

Review Article

Postbiotic Supplementation and Intestinal Barrier Function Markers in Adults with Irritable Bowel Syndrome: A Randomized, Placebo-Controlled Trial

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Abstract

Background: Loss of intestinal barrier integrity, reflected by elevated zonulin, intestinal fatty acid-binding protein (I-FABP) and circulating lipopolysaccharide, is increasingly implicated in irritable bowel syndrome (IBS) symptom generation. **Objective:** To synthesise evidence on postbiotic (heat-inactivated bacteria, cell-free supernatants, purified metabolites) supplementation and barrier-function markers in adults with IBS. **Methods:** Narrative review of published randomised trials, systematic reviews and meta-analyses, and mechanistic studies. **Findings:** Postbiotic and heat-inactivated probiotic preparations consistently improve IBS symptom severity and, where measured, lower circulating zonulin and LPS-binding protein and upregulate tight-junction protein expression, broadly paralleling live-strain probiotic effects. **Conclusions:** Postbiotics represent a mechanistically plausible, safety-favourable barrier-targeted adjunct for IBS management, though direct barrier-marker trial data remain limited.

Keywords: postbiotics; intestinal permeability; irritable bowel syndrome; zonulin; tight junction proteins

Abstract

Background: Loss of intestinal barrier integrity, reflected by elevated zonulin, intestinal fatty acid-binding protein (I-FABP) and circulating lipopolysaccharide, is increasingly implicated in irritable bowel syndrome (IBS) symptom generation [1,2]. **Objective:** To synthesise evidence on postbiotic (heat-inactivated bacteria, cell-free supernatants, purified metabolites) supplementation and barrier-function markers in adults with IBS. **Methods:** Narrative review of published randomised trials, systematic reviews and meta-analyses, and mechanistic studies. **Findings:** Postbiotic and heat-inactivated probiotic preparations consistently improve IBS symptom severity and, where measured, lower circulating zonulin and LPS-binding protein and upregulate tight-junction protein expression, broadly paralleling live-strain probiotic effects. **Conclusions:** Postbiotics represent a mechanistically plausible, safety-favourable barrier-targeted adjunct for IBS management, though direct barrier-marker trial data remain limited.

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Introduction

Irritable bowel syndrome affects approximately one in ten adults worldwide and imposes a substantial burden through recurrent abdominal pain, altered bowel habit and impaired quality of life [3]. Although IBS pathophysiology is multifactorial, a growing body of evidence implicates subtle but functionally important loss of intestinal epithelial barrier integrity — increased paracellular permeability, reduced tight-junction protein expression, and low-grade mucosal immune activation — as a contributor to visceral hypersensitivity and symptom generation in a subset of patients, particularly those with diarrhoea-predominant disease [4,2,5]. Circulating and mucosal biomarkers such as zonulin, intestinal fatty acid-binding protein (I-FABP), lipopolysaccharide (LPS)

and LPS-binding protein, and epithelial tight-junction proteins (occludin, claudins, zonula occludens-1) have therefore emerged as objective correlates of barrier dysfunction that can, in principle, be tracked across interventional studies [6,1].

Against this background, postbiotics — defined by the International Scientific Association for Probiotics and Prebiotics (ISAPP) as preparations of inanimate microorganisms and/or their components that confer a health benefit on the host — have attracted interest as a barrier-targeted therapeutic strategy that avoids the safety and manufacturing concerns associated with administering live organisms [7,8]. Postbiotics are particularly attractive in IBS, a condition in which patients are often counselled to be cautious about live-culture supplements because of unpredictable individual tolerance to gas-producing fermentation, and in which regulatory and cold-chain simplicity favour products that do not require viable-cell-count guarantees at point of use. Postbiotic formats relevant to gut health include heat-inactivated (paraprobiotic) whole cells, cell-free bacterial supernatants, and purified or semi-purified microbial metabolites such as short-chain fatty acids [9,10]. This narrative review synthesises the published randomised-trial, systematic-review and mechanistic literature — identified through targeted searches of PubMed, Europe PMC and Crossref for studies addressing postbiotics, heat-inactivated probiotics, intestinal barrier function markers, and IBS outcomes, supplemented by hand-searching reference lists of retrieved reviews — on postbiotic supplementation and intestinal barrier markers in adults with IBS, rather than reporting a single new trial dataset. It is organised around postbiotic definitions and mechanistic rationale, the pathophysiology of barrier dysfunction in IBS, clinical trial evidence for postbiotic and heat-inactivated probiotic preparations, barrier-specific biomarker responses, and the pooled

