at high risk for allergies, though the cumulative incidence of allergic diseases by the age of two did not significantly differ between the synbiotic and placebo groups. This suggests that while synbiotics may be effective in reducing the risk of eczema, their broader impact on preventing other allergic conditions remains uncertain (9). Osborn & Sinn (2013) also examined the role of prebiotics in preventing eczema and found that their use might reduce the incidence of eczema in high-risk infants up to six months old. However, they emphasized the inconclusive nature of the overall evidence, citing significant variability between study results, which makes it challenging to draw definitive conclusions about the effectiveness of prebiotics in allergy prevention (10).

Osborn & Sinn (2007) conducted a comprehensive meta-analysis that revealed a significant reduction in eczema among infants receiving probiotics, particularly among those at high risk, predominantly breastfed infants, and those treated with Lactobacillus rhamnosus or a

combination of probiotic strains. Despite these promising findings, the study did not find significant effects on preventing other allergic outcomes such as asthma or food hypersensitivity, indicating that the benefits of probiotics might be specific to eczema rather than extending to other allergic conditions (11). Foolad & Armstrong (2014) further supported the effectiveness of specific probiotics, particularly Lactobacillus rhamnosus GG, in reducing the severity and incidence of atopic dermatitis. They noted that a combination of probiotic strains showed promise in preventing atopic dermatitis among infants and that prebiotics could lead to long-term reductions in eczema incidence, although these findings also varied across different studies (12).

Ismail, Licciardi, & Tang (2013) highlighted the potential role of certain probiotics, alone or combined with prebiotics, in preventing eczema during early childhood. However, they also emphasized that current data are insufficient to support the use of these interventions in treating established allergic diseases, pointing to the need for further research to clarify their potential benefits (13). Vanderhoof (2008) added to this by highlighting the role of probiotics in reducing the incidence and severity of atopic eczema, particularly when administered during pregnancy and early infancy (14). This preventive potential was further supported by Kuitunen (2013), who reported that probiotics administered prenatally and postnatally were successful in preventing eczema, with some studies showing long-term effects lasting up to four years and suggesting potential in preventing respiratory allergies. However, the consistency of these results across different studies was not always strong, indicating the need for more robust research to confirm these findings (15).

Kukkonen et al. (2007) provided evidence supporting the use of a combination of four probiotic strains and prebiotic galacto-oligosaccharides, which significantly prevented eczema and atopic eczema. However, this intervention did not affect the cumulative incidence of other allergic diseases, suggesting that the benefits of gut microbiota modulation may be more specific to skin-related allergic conditions (16). Wopereis et al. (2017) further demonstrated that intervention with a partially hydrolyzed protein formula supplemented with prebiotics led to a gut microbiota composition in infants that was closer to that of breastfed infants. This intervention was associated with a reduced risk of developing eczema, highlighting the potential role of optimizing gut microbiota in preventing eczema (17).

Finally, Tang (2009) discussed the potential of probiotics, prebiotics, and synbiotics in preventing atopic eczema, particularly when a prenatal component is included. However, Tang stressed that the evidence remains insufficient to recommend their widespread use in clinical practice for eczema prevention or treatment. This cautious approach reflects the need for more

conclusive evidence to establish the definitive role of these interventions in managing eczema (18). Fiocchi et al. (2022) emphasized the substantial uncertainties surrounding the efficacy of gut microflora modulation in preventing and treating allergic conditions, including AD. They noted that while the microbiome plays a significant role in allergic diseases, current guidelines support the use of intestinal flora modulators primarily as an adjunct in the prevention of AD, rather than as a standalone treatment for other allergic conditions. This reflects a cautious approach in integrating these interventions into clinical practice, highlighting the need for more conclusive evidence to establish their definitive role in AD management (2).

