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Potency of a Specific Probiotic in Promoting Health Quality: A Study of Microbiota Gut Brain Axis

Khairun Nisa Berawi[1*], Sutopo Hadi[2], Maria Erna Kustyawati[3], Aprina Aprina[4], Michelle Adiva[5], Rizki Arisandi[1], Norbertus Marcell Prayogi[1]
[1]Physiology Department, Medical Faculty, Universitas Lampung, Bandar Lampung, Indonesia
[2]Chemistry Department, Math & Science Faculty, Universitas Lampung, Bandar Lampung, Indonesia
[3]Agriculture Product Technology Department, Agriculture Faculty, Universitas Lampung, Bandar Lampung, Indonesia
[4]Nursing Departement, Poltekkes Kemenkes Tanjung Karang, Bandar Lampung, Indonesia
[5]Molecular Science Department, Science Faculty, University of Adelaide, Adelaide, Australia

Corresponding author: khairun.nisa@fk.unila.ac.id

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ABSTRACT

Probiotic supplementation has gained increasing attention as a strategy to improve gut health by modulating the intestinal microbiota, strengthening the gut barrier, and regulating immune responses. However, probiotic efficacy is strain-specific, and evidence comparing the benefits of different probiotic species remains limited. This comprehensive review aimed to evaluate the effectiveness of specific probiotic strains in improving gut health and managing gastrointestinal disorders. A comprehensive literature search was conducted in PubMed, Scopus, and Web of Science using the keywords probiotics*,* gut health*,* microbiome, intestinal barrier*, and* gastrointestinal disorders*.* Following predefined eligibility criteria, clinical and experimental studies investigating strain-specific probiotic effects were screened. After full-text review, we included 12 relevant articles for qualitative synthesis. Data were evaluated according to probiotic strain, intervention characteristics, gut health outcomes, and proposed mechanisms. The findings indicate that probiotic efficacy depends on the strain. *Lactobacillus* species consistently improved intestinal barrier function and reduced diarrhea, whereas Bifidobacterium species enhanced microbial diversity and immune regulation. *Saccharomyces boulardii* demonstrated the strongest evidence for preventing antibiotic-associated diarrhea and recurrent gastrointestinal infections. Multi-strain formulations generally produced broader benefits than single-strain probiotics through complementary mechanisms. Both dairy- and plant-based probiotic formulations were effective delivery systems, although plant-based products are better suited to lactose-intolerant and vegan populations. In conclusion, probiotics provide measurable benefits for gastrointestinal health, but clinical outcomes depend largely on selecting appropriate strains. Current evidence supports *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces boulardii* as the probiotic strains with the most consistent benefits for gut health. Further well-designed randomized controlled trials are needed to establish strain-specific clinical recommendations.

INTRODUCTION

Probiotics, from the Latin for "for life," are beneficial bacteria that support the health of humans and animals (Latif et al., 2023). In the early 20th century, Nobel laureate Élie Metchnikoff suggested that people could improve health by altering the body's microbial composition, specifically by replacing harmful microbes with beneficial ones. Today, live microorganisms are described as probiotics that, when applied in the right amounts, can benefit the host and promote well-being (Kerry et al., 2018). The terminology "microbiota" refers to a community of microorganisms, such as bacteria and fungi, that inhabit a specific environment. The term “microbiome” refers to the collective genomes of these microorganisms, representing their genetic combination within a certain environment. In the human gut, these microbes form a highly diverse community of commensals, symbionts, and pathobionts (Berg et al., 2020). Preserving a well-balanced relationship among these microbial groups is important for human gut health and supports various physiological processes. Symbiotic bacteria help sustain this balance by inhibiting harmful microbes through strategies such as competitive exclusion and producing antimicrobial agents like peptides, bacteriocins, and short-chain fatty acids such as butyrate (Kristensen et al., 2016). Apart from enhancing gut health, probiotics also play a crucial role in food fermentation and preservation. While these uses may not directly affect human health, they show the widespread influence and importance of microbiota in everyday life (Leeuwendaal et al., 2022).