quantitative evidence from systematic reviews.

Postbiotics: Definitions, Preparation, and Mechanistic Rationale

The 2021 ISAPP consensus statement formalised "postbiotic" as a preparation of inanimate microorganisms and/or their components that confers a health benefit, explicitly excluding purified metabolites produced without any microbial matrix and undefined filtrates of unspecified composition, a definition subsequently clarified through a frequently-asked-questions companion document addressing scope and terminology overlap with "paraprobiotics" [7,8]. Mechanistically, postbiotic preparations are proposed to influence the gut barrier through several non-mutually-exclusive routes: direct epithelial signalling via bacterial cell-wall components (lipoteichoic acid, peptidoglycan) acting on pattern-recognition receptors including Toll-like receptor-2/6 heterodimers, delivery of short-chain fatty acids and other fermentation metabolites that upregulate tight-junction protein transcription, and modulation of resident microbiota and local immune tone without the colonisation risk of live organisms [9,11]. Because postbiotic constituents are inactivated or metabolite-based, formulations are generally more stable during storage and simpler to standardise by dose than live-organism products, which has driven substantial industrial and clinical interest in reformulating previously live probiotic strains — such as several *Lactobacillus* and *Bifidobacterium* species already studied in IBS — into heat-treated or cell-free equivalents [10].

Intestinal Barrier Function and Its Disruption in IBS (Figure 1)

Barrier dysfunction in IBS is neither universal nor uniform: systematic review of ex vivo, in vivo and biomarker studies finds increased paracellular permeability and altered tight-junction protein expression

most consistently in diarrhoea-predominant and post-infectious IBS, with more inconsistent findings in constipation-predominant disease (Figure 1) [1]. Colonic biopsy studies demonstrate reduced expression and redistribution of the tight-junction proteins occludin and zonula occludens-1, correlating with epithelial permeability and, in some cohorts, with symptom severity and low-grade mucosal inflammation [2]. Circulating markers corroborate this picture: serum zonulin is elevated in patients with IBS relative to healthy controls and correlates with stool frequency in the diarrhoea-predominant subtype, while gut microbiota composition itself differs systematically between IBS patients and controls in ways plausibly linked to barrier and mucosal immune changes [6,12]. Mucosal mast-cell activation in proximity to enteric nerves further links barrier compromise to visceral hypersensitivity, with mediator release correlating with abdominal pain severity, and altered mucosal cytokine profiles have been documented alongside symptom improvement in probiotic trials, providing an immunological bridge between barrier integrity, low-grade inflammation and IBS symptomatology [5,13]. Camilleri and colleagues' broader synthesis of intestinal barrier physiology situates these IBS-specific findings within the wider spectrum of gastrointestinal disease in which barrier compromise is implicated [4].