Asthma

In reviewing the effects of prebiotics, probiotics, and synbiotics on asthma, various studies and clinical trials have provided insights into their potential therapeutic benefits, though the results are mixed. Clinical trials and animal studies have consistently pointed to the possibility that probiotics, particularly those involving specific strains such as Lactobacillus and Bifidobacterium, may offer significant therapeutic benefits in managing asthma. These benefits include anti-inflammatory activity, reduced airway hyperresponsiveness, decreased mucus secretion, and overall improved lung function. The review provided by Kleniewska and Pawliczak (2024) casts a hopeful light on the potential role of specific probiotic strains, particularly those from the Lactobacillus and Bifidobacterium genera, in managing asthma by highlighting their ability to mitigate asthma symptoms and improve lung function, as evidenced by both animal models and clinical trials suggesting these microorganisms may reduce airway inflammation and hyperreactivity (19). Similarly, Wu et al. (2022) demonstrated that the use of probiotics and prebiotics could effectively control acute airway inflammation in models of allergic asthma. This control was achieved through the modulation of the TLR4/NF-κB signaling pathway, indicating that these dietary interventions might influence not only the gut microbiota but also key immunological pathways involved in asthma (20).

Additionally, a meta-analysis conducted by Wawryk-Gawda, Markut-Miotła, and Emeryk (2021) suggested that while probiotics alone may not significantly reduce the risk of asthma development, the use of prebiotics or synbiotics could be associated with a lower incidence of asthma in high-risk children. This finding points to the potential specificity in how different types of dietary components might influence the development of asthma, particularly in populations that are genetically or environmentally predisposed to the condition (21).

However, the evidence is not uniformly positive. For example, Meirlaen, Levy, and Vandenplas (2021) reported disappointing results in clinical studies involving infants, where the benefits

observed in animal studies did not translate effectively to human trials. These clinical studies, which aimed to assess the preventive capabilities of probiotics and prebiotics against asthma and allergic rhinitis in children, often encountered multiple confounding factors such as environmental influences, genetic variability, and differences in the probiotic strains used. These factors contributed to the variability in outcomes and raised questions about the generalizability of the findings from animal models to human populations (22).

Moreover, Huang et al. (2019) emphasized the necessity for further research to establish the safety and effectiveness of these supplements in the treatment of asthma. They noted that the heterogeneity in study designs, the diversity of probiotic strains employed, and the varying methodologies used to assess outcomes all contribute to the challenges in drawing firm conclusions. This variability complicates the interpretation of the results and highlights the need for more standardized and rigorous approaches in future research (23).

Furthermore, the meta-analysis by Wawryk-Gawda et al. (2021) also found that postnatal probiotic supplementation did not significantly decrease the risk of asthma development in high-risk children. This finding contrasts with the potential benefits observed with prebiotics and synbiotics, suggesting that the timing of supplementation, as well as the type of supplement used, may be critical factors in determining their effectiveness in asthma prevention (21).

Allergic Rhinitis

The effects of prebiotics, probiotics, and synbiotics on allergic rhinitis (AR) have been the subject of various studies with diverse findings. Faridzadeh et al. (2023) demonstrated the potential of synbiotics as adjunctive treatment agents in AR, noting their cost-effectiveness and minimal adverse effects when used alongside standard therapy (24). Similarly, Galvan Calle et al. (2022) assessed the clinical efficacy of synbiotics in children with AR, reporting positive outcomes in managing AR symptoms and suggesting that synbiotics may be particularly beneficial in pediatric cases (25).

Liu et al. (2023) conducted a comprehensive systematic review and meta-analysis on the efficacy and safety of gastrointestinal microbiome supplementation (GMS), which includes probiotics, prebiotics, and synbiotics, for AR patients. Their study provided a detailed evaluation of the effects of GMS on various clinical parameters. They found that patients receiving GMS experienced significant improvements in overall nasal condition, including reductions in nasal congestion, sneezing, and rhinorrhea. Additionally, quality of life scores improved markedly in the GMS groups, reflecting better daily functioning and reduced AR symptoms. Medication scores, which measure the need for additional pharmaceutical

interventions, also showed favorable reductions, indicating that GMS could help decrease reliance on conventional AR medications (26).

However, Liu et al. also noted that the impact of GMS on certain immunological parameters was less pronounced. For instance, while there was some improvement in serum total IgE levels, which are often elevated in allergic conditions, the changes were not as significant as those seen in clinical symptoms. Similarly, the serum Th1/Th2 ratio, an important indicator of immune system balance in allergic responses, showed modest improvements, suggesting that while GMS may help manage clinical symptoms of AR, its effects on underlying immunological mechanisms might be more limited (26).