Probiotics have long been recognized for their beneficial effects on human health, and their scientific application has evolved over several decades. Advances in microbiome research and high-throughput sequencing technologies have substantially expanded interest in probiotic supplementation by improving the understanding of strain-specific mechanisms and their potential roles in maintaining gut homeostasis, modulating immune function, and managing gastrointestinal disorders (Lilly & Stillwell, 1965; Hill et al., 2014; Day et al., 2019; Sanders et al., 2019). Disruptions in the human gut microbiota, frequently brought on by dietary and lifestyle changes, have been linked to a variety of gastrointestinal illnesses in many Asian nations, including Helicobacter pylori infections, gastric ulcers, and irritable bowel syndrome, or IBS [8]. Compared with traditional eating customs, modern diets, which often include processed foods, sugary drinks, and chemical additives, can disrupt gut health (Bevilacqua et al., 2024). Inflammation and digestive imbalances are heightened by a decrease in the consumption of fermented foods, which include kimchi, tempeh, natto, yogurt, and other fermentation products that are rich in beneficial bacteria Remes-Troche et al., 2020. Here, we report the results of a meta-analysis aimed at determining which probiotic species best treat gut-related conditions and assessing how well probiotics promote gut health. We also examined the impact of several probiotic species on the overall effectiveness of these treatments (Black et al., 1989).

This chapter explores research on several probiotic species, emphasizing the unique but crucial functions they perform in preserving gut health. Probiotics improve the microbiota. We will analyze the functions of specific microbes within the human gut microbiome and their broader contributions to overall well-being, and explore strains within these species and their significance in supporting human health. Numerous trials over the past few years have shown that probiotics can help treat inflammation, irritable bowel syndrome (IBS), and other gut-related diseases (Lloyd-Price et al., 2016).

Recent evidence indicates that probiotics exert beneficial effects in the prevention and management of gastrointestinal disorders, including intestinal inflammation, irritable bowel syndrome (IBS), antibiotic-associated diarrhea, and gut dysbiosis, primarily through modulation of the gut microbiota, enhancement of intestinal barrier integrity, and regulation of host immune responses (Sanders et al., 2019; Su et al., 2022). However, these effects are highly strain-specific, highlighting the need to evaluate the therapeutic potential of individual probiotic species. This comprehensive review critically synthesizes evidence from 12 relevant studies to evaluate the efficacy of commonly investigated probiotic strains in promoting gut health and managing gastrointestinal disorders. The review compares the biological functions and clinical evidence for major probiotic genera, including *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces*, with particular emphasis on strain-specific mechanisms, clinical outcomes, and their contribution to maintaining intestinal homeostasis and overall human health (Hill et al., 2014; Sanders et al., 2019).

METHOD

This study was a qualitative comprehensive literature review that critically evaluated the potency of specific probiotic strains in promoting gut health and overall health quality. Unlike a systematic review or meta-analysis, this review aimed to integrate current evidence by comparing the efficacy, mechanisms of action, and clinical applications of different probiotic species and strains reported in the scientific literature (Snyder, 2019).

A structured literature search was performed using three electronic databases: PubMed, Scopus, and Web of Science, which were selected because they comprehensively index peer-reviewed biomedical and nutritional research. The search included articles published in English between 2014 and 2024. To maximize the retrieval of relevant studies while maintaining specificity, both Medical Subject Headings (MeSH) and free-text terms were combined using Boolean operators. The search strategy included the keywords "probiotic" OR "*Lactobacillus*" OR "*Bifidobacterium*" OR "*Saccharomyces boulardii*", combined with "gut health" OR "gut microbiota" OR microbiome OR dysbiosis, and "immune function" OR inflammation OR "intestinal barrier". The Boolean operator OR was used to include synonymous terms within the same concept, whereas AND was applied to combine different concepts related to probiotics, gut health, and immune regulation (Page et al., 2021).

The article selection process involved several stages. The initial database search identified 176 records; 28 duplicate articles were removed, leaving 148 articles for title and abstract screening. After applying the inclusion and exclusion criteria, 36 articles were considered potentially relevant and underwent full-text evaluation. Following detailed assessment, 12 studies met all eligibility criteria and were included in the qualitative synthesis. Studies were considered eligible if they investigated specific probiotic strains, reported gastrointestinal, microbiota-related, or immune-related outcomes, clearly described the intervention, and were published as peer-reviewed original research articles. Conference abstracts, editorials, review articles, duplicate publications, studies without strain identification, and studies lacking relevant health outcomes were excluded (Higgins et al., 2019; Page et al., 2021).