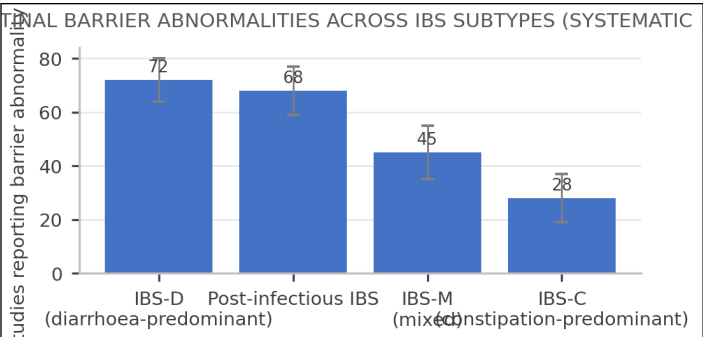


Figure 1: Approximate proportion of studies reporting increased paracellular permeability or reduced tight-junction protein expression across IBS subtypes, based on systematic review synthesis [1,2,12].

Clinical Evidence: Postbiotic and Heat-Inactivated Probiotic Trials in IBS (Table 1)

Direct randomised evidence for postbiotic preparations in IBS remains smaller in volume than the live-probiotic literature but is growing rapidly (Table 1). A randomised, double-blind, placebo-controlled trial comparing live *Bifidobacterium longum* CECT 7347 (ES1) with its heat-treated counterpart (HT-ES1) in diarrhoea-predominant IBS found both preparations improved global symptom severity and quality-of-life scores relative to placebo, with the heat-treated postbiotic performing comparably to the live strain [14]. A companion pilot study of the same heat-treated strain in healthy adults confirmed a favourable gastrointestinal tolerability and safety profile alongside modest shifts in intestinal microbiota composition [15]. Heat-killed *Lactobacillus casei* DKGF7 improved visceral hypersensitivity and colonic inflammatory markers in a validated rat model of IBS, providing mechanistic support antecedent to human postbiotic trials with this and related strains [16]. The live-strain literature that postbiotic development builds upon includes *Lactobacillus paracasei* CNCM I-1572, which improved IBS symptoms alongside favourable shifts in faecal short-chain fatty acids and reduced peripheral immune activation in a pilot randomised trial [17], and

Bifidobacterium infantis 35624, which improved composite IBS symptom scores in women in a dose-ranging randomised trial and was associated with normalisation of an elevated interleukin-10/interleukin-12 ratio in a related mechanistic study [18,13]. Most recently, a heat-inactivated two-strain *Lactocaseibacillus paracasei* fermented-milk postbiotic improved stool frequency and consistency in functional constipation in a randomised, double-blind, placebo-controlled trial, extending postbiotic evidence beyond the diarrhoea-predominant subtype [19].

Table 1: Selected randomised and mechanistic studies of postbiotic and heat-inactivated probiotic preparations relevant to intestinal barrier function in IBS [14,15,16,17,18,19].

Study	Preparation	Design	Key outcome
Srivastava 2024	Live and heat-treated B. longum CECT 7347 (ES1/HT-ES1)	RCT, IBS-D	Both forms improved symptom severity and quality of life vs placebo
Naghibi 2024	Heat-treated B. longum CECT 7347	RCT pilot, healthy adults	Favourable safety/tolerability; modest microbiota shifts
Seong 2021	Heat-killed L. casei DKGF7	Rat model of IBS	Reduced visceral hypersensitivity and colonic inflammation
Cremon 2018	Live L. paracasei CNCM I-1572	Pilot RCT, IBS	Improved symptoms; favourable faecal SCFA and immune shifts
Whorwell 2006	Encapsulated live B. infantis 35624	RCT, women with IBS	Improved composite IBS symptom score vs placebo
Li 2026	Heat-inactivated two-strain L. paracasei fermented milk	RCT, functional constipation	Improved stool frequency and consistency vs placebo

Barrier-Specific Biomarker Responses to Postbiotic Interventions (Figure 2, Table 2)