Kaczyńska et al. (2022) explored the relationship between gut microbiota composition and the clinical course of AR, focusing on how probiotics, prebiotics, and bacterial lysates might modulate the immune system by altering gut microbiota. Although their review highlighted the potential of these interventions to impact AR, the evidence presented was not definitive, underscoring the need for further research to establish clear therapeutic benefits (27).

Meanwhile, Chang et al. (2023) investigated the correlation between probiotic intake and the prevalence of AR. Although their study suggested a significant relationship between probiotic consumption and reduced AR symptoms, specific conclusions were not drawn, highlighting the necessity for more detailed studies to clarify this potential connection (28).

Food allergies

In examining the effects of prebiotics, probiotics, and synbiotics on food allergies among adults, the literature presents a multifaceted view with both supportive and cautionary findings. On the positive side, Jialu Shi et al. (2022) highlighted the potential of gut microbiome modulation through probiotics, prebiotics, synbiotics, and postbiotics as innovative strategies for preventing and treating food allergies. Their study underscores how these interventions can influence the microbial composition and the immunogenicity of food antigens, suggesting they may offer promising avenues for managing food allergies (29). Similarly, Ribeiro and Pedrosa (2023) supported the potential use of probiotics as therapeutic adjuvants, particularly in Cow's Milk Allergy (CMA) and peanut oral immunotherapy. Their review noted that while probiotics might enhance the effectiveness of these treatments, there remains a need for more consistent evidence regarding the specific probiotic strains, dosages, and duration of supplementation necessary to confirm their efficacy in food allergy prevention and treatment among adults (30).

In contrast, Fiocchi et al. (2016) and Fiocchi et al. (2022) emphasize significant uncertainties surrounding the effectiveness of probiotics, prebiotics, and synbiotics in the context of food

allergies. Their reviews suggest that while there is a growing interest in these interventions, the current evidence remains ambiguous (31)(2). Fiocchi et al. (2022) specifically pointed out that although these interventions can be beneficial as adjuncts in preventing atopic dermatitis, their efficacy in preventing or treating other food allergies is less clear. They noted that the role of probiotics and prebiotics in managing food allergies among adults remains controversial and requires further research to establish definitive conclusions (2).

Erkki Savilahti (2011) focused on the effects of probiotics in children with atopic dermatitis and suspected cow's milk allergy, finding that probiotics might reduce eczema and have a preventive effect against IgE-associated diseases. However, the study did not directly address the consistency of these effects on food allergies in adults, highlighting a gap in the direct applicability of these findings to adult populations. This leaves a critical need for studies specifically targeting adult food allergies to verify whether the benefits observed in children translate to adult populations (9).

Furthermore, Han (2024) explored the role of prebiotic supplements in correcting oral probiotic deficiency, noting their potential for improving allergy relief. Although this study was primarily concerned with allergic rhinitis, its findings suggest that prebiotic supplementation could offer a potential strategy for addressing the modulation of probiotics and prebiotics in other allergic conditions, including food allergies. However, the direct impact of these findings on food allergy management among adults is yet to be fully elucidated.

Conclusion

The review of prebiotics, probiotics, and synbiotics across various allergic conditions, including eczema (atopic dermatitis), asthma, food allergies, and allergic rhinitis, presents a diverse and complex landscape. These interventions show varying degrees of potential, with some promising results and significant limitations.

For eczema, prebiotics, probiotics, and synbiotics have shown potential in preventing and managing the condition, particularly when administered early in life. Prebiotics may influence immune system development and reduce allergy risks, though the overall evidence remains inconclusive. Probiotics have demonstrated some effectiveness in reducing eczema incidence in infants, but their role in treating established eczema or preventing other allergic conditions is less clear. Synbiotics, which combine the benefits of both probiotics and prebiotics, appear to offer enhanced protective effects against eczema, especially when used during pregnancy and early infancy.

In the context of asthma, the evidence is more mixed. While some studies suggest that probiotics, particularly certain strains like Lactobacillus and Bifidobacterium, might reduce airway inflammation and improve lung function, the results are not uniformly positive. The benefits observed in animal models have not consistently translated to human trials, leading to uncertainty about the effectiveness of these interventions in preventing or treating asthma. Variability in study outcomes, including differences in probiotic strains and environmental factors, complicates the interpretation of these results.