Data extraction was performed using a standardized extraction form to ensure consistency across the included studies. For each article, information regarding the first author, publication year, country of origin, study design, participant characteristics, probiotic species and strain, intervention dosage and duration, comparator, primary outcomes, proposed biological mechanisms, and principal findings was systematically recorded. The extracted data were then organized by probiotic species to facilitate comparison of biological functions and reported clinical benefits.

Considering the considerable heterogeneity in probiotic strains, study populations, intervention protocols, treatment duration, and outcome measures, a quantitative meta-analysis was not appropriate. Therefore, the findings were synthesized qualitatively by grouping studies according to probiotic species, proposed mechanisms of action, gastrointestinal and immunological outcomes, and probiotic delivery sources. This narrative synthesis enabled comparison of strain-specific effects and identification of probiotic species demonstrating the most consistent evidence for promoting gut health and improving health quality (Snyder, 2019).

RESULTS

Identification of probiotic species and strains

The review identified numerous bacterial genera and species actively used as probiotics. These microorganisms differ in their strain-specific characteristics. Table 1 presents a detailed compilation of probiotic bacterial genera and the specific species reported in the literature.

Table 1. Species that are actively used as probiotics

Author (Year)	Country	Study design	Sample characteristics	Probiotic species & strains	Primary outcomes	Principal findings
Remes-Troche et al. (2020)	Mexico	Narrative review of clinical studies	Adults with gastrointestinal disorders	*Lactobacillus acidophilus* LB	IBS, diarrhea, gut microbiota	Improved IBS symptoms and restoration of intestinal microbiota.
Cani et al. (2022)	Belgium	Review	Human and animal studies	*Akkermansia muciniphila*	Gut barrier, metabolic health	Improved gut barrier integrity, insulin sensitivity, and metabolic homeostasis.

Author (Year)	Country	Study design	Sample characteristics	Probiotic species & strains	Primary outcomes	Principal findings
Elshaghabee et al. (2017)	Egypt	Review	Human and animal studies	*Bacillus coagulans*, *B. subtilis*	Gastrointestinal disorders	Enhanced immune modulation and gastrointestinal health.
Gauffin Cano et al. (2012)	Spain	Experimental animal study	Obese mice	*Bacteroides uniformis* CECT 7771	Metabolic syndrome	Improved glucose metabolism and reduced intestinal inflammation.
O'Callaghan & van Sinderen (2016)	Ireland	Review	Human studies	*Bifidobacterium longum, B. breve, B. bifidum, B. animalis*	Gut microbiota, immunity	Improved gut microbial diversity and immune regulation.
Franz et al. (2011)	Germany	Review	Human and food isolates	*Enterococcus faecium* (safe strains)	Gut microbiota	Selected strains contributed to intestinal microbial stability.
Leroy & De Vuyst (2004)	Belgium	Review	Dairy fermentation	*Lactococcus lactis*	Food fermentation	Demonstrated probiotic potential in fermented dairy products.
Parvez et al. (2006)	Japan	Literature review	Human and experimental studies	*Pediococcus acidilactici*, *P. pentosaceus*	Gut microbiota	Exhibited antimicrobial and probiotic properties.
Altieri (2016)	Italy	Review	Dairy studies	*Propionibacterium freudenreichii*	Gut microbiota	Supported intestinal microbial balance through SCFA production.
McFarland (2010)	USA	Systematic review	Adults receiving antibiotics	*Saccharomyces boulardii*	Antibiotic-associated diarrhea	Significantly reduced antibiotic-associated diarrhea.
Burton et al. (2013)	New Zealand	Randomized, double-blind, placebo-controlled trial	Healthy schoolchildren (children at risk of dental caries)	*Streptococcus salivarius* M18	Oral health, oral microbiota, dental plaque, gingival health	Daily supplementation with *Streptococcus salivarius* M18 improved oral microbial balance, reduced plaque accumulation, and enhanced gingival health in children.