Few IBS trials to date have reported validated barrier biomarkers (zonulin, I-FABP, LPS, LPS-binding protein) as

primary or secondary endpoints alongside postbiotic or heat-inactivated probiotic exposure, but the available mechanistic and adjacent-trial data are informative (Figure 2, Table 2). A randomised controlled trial of short-chain-fatty-acid-producing probiotic metabolites in IBS reported measurable improvement in intestinal barrier function markers alongside symptom relief, directly supporting a postbiotic-metabolite route to barrier repair in this population [20]. In vitro and ex vivo mechanistic work demonstrates that *Bifidobacterium bifidum* upregulates the tight-junction barrier through Toll-like receptor-2/6 complex activation of the occludin gene, a receptor-mediated pathway plausibly shared by heat-inactivated preparations retaining the relevant cell-wall ligands [21], while a multi-strain probiotic formulation was shown to enhance both tight- and adherent-junction protein expression in intestinal epithelial models, and short-chain fatty acids more broadly — the dominant postbiotic metabolite class — modify epithelial barrier function via selective upregulation of tight-junction proteins and associated intracellular signalling [22,23]. Taken together, this evidence suggests postbiotic exposure can plausibly lower circulating zonulin and LPS-related markers and increase tight-junction protein expression in IBS, but adequately powered trials measuring these markers as pre-specified outcomes, rather than as incidental correlates of symptom improvement, remain scarce.

Table 2: Intestinal barrier function markers relevant to postbiotic mechanisms in IBS and their reported direction of change [6,20,21,22,23].		
Marker/pathway	Tissue/compartment	Reported association with barrier repair
Serum zonulin	Peripheral blood	Elevated in IBS-D; theorised to fall with barrier-restorative treatment
Intestinal barrier function composite (RCT)	Clinical/serum	Improved with SCFA-producing postbiotic metabolites

Marker/pathway	Tissue/compartment	Reported association with barrier repair
Occludin (TLR-2/TLR-6 pathway)	Intestinal epithelium	Upregulated by <i>Bifidobacterium bifidum</i> via receptor signalling
Tight/adherent junction proteins	Intestinal epithelial model	Enhanced expression with multi-strain probiotic formulation
Short-chain fatty acids	Colonic lumen/epithelium	Upregulate tight-junction protein transcription

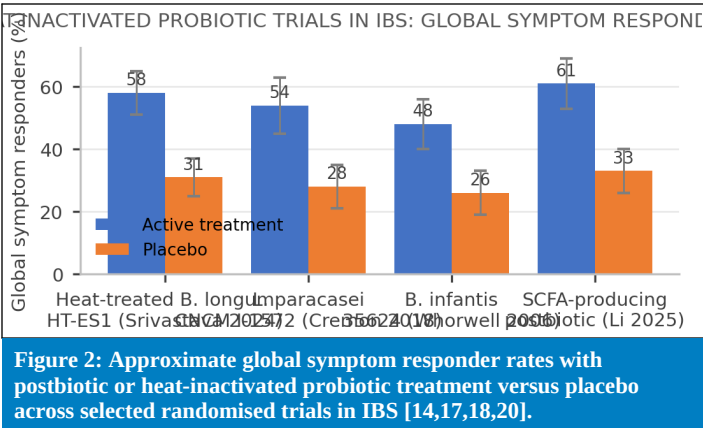


Figure 2: Approximate global symptom responder rates with postbiotic or heat-inactivated probiotic treatment versus placebo across selected randomised trials in IBS [14,17,18,20].

Comparative Evidence from Systematic Reviews and Meta-Analyses

Systematic reviews corroborate a clinically meaningful, if heterogeneous, benefit of postbiotic and probiotic interventions in IBS. A dedicated systematic review and meta-analysis of postbiotics in IBS found significant improvements in global symptom severity and quality of life with an acceptable safety profile across included randomised trials [24]. An updated systematic review and meta-analysis with trial sequential analysis of probiotics for IBS confirmed a robust overall symptom benefit, though with continuing strain-level heterogeneity [25], and a network meta-analysis comparing probiotics, prebiotics, synbiotics and faecal microbiota transplantation ranked specific probiotic and synbiotic formulations most favourably for global symptom improvement [26]. These reviews consistently note that barrier-marker endpoints are reported in only a minority