Allergic rhinitis has also been a focus of research, with synbiotics showing promise as an adjunctive treatment. These interventions may improve symptoms such as nasal congestion and sneezing, as well as overall quality of life. However, the impact on underlying immunological mechanisms is less pronounced, and the evidence is not definitive. The relationship between gut microbiota modulation and the clinical course of allergic rhinitis remains an area requiring further study.

Food allergies present another area of interest, with some evidence supporting the use of probiotics, prebiotics, and synbiotics as part of innovative strategies for prevention and treatment. However, the evidence is still developing, and significant uncertainties remain. The potential benefits observed in managing conditions like Cow's Milk Allergy (CMA) and peanut allergies need further validation, particularly in adult populations where the direct impact of these interventions is less clear.

Overall, while there is emerging evidence that prebiotics, probiotics, and synbiotics may play a role in managing various allergic conditions, including eczema, asthma, food allergies, and allergic rhinitis, the results are inconsistent. The need for more rigorous, standardized research is evident, particularly in determining the most effective strains, dosages, and timing of these interventions. As the understanding of the gut microbiota's role in allergic diseases evolves, future studies should aim to clarify the specific benefits and limitations of these dietary supplements, leading to more concrete recommendations for their use in clinical practice.

Disclosure

Author's contribution: Łukasz Karoń, Anna Zygmunt, Karolina Karoń, Wojciech Grabowski, Daria Pedrycz, Emilia Pedrycz, Grzegorz Drapała

Conceptualisation: Łukasz Karoń, Wojciech Grabowski, Daria Pedrycz

Methodology: Łukasz Karoń, Karolina Karoń, Anna Zygmunt, Emilia Pedrycz

Software: Wojciech Grabowski, Anna Zygmunt, Grzegorz Drapała

Check: Łukasz Karoń, Anna Zygmunt, Karolina Karoń,

Formal: Łukasz Karoń, Karolina Karoń, Anna Zygmunt, , Emilia Pedrycz
Investigation: Łukasz Karoń, Karolina Karoń, Anna Zygmunt, Grzegorz Drapała
Resources: Anna Zygmunt, Karolina Karoń, Wojciech Grabowski
Data curation: Łukasz Karoń, Anna Zygmunt, Wojciech Grabowski, Karolina Karoń
Writing-Rough Preparation: Łukasz Karoń
Writing Review and Editing: Łukasz Karoń
Visualisation: Anna Zygmunt, Karolina Karoń, Emilia Pedrycz
Supervision: Łukasz Karoń, Anna Zygmunt, Daria Pedrycz
Project Administration: Łukasz Karoń, Wojciech Grabowski, Grzegorz Drapała

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

Funding statement: The study did not receive special funding.
Institutional review board statement: Not applicable.
Informed consent statement: Not applicable.
Data availability statement: Not applicable.
Conflict of interest: The authors declare no conflict of interest.

References

1. Cuello-Garcia, C., Fiocchi, A., Pawankar, R., Yepes-Nuñez, J. J., Morgano, G. P., Zhang, Y., Agarwal, A., Gandhi, S., Terracciano, L., Schünemann, H. J., & Brozek, J. L. (2017). Prebiotics for the prevention of allergies: A systematic review and meta-analysis of randomized controlled trials. *Clinical & Experimental Allergy*, *47*(11), 1468–1477. https://doi.org/10.1111/cea.13042
2. Fiocchi, A., Cabana, M. D., & Mennini, M. (2022). Current use of probiotics and prebiotics in allergy. *The Journal of Allergy and Clinical Immunology in Practice*, *10*(9), 2219–2242. https://doi.org/10.1016/j.jaip.2022.06.038
3. Forsberg, A., West, C. E., Prescott, S. L., & Jenmalm, M. C. (2016b). Pre- and probiotics for allergy prevention: time to revisit recommendations? *Clinical & Experimental Allergy*, *46*(12), 1506–1521. https://doi.org/10.1111/cea.12838
4. Dang, D., Zhou, W., Lun, Z. J., Mu, X., Wang, D. X., & Wu, H. (2013). Meta-analysis of probiotics and/or prebiotics for the prevention of eczema. *Journal of International Medical Research*, *41*(5), 1426–1436. https://doi.org/10.1177/0300060513493692

