Health benefits of Probiotics, Prebiotics, Postbiotics and Synbiotics

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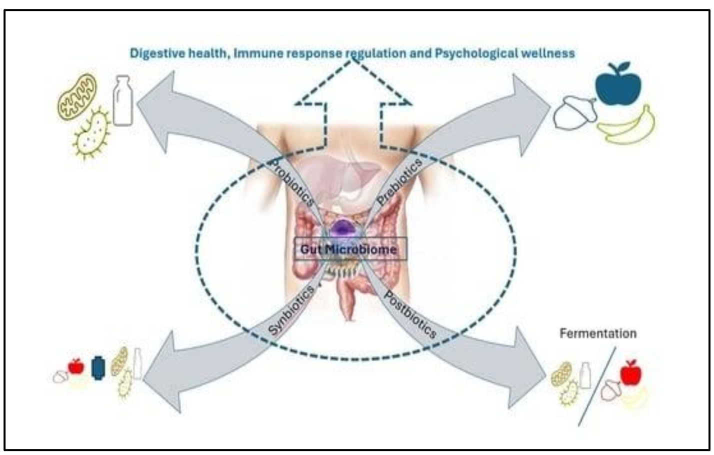
The human gut microbiome, composed of trillions of microorganisms, plays a pivotal role in digestion, immune regulation, and mental health. Maintaining its balance is essential, as disruptions are linked to various metabolic disorders. Functional dietary components—prebiotics, probiotics, synbiotics, and postbiotics (PPSPs)—have emerged as promising strategies to support gut health.

Probiotics are live microorganisms that confer health benefits when consumed in adequate amounts, while prebiotics are non-digestible fibers that stimulate the growth of beneficial bacteria. Synbiotics combine both, enhancing microbial survival and immune function. Postbiotics, produced during probiotic fermentation or derived from inactivated microbial cells, also exert beneficial effects through their bioactive compounds. **Together, PPSPs influence gut microbiota composition, strengthen the intestinal barrier, and regulate metabolic activity, thereby offering therapeutic potential against metabolic diseases.**

Evidence from laboratory and clinical studies highlights their ability to improve immunity, alleviate irritable bowel disease, prevent diarrhoea, reduce allergy severity, and provide anti-inflammatory and antimicrobial effects.



Source: Al-Habsi *et al.* (2024)

Emerging findings suggest additional benefits, including improved lipid metabolism and protection against cardiovascular risks, though long-term randomized trials are needed to confirm these outcomes. Similarly, the immune-modulating role of prebiotics requires further validation, particularly from early life.

Health benefits

Prebiotics and probiotics support immune function by modulating gut microbiota, leading to an increased abundance of beneficial species such as *Bifidobacteria*. They also exhibit significant cholesterol-lowering effects by reducing total cholesterol, LDL cholesterol, and non-HDL cholesterol, thereby contributing to improved cardiovascular health. Synbiotics and postbiotics, on the other hand, provide anti-inflammatory benefits that help manage conditions like colitis and relieve gastrointestinal discomfort. In addition, their antioxidant properties reduce oxidative stress, offering protective effects in metabolic disorders, including diabetes, and promoting overall health.

Benefits of Prebiotics

Prebiotics are indigestible dietary fibers that play an important role in enhancing host cell function and selectively modulating the gut microbiota. Increasing evidence links prebiotic-rich diets with improved immune responses and overall health benefits. Clinical studies, such as that by Soldi et al. demonstrated that supplementation with inulin-type fructans (Orafti®, 6 g/day for 24 weeks) in healthy children increased *Bifidobacteria* levels ($p = 0.014$) and improved immune functions, highlighting their ability to alter gut microbial composition.

Prebiotics exert immunomodulatory effects through two main mechanisms: by reshaping microbial populations or by generating metabolites such as short-chain fatty acids (SCFAs). Experimental work in obese and diabetic mice further supports their role in reducing metabolic endotoxemia and inflammation. Cani et al. showed that prebiotic supplementation reduced plasma lipopolysaccharides and cytokines, decreased hepatic oxidative stress markers, and improved gut barrier integrity through increased tight-junction protein expression. Enhanced glucagon-like peptide-2 (GLP-2) secretion and its downstream effects—crypt cell proliferation, villus elongation, and reduced apoptosis—also contribute to strengthening barrier function.

In early-life nutrition, prebiotic oligosaccharides have shown promise in allergy prevention. Clinical trials demonstrate that infants fed prebiotic-supplemented hypoallergenic formulas had reduced risk of developing atopic dermatitis and other allergic conditions, suggesting immunomodulatory effects via altered gut flora and improved T-regulatory (Treg) cell activity. Prebiotics have also been associated with clinical improvements in atopic dermatitis symptoms, such as reduced itching and normalized epidermal lipid profiles, potentially through changes in eosinophil levels and immune signaling pathways.