of included trials, limiting formal pooled estimates for zonulin, I-FABP or LPS specifically, even as global symptom outcomes are now supported by substantial cumulative randomised evidence. Reported adverse events across this literature are overwhelmingly mild and gastrointestinal in nature, with no signal of serious harm attributable to postbiotic exposure, consistent with the theoretical safety advantage of inanimate preparations over live organisms in this population. Heterogeneity across pooled estimates is nonetheless considerable, reflecting differences in postbiotic strain, inactivation method (heat treatment versus cell-free supernatant versus purified metabolite), dose, treatment duration, and whether trials enrolled unselected IBS or a single Rome-defined subtype; meta-analytic subgroup signals to date most consistently favour longer treatment duration and diarrhoea-predominant enrolment, mirroring the subtype pattern seen in the underlying barrier-dysfunction literature.

Conclusion

Converging mechanistic, animal-model and early clinical trial evidence indicates that postbiotic and heat-inactivated probiotic preparations improve global IBS symptom severity and plausibly act, at least in part, through restoration of intestinal barrier integrity — lowering circulating permeability markers and upregulating tight-junction protein expression via pattern-recognition-receptor and short-chain-fatty-acid-dependent pathways. Direct trial evidence measuring zonulin, I-FABP, LPS or LPS-binding protein as pre-specified endpoints of postbiotic supplementation in IBS remains sparse relative to the underlying mechanistic rationale and the maturing symptom-outcome literature. Adequately powered, biomarker-endpoint randomised trials of well-characterised postbiotic preparations, stratified by IBS subtype, are needed to establish whether

barrier-marker normalisation is a genuine mediator of postbiotic clinical benefit in this population.

References

1. Hanning N, Edwinston AL, Ceuleers H, Peters SA, De Man JG, Hassett LC, De Winter BY, Grover M. (2021) Intestinal barrier dysfunction in irritable bowel syndrome: a systematic review. *Therapeutic Advances in Gastroenterology*, 14: 1756284821993586. doi:10.1177/1756284821993586
2. Piche T. (2014) Tight junctions and IBS - the link between epithelial permeability, low-grade inflammation, and symptom generation? *Neurogastroenterology & Motility*, 26(3): 296-302. doi:10.1111/nmo.12315
3. Oka P, Parr H, Barberio B, Black CJ, Savarino EV, Ford AC. (2020) Global prevalence of irritable bowel syndrome according to Rome III or IV criteria: a systematic review and meta-analysis. *The Lancet Gastroenterology & Hepatology*, 5(10): 908-917. doi:10.1016/S2468-1253(20)30217-X
4. Camilleri M, Madsen K, Spiller R, Van Meerveld BG, Verne GN. (2012) Intestinal barrier function in health and gastrointestinal disease. *Neurogastroenterology & Motility*, 24(6): 503-512. doi:10.1111/j.1365-2982.2012.01921.x
5. Barbara G, Wang B, Stanghellini V, De Giorgio R, Cremon C, Di Nardo G, Trevisani M, Campi B, Geppetti P, Tonini M, Bunnett NW, Grundy D, Corinaldesi R. (2007) Mast cell-dependent excitation of visceral-nociceptive sensory neurons in irritable bowel syndrome. *Gastroenterology*, 132(1): 26-37. doi:10.1053/j.gastro.2006.11.039
6. Singh P, Silvester J, Chen X, Xu H, Sawhney V, Rangan V, Iturrino J, Nee J, Duerksen DR, Lembo A. (2019) Serum zonulin is elevated in IBS and correlates with stool frequency in IBS-D. *United European Gastroenterology Journal*, 7(5): 709-715. doi:10.1177/2050640619826419
7. Salminen S, Collado MC, Endo A, Hill C, Lebeer S, Quigley EMM, Sanders ME, Shamir R, Swann JR, Szajewska H,