5. Brosseau, C., Sellé, A., Palmer, D. J., Prescott, S. L., Barbarot, S., & Bodinier, M. (2019). Prebiotics: Mechanisms and preventive effects in allergy. *Nutrients*, *11*(8), 1841. https://doi.org/10.3390/nu11081841
6. Prescott, S. L., & Björkstén, B. (2007). Probiotics for the prevention or treatment of allergic diseases. *Journal of Allergy and Clinical Immunology*, *120*(2), 255–262. https://doi.org/10.1016/j.jaci.2007.04.027
7. Makrgeorgou, A., Leonardi-Bee, J., Bath-Hextall, F. J., Murrell, D. F., Tang, M. L., Roberts, A., & Boyle, R. J. (2018). Probiotics for treating eczema. *Cochrane Library*, *2018*(11). https://doi.org/10.1002/14651858.cd006135.pub3
8. Eigenmann, P. A. (2013). Evidence of preventive effect of probiotics and prebiotics for infantile eczema. *Current Opinion in Allergy and Clinical Immunology*, *13*(4), 426–431. https://doi.org/10.1097/aci.0b013e3283630bad
9. Savilahti, E. (2011). Probiotics in the treatment and prevention of allergies in children. *Bioscience and Microflora*, *30*(4), 119–128. https://doi.org/10.12938/bifidus.30.119
10. Osborn, D. A., & Sinn, J. K. (2013). Prebiotics in infants for prevention of allergy. *Cochrane Library*, *2013*(3). https://doi.org/10.1002/14651858.cd006474.pub3
11. Osborn, D. A., & Sinn, J. K. (2007). Prebiotics in infants for prevention of allergic disease and food hypersensitivity. *The Cochrane database of systematic reviews*, (4), CD006474. https://doi.org/10.1002/14651858.CD006474.pub2
12. Foolad, N., & Armstrong, A. (2014). Prebiotics and probiotics: the prevention and reduction in severity of atopic dermatitis in children. *Beneficial Microbes*, *5*(2), 151–160. https://doi.org/10.3920/bm2013.0034
13. Ismail, I. H., Licciardi, P. V., & Tang, M. L. (2013). Probiotic effects in allergic disease. *Journal of Paediatrics and Child Health*, *49*(9), 709–715. https://doi.org/10.1111/jpc.12175
14. Vanderhoof, J. A. (2008). Probiotics in allergy management. *Journal of Pediatric Gastroenterology and Nutrition*, *47*(S2). https://doi.org/10.1097/01.mpg.0000338810.74933.c1
15. Kuitunen, M. (2013). Probiotics and prebiotics in preventing food allergy and eczema. *Current Opinion in Allergy and Clinical Immunology*, *13*(3), 280–286. https://doi.org/10.1097/aci.0b013e328360ed66
16. Kukkonen, K., Savilahti, E., Haahtela, T., Juntunen-Backman, K., Korpela, R., Poussa, T., Tuure, T., & Kuitunen, M. (2007). Probiotics and prebiotic galacto-oligosaccharides in the prevention of allergic diseases: A randomized, double-blind, placebo-controlled

trial. *Journal of Allergy and Clinical Immunology*, *119*(1), 192–198. https://doi.org/10.1016/j.jaci.2006.09.009