Beyond indirect effects mediated by microbiota, some prebiotics directly influence host immunity. Wu et al. (2017) reported that non-digestible oligosaccharides modulate host kinome and mucosal immune responses independent of microbial shifts, suppressing pro-inflammatory signaling via MAPK and NF-κB pathways. These findings suggest that prebiotics act both as substrates for beneficial bacteria and as direct modulators of host immune function. Overall, prebiotic supplementation is strongly associated with enhanced immune function, improved gut barrier integrity, reduced inflammatory markers, and potential prevention of metabolic and allergic disorders.

Benefits of Probiotics

An increasing body of research indicates that probiotics can exert cholesterol-lowering and cardiometabolic benefits when consumed in adequate amounts. In a clinical study on hypercholesterolemic men, supplementation with *Enterococcus faecium* CRL 183 and *Lactobacillus helveticus* 416, combined with soy products, significantly reduced total cholesterol (13.8%), non-HDL cholesterol (14.7%), and LDL-C (24%), while HDL-C remained unchanged. The lipid-lowering actions of probiotics have been attributed to cholesterol assimilation, bile salt deconjugation, microbiota modulation, and the production of short-chain fatty acids (SCFAs) during fermentation.

Further evidence supports probiotic actions in regulating lipid metabolism through multiple pathways, including cholesterol binding in the intestine, modulation of bile acid synthesis, and hepatic cholesterol regulation via SCFA production. For example, *Lactobacillus rhamnosus* BFE5264 from fermented milk reduced cholesterol levels by modulating gut microbiota composition and increasing SCFA production. Subsequent studies linked these effects to improved cholesterol efflux through ABCG5/8 upregulation, mediated by liver X receptor activation. Similarly, randomized controlled trials with *Lactobacillus reuteri* NCIMB 30242 in yogurt formulations demonstrated significant reductions in LDL-C, total cholesterol, and non-HDL-C among hypercholesterolemic subjects.

Pediatric studies also highlight probiotic potential. Guardamagna et al. reported that supplementation with *Bifidobacterium* strains improved lipid profiles in children with dyslipidemia, while other evidence suggests that certain *Bifidobacterium* species enhance biological processes through conjugated linoleic acid synthesis. In addition to lipid regulation, probiotics exhibit immunomodulatory actions by competitively adhering to intestinal mucosa, thereby reducing endotoxin circulation and improving host immune responses. Multi-strain probiotic formulations, such as Ecologic® Barrier, significantly lowered endotoxin levels and improved glycemic and lipid parameters in patients with type 2 diabetes mellitus (T2DM), with reductions of up to 70% in endotoxin and 19% in TC:HDL ratio.

Clinical studies further support their role in metabolic health. Supplementation with *Lactobacillus plantarum* strains reduced triglycerides and cholesterol, modified gut microbiota composition, and increased SCFA production. These SCFAs, particularly butyrate and propionate, regulate gut hormones such as GLP-1, GIP, peptide YY, and ghrelin, thereby influencing triglyceride turnover and energy balance. In T2DM patients with nephropathy, *L. plantarum* A7 supplementation improved lipid profiles and glomerular function, reducing LDL-C, total cholesterol, non-HDL-C, and triglycerides.

Overall, probiotics demonstrate consistent potential in lowering LDL-C, TC, and non-HDL-C, improving glycemic control, reducing endotoxemia, and enhancing immune responses. However, outcomes vary across strains and populations, and some studies report negligible effects. These inconsistencies highlight the need for more long-term, strain-specific clinical trials to validate their role as a sustainable therapeutic strategy for hyperlipidemia, diabetes, and related metabolic disorders.

Benefits of Postbiotics and Synbiotics

Postbiotics and synbiotics represent emerging innovations in nutritional science with significant health-promoting potential. Postbiotics, derived from probiotic fermentation products, exert biological effects through bioactive metabolites that support gut homeostasis, immune regulation, and disease prevention. Synbiotics, combining probiotics with prebiotics, enhance the survival and activity of beneficial microbes, offering synergistic improvements in gastrointestinal health and systemic immunity. Together, these interventions highlight a holistic approach to modulating the gut microbiota and improving host health outcomes.

Antimicrobial Properties

Both postbiotics and synbiotics exhibit strong antimicrobial potential. In vivo studies show that *Lactobacillus* spp. reduce *Escherichia coli*-induced intestinal inflammation by suppressing NF-κB activation, thereby limiting excessive immune responses. Their antimicrobial effect is attributed to the synergistic action of lactic acid and bacteriocins. In livestock, synbiotic supplementation (e.g., *Saccharomyces cerevisiae* + mannan oligosaccharides) improved feed efficiency, weight gain, and gut health in broilers while significantly reducing pathogenic *E. coli* counts in the intestine and cecum. Additionally, postbiotics derived from *Lactobacillus paracasei* CCFM1224 mitigated non-alcoholic fatty liver disease (NAFLD) in mice by modulating gut microbiota composition and liver metabolism, resulting in reduced hepatic steatosis, insulin resistance, and inflammation.