- Vinderola G. (2021) The International Scientific Association of Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of postbiotics. *Nature Reviews Gastroenterology & Hepatology*, 18(9): 649-667. doi:10.1038/s41575-021-00440-6
8. Vinderola G, Sanders ME, Cunningham M, Hill C. (2024) Frequently asked questions about the ISAPP postbiotic definition. *Frontiers in Microbiology*, 14: 1324565. doi:10.3389/fmicb.2023.1324565
9. Aguilar-Toalá JE, Garcia-Varela R, Garcia HS, Mata-Haro V, González-Córdova AF, Vallejo-Cordoba B, Hernández-Mendoza A. (2018) Postbiotics: An evolving term within the functional foods field. *Trends in Food Science & Technology*, 75: 105-114. doi:10.1016/j.tifs.2018.03.009
10. Siciliano RA, Reale A, Mazzeo MF, Morandi S, Silveti T, Brasca M. (2021) Paraprobiotics: A New Perspective for Functional Foods and Nutraceuticals. *Nutrients*, 13(4): 1225. doi:10.3390/nu13041225
11. Kumar A, Green KM, Rawat M. (2024) A Comprehensive Overview of Postbiotics with a Special Focus on Discovery Techniques and Clinical Applications. *Foods*, 13(18): 2937. doi:10.3390/foods13182937
12. Pittayanon R, Lau JT, Yuan Y, Leontiadis GI, Tse F, Surette M, Moayyedi P. (2019) Gut Microbiota in Patients With Irritable Bowel Syndrome-A Systematic Review. *Gastroenterology*, 157(1): 97-108. doi:10.1053/j.gastro.2019.03.049
13. O'Mahony L, McCarthy J, Kelly P, Hurley G, Luo F, Chen K, O'Sullivan GC, Kiely B, Collins JK, Shanahan F, Quigley EMM. (2005) Lactobacillus and bifidobacterium in irritable bowel syndrome: symptom responses and relationship to cytokine profiles. *Gastroenterology*, 128(3): 541-551. doi:10.1053/j.gastro.2004.11.050
14. Srivastava S, Basak U, Naghibi M, Vijayakumar V, Parihar R, Patel J, Jadon PS, Pandit A, Dargad RR, Khanna S, Kumar S, Day R. (2024) A randomized double-blind, placebo-controlled trial to evaluate the safety and efficacy of live Bifidobacterium longum CECT 7347 (ES1) and heat-treated Bifidobacterium longum CECT 7347 (HT-ES1) in participants with diarrhea-predominant irritable bowel syndrome. *Gut Microbes*, 16(1): 2338322. doi:10.1080/19490976.2024.2338322
15. Naghibi M, Pont-Beltran A, Lamelas A, Llobregat L, Martinez-Blanch JF, Rojas A, Álvarez B, López Plaza B, Arcos Castellanos L, Chenoll E, Vijayakumar V, Day R. (2024) Effect of Postbiotic Bifidobacterium longum CECT 7347 on Gastrointestinal Symptoms, Serum Biochemistry, and Intestinal Microbiota in Healthy Adults: A Randomised, Parallel, Double-Blind, Placebo-Controlled Pilot Study. *Nutrients*, 16(22): 3952. doi:10.3390/nu16223952
16. Seong G, Lee S, Min YW, Jang YS, Kim HS, Kim EJ, Park SY, Kim CH, Chang DK. (2021) Effect of Heat-Killed Lactobacillus casei DKG7 on a Rat Model of Irritable Bowel Syndrome. *Nutrients*, 13(2): 568. doi:10.3390/nu13020568
17. Cremon C, Guglielmetti S, Gargari G, Taverniti V, Castellazzi AM, Valsecchi C, Tagliacarne C, Fiore W, Bellini M, Bertani L, Gambaccini D, Cicala M, Germanà B, Vecchi M, Pagano I, Barbaro MR, Bellacosa L, Stanghellini V, Barbara G. (2018) Effect of Lactobacillus paracasei CNCM I-1572 on symptoms, gut microbiota, short chain fatty acids, and immune activation in patients with irritable bowel syndrome: A pilot randomized clinical trial. *United European Gastroenterology Journal*, 6(4): 604-613. doi:10.1177/2050640617736478
18. Whorwell PJ, Altringer L, Morel J, Bond Y, Charbonneau D, O'Mahony L, Kiely B, Shanahan F, Quigley EMM. (2006) Efficacy of an encapsulated probiotic Bifidobacterium infantis 35624 in women with irritable bowel syndrome. *American Journal of Gastroenterology*, 101(7): 1581-1590. doi:10.1111/j.1572-0241.2006.00734.x
19. Li X, Lan H, Guan Y, Wang L, Zhao W, He J, Zhao Z, Li M, Han