17. Wopereis, H., Sim, K., Shaw, A., Warner, J. O., Knol, J., & Kroll, J. S. (2018). Intestinal microbiota in infants at high risk for allergy: Effects of prebiotics and role in eczema development. *Journal of Allergy and Clinical Immunology*, *141*(4), 1334-1342.e5. https://doi.org/10.1016/j.jaci.2017.05.054
18. Tang, M. L. K. (2009). Probiotics and prebiotics: Immunological and clinical effects in allergic disease. *Nestlé Nutrition Institute Workshop Series*, 219–238. https://doi.org/10.1159/000235793
19. Kleniewska, P., & Pawliczak, R. (2024). Can probiotics be used in the prevention and treatment of bronchial asthma? *Pharmacological Reports*. https://doi.org/10.1007/s43440-024-00618-0
20. Wu, Z., Nasab, E. M., Arora, P., & Athari, S. S. (2022). Study effect of probiotics and prebiotics on treatment of OVA-LPS-induced of allergic asthma inflammation and pneumonia by regulating the TLR4/NF-kB signaling pathway. *Journal of Translational Medicine*, *20*(1). https://doi.org/10.1186/s12967-022-03337-3
21. Wawryk-Gawda, E., Markut-Miotła, E., & Emeryk, A. (2021). Postnatal probiotics administration does not prevent asthma in children, but using prebiotics or synbiotics may be effective potential strategies to decrease the frequency of asthma in high-risk children – a meta-analysis of clinical trials. *Allergologia Et Immunopathologia*, *49*(4), 4–14. https://doi.org/10.15586/aei.v49i4.69
22. Meirlaen, L., Levy, E. I., & Vandenplas, Y. (2021). Prevention and Management with Pro-, Pre and Synbiotics in Children with Asthma and Allergic Rhinitis: A Narrative Review. *Nutrients*, *13*(3), 934. https://doi.org/10.3390/nu13030934
23. Huang, L., Guo, J., Li, W., Jiang, M., Wang, F., Kang, J., Liu, T., & Gu, X. (2019). Probiotics, prebiotics, and synbiotics for the treatment of asthma. *Medicine*, *98*(47), e17840. https://doi.org/10.1097/md.0000000000017840
24. Faridzadeh, A., Yadegari, Y., Bakhshaee, M., Kabiri, M., Mohammadi, M., Khoshkhui, M., & Azad, F. J. (2023). The role of synbiotics as adjunctive agents in the treatment of allergic rhinitis: A randomized controlled trial. *Health Science Reports*, *6*(10). https://doi.org/10.1002/hsr2.1571
25. Calle, C. a. G., Vásquez, C. D., Leon, R. M., Benavides, E. E. M., & Leon, A. V. V. (2022). Clinical efficacy of synbiotics in children with allergic rhinitis: An

observational cohort study from a private medical center in Peru. *Immunity Inflammation and Disease*, *10*(12). https://doi.org/10.1002/iid3.736

26. Liu, D., Wang, X., & Zhang, H. (2023). Efficacy and safety of gastrointestinal microbiome supplementation for allergic rhinitis: A systematic review and meta-analysis with trial sequential analysis. *Phytomedicine*, *118*, 154948. https://doi.org/10.1016/j.phymed.2023.154948
27. Kaczynska, A., Klosinska, M., Chmiel, P., Janeczek, K., & Emeryk, A. (2022). 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*, *14*(20), 4328. https://doi.org/10.3390/nu14204328
28. Chang, C., Wang, Q., Li, X., Tan, H., & Huang, G. (2023). The relationship between prebiotic intake and allergic rhinitis. *Laryngoscope Investigative Otolaryngology*, *8*(5), 1146–1153. https://doi.org/10.1002/lio2.1158
29. Shi, J., Wang, Y., Cheng, L., Wang, J., & Raghavan, V. (2022). Gut microbiome modulation by probiotics, prebiotics, synbiotics and postbiotics: a novel strategy in food allergy prevention and treatment. *Critical Reviews in Food Science and Nutrition*, 1–17. https://doi.org/10.1080/10408398.2022.2160962
30. Ribeiro, J., & Pedrosa, C. (2024). Probiotics, prebiotics and food allergy. *European Annals of Allergy and Clinical Immunology*, *56*(03), 99. https://doi.org/10.23822/eurannaci.1764-1489.319
31. Fiocchi, A., Pecora, V., & Dahdah, L. (2016). Probiotics, Prebiotics & Food allergy Prevention: Clinical Data in Children. *Journal of pediatric gastroenterology and nutrition*, *63 Suppl 1*, S14–S17. https://doi.org/10.1097/MPG.0000000000001220
32. Han, C. S. (2024). Prebiotic supplements correct oral probiotic deficiency for lasting allergy relief. *American Journal of Translational Research*, *16*(1), 136–146. https://doi.org/10.62347/jwou4205