Antioxidant Properties

Postbiotics and synbiotics also enhance antioxidant defense. For instance, dietary supplementation with *Lactobacillus plantarum* postbiotics improved antioxidant enzyme activity, reduced lipid peroxidation, and enhanced rumen barrier function in lambs. Clinical evidence supports similar effects in humans: a trial combining *L. acidophilus*with cinnamon in type 2 diabetes mellitus (T2DM) patients significantly reduced fasting blood sugar and enhanced antioxidant enzyme activity, partly due to synergistic antimicrobial and antioxidant actions of probiotics and cinnamaldehyde. Synbiotic supplementation in diabetic hemodialysis patients also improved glycemic control, reduced inflammation, and enhanced antioxidant capacity. Collectively, these findings suggest that PPSPs reduce oxidative stress by scavenging free radicals, lowering pro-inflammatory cytokines, and boosting endogenous antioxidant systems.

Anti-Inflammatory Properties

Numerous studies highlight the anti-inflammatory capacity of postbiotics and synbiotics. *Lactobacillus bulgaricus* and *Streptococcus thermophilus* postbiotics reduced colitis severity in murine models by modulating intestinal immune responses. Clinical supplementation with *Bifidobacterium lactis* plus fructo-oligosaccharides in T2DM patients decreased gastrointestinal discomfort and pro-inflammatory cytokines such as IFN-γ. In calves, synbiotics (inulin + *S. cerevisiae*) improved gut morphology and reduced intestinal pH, supporting gastrointestinal resilience. In pregnant women with gestational diabetes mellitus, synbiotic supplementation significantly improved atherogenic indices (TG/HDL-C ratio), reduced inflammatory biomarkers, and lowered cardiovascular risk factors. These findings underscore their role in mitigating chronic inflammation and associated metabolic risks.

Food Quality Applications

Beyond health effects, postbiotics and synbiotics contribute to functional food innovation. Incorporating postbiotic-producing strains such as *Lactobacillus rhamnosus* improved cheese yield, texture, and moisture retention. Postbiotic supernatants (e.g., *Lactobacillus sakei*) reduced pathogenic contamination in grilled meats, while supplementation with Bimuno® galactooligosaccharides (B-GOS®) improved gut microbiota composition and reduced gastrointestinal symptoms in autistic children. In fermented dairy, polysaccharides from *Lactarius volemus* enhanced probiotic yogurt fermentation, water retention, and nutritional quality. Similarly, postbiotic-treated soybeans exhibited extended shelf life and reduced microbial spoilage. These applications highlight the potential of PPSPs to improve both the nutritional and sensory qualities of food while enhancing safety and sustainability.

Conclusions

Prebiotics support gut microbiota modulation and integrity, while probiotics show benefits not only in gastrointestinal disorders but also in metabolic conditions such as hypercholesterolemia and type 2 diabetes. Synbiotics exert synergistic effects on gut health and immunity, whereas postbiotics offer antibacterial and anti-inflammatory potential through bioactive compounds. Fecal microbiota transplantation, despite certain risks, remains a promising approach for restoring microbial balance. Although gastrointestinal disorders have been the primary focus, future research should extend to metabolic diseases, including cardiovascular disorders and hyperuricemia.

References

Li, H.-Y.; Zhou, D.-D.; Gan, R.-Y.; Huang, S.-Y.; Zhao, C.-N.; Shang, A.O.; Xu, X.-Y.; Li, H.-B. Effects and Mechanisms of Probiotics, Prebiotics, Synbiotics, and Postbiotics on Metabolic Diseases Targeting Gut Microbiota: A Narrative Review. *Nutrients* 2021, *13*, 3211.

Thorakkattu, P.; Khanashyam, A.C.; Shah, K.; Babu, K.S.; Mundanat, A.S.; Deliephan, A.; Deokar, G.S.; Santivarangkna, C.; Nirmal, N.P. Postbiotics: Current Trends in Food and Pharmaceutical Industry. *Foods*2022, *11*, 3094.

Fiore, W.; Arioli, S.; Guglielmetti, S. The Neglected Microbial Components of Commercial Probiotic Formulations. *Microorganisms* 2020, *8*, 1177.

Salminen, S.; Collado, M.C.; Endo, A.; Hill, C.; Lebeer, S.; Quigley, E.M.M.; Sanders, M.E.; Shamir, R.; Swann, J.R.; Szajewska, H.; et al. The International Scientific Association of Probiotics and Prebiotics (ISAPP) Consensus Statement on the Definition and Scope of Postbiotics. *Nat. Rev. Gastroenterol. Hepatol.* 2021, *18*, 649–667.

Lockyer, S.; Stanner, S. Prebiotics—An Added Benefit of Some Fibre Types. *Nutr. Bull.* 2019, *44*, 74–91.

Rastall, R.A.; Diez-Municio, M.; Forssten, S.D.; Hamaker, B.; Meynier, A.; Moreno, F.J.; Respondek, F.; Stahl, B.; Venema, K.; Wiese, M. Structure and Function of Non-Digestible Carbohydrates in the Gut Microbiome. *Benef. Microbes* 2022, *13*, 95–168.

Al-Habsi, N., Al-Khalili, M., Haque, S. A., Elias, M., Olqi, N. A., & Al Uraimi, T. (2024). Health Benefits of Prebiotics, Probiotics, Synbiotics, and Postbiotics. *Nutrients*, *16*(22), 3955

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