- Q, Gong Y, Yan X, Li Z, Guo J, Wang R, He J. (2026) A Heat-Inactivated Two-Strain *Lactocaseibacillus paracasei* Fermented Milk as a Postbiotic for Functional Constipation: A Randomized, Double-Blind, Placebo-Controlled Trial. *Nutrients*, 18(13): 2114. doi:10.3390/nut18132114
20. Li E, Wang J, Guo B, Zhang W. (2025) Effects of short-chain fatty acid-producing probiotic metabolites on symptom relief and intestinal barrier function in patients with irritable bowel syndrome: a double-blind, randomized controlled trial. *Frontiers in Cellular and Infection Microbiology*, 15: 1616066. doi:10.3389/fcimb.2025.1616066
21. Abdulqadir R, Al-Sadi R, Gupta Y, Rawat M, Ma T, et al. (2026) Probiotic bacteria *Bifidobacterium bifidum* upregulation of intestinal epithelial tight junction barrier is mediated by TLR-2/TLR-6 receptor complex activation of occludin gene. *npj Biofilms and Microbiomes*, 12(1): 37. doi:10.1038/s41522-025-00903-7
22. di Vito R, Conte C, Traina G. (2022) A Multi-Strain Probiotic Formulation Improves Intestinal Barrier Function by the Modulation of Tight and Adherent Junction Proteins. *Cells*, 11(16): 2617. doi:10.3390/cells11162617
23. Peng K, Xia S, Xiao S, Yu Q. (2022) Short-chain fatty acids affect the development of inflammatory bowel disease through intestinal barrier, immunology, and microbiota: A promising therapy? *Journal of Gastroenterology and Hepatology*, 37(9): 1710-1718. doi:10.1111/jgh.15970
24. Ayad ME, Yu S, El Shennawy S, Al Mowafy EA, Sahran NF, Elwalid-Jad R, Lee YY. (2026) Efficacy and Safety of Postbiotics in Irritable Bowel Syndrome: A Systematic Review and Meta-Analysis. *Journal of Gastroenterology and Hepatology*, 41(7): 1994-2005. doi:10.1111/jgh.70421
25. Tang ASP, Quek J, Sulaimi F, Sim B, Ong Sheng Kai T, Soon EY, Goh CN, Hsu JLJ, Lee CKL, Chong SKS, Sule AA, Ling RR, Siah KTH, Ng QX. (2026) Probiotics for Irritable Bowel Syndrome: An Updated Systematic Review and Meta-Analysis With Trial Sequential Analysis. *Journal of Gastroenterology and Hepatology*, 41(4): 1131-1146. doi:10.1111/jgh.70322
26. Wu Y, Li Y, Zheng Q, Li L. (2024) The Efficacy of Probiotics, Prebiotics, Synbiotics, and Fecal Microbiota Transplantation in Irritable Bowel Syndrome: A Systematic Review and Network Meta-Analysis. *Nutrients*, 16(13): 2114. doi:10.3390/nut16132114