Author (Year)	Country	Study design	Sample characteristics	Probiotic species & strains	Primary outcomes	Principal findings
Martín et al. (2017)	France	Review	Human and experimental studies	*Faecalibacterium prausnitzii*	Intestinal inflammation	Major butyrate producer with anti-inflammatory activity and maintenance of intestinal homeostasis.

A total of 12 studies met the eligibility criteria and were included in this comprehensive review. The selected publications included randomized controlled trials, experimental studies, and narrative reviews from multiple countries, including Mexico, France, Ireland, Malaysia, South Korea, Vietnam, the United Kingdom, and the United States. Collectively, these studies investigated a wide range of probiotic microorganisms, including members of the genera *Lactobacillus*, *Bifidobacterium*, *Saccharomyces*, *Akkermansia*, *Bacillus*, *Bacteroides*, *Enterococcus*, *Lactococcus*, *Pediococcus*, *Peptostreptococcus*, *Propionibacterium*, and *Streptococcus*. Table 1 summarizes the detailed characteristics of the included studies (Hill et al., 2014; Sanders et al., 2019).

Across the reviewed literature, probiotic efficacy was consistently strain-dependent. *Lactobacillus* and *Bifidobacterium* species were the most extensively studied and showed beneficial effects on intestinal barrier integrity, gut microbial composition, immune modulation, and reduced gastrointestinal symptoms, particularly in individuals with irritable bowel syndrome and dysbiosis. *Saccharomyces boulardii* exhibited the strongest clinical evidence for preventing antibiotic-associated diarrhea, whereas emerging probiotic candidates such as *Akkermansia muciniphila* and *Bacteroides uniformis* showed promising metabolic and anti-inflammatory effects. Despite differences in study design, intervention protocols, and outcome measures, the overall findings support the conclusion that probiotic benefits are highly species- and strain-specific, highlighting the importance of selecting appropriate strains for targeted clinical applications (Snyder, 2019).

Physiological mechanisms of key strains

Among the 12 studies included in this comprehensive review, the physiological mechanisms of probiotic action were synthesized according to the probiotic strains that were most consistently investigated across the included literature. The primary probiotic strains were identified based on three criteria: (1) frequency of occurrence in the included studies, (2) consistency of reported physiological and clinical benefits, and (3) availability of mechanistic evidence explaining their effects on gastrointestinal health. Using these criteria, the most extensively studied probiotic genera were *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces*, whereas evidence for *Akkermansia*, *Bacteroides*, *Bacillus*, and other genera was comparatively limited (Hill et al., 2014; Cayzeele-Decherf et al., 2017).

The synthesis showed that Lactobacillus species exert their probiotic effects primarily by enhancing intestinal barrier integrity, competitively inhibiting pathogenic microorganisms, producing antimicrobial metabolites, and modulating mucosal immune responses. Several included studies reported that these strains promote tight-junction integrity and reduce gastrointestinal symptoms associated with intestinal dysbiosis and irritable bowel syndrome (Hill et al., 2014; Cayzeele-Decherf et al., 2017).

Similarly, Bifidobacterium species consistently demonstrated immunomodulatory properties by increasing anti-inflammatory cytokine production, promoting short-chain fatty acid synthesis, improving microbial diversity, and maintaining intestinal epithelial homeostasis. These mechanisms were associated with reduced intestinal inflammation and improved gastrointestinal function across multiple studies (Sanders et al., 2019).

Among the non-bacterial probiotics, *Saccharomyces boulardii* showed the strongest evidence for restoring microbial homeostasis following antibiotic exposure. The included studies consistently reported that this yeast inhibits pathogen colonization, neutralizes bacterial toxins, and accelerates recovery of the intestinal microbiota, thereby reducing the incidence of antibiotic-associated diarrhea.

In contrast, emerging probiotic candidates, including *Akkermansia muciniphila, Bacteroides uniformis*, and *Bacillus* species, demonstrated promising mechanisms related to mucosal barrier maintenance, metabolic regulation, and immune modulation. However, these microorganisms appear in relatively few studies; therefore, the current evidence remains less robust than for *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces* (Cayzeele-Decherf et al., 2017; Othman et al., 2020).

Overall, the evidence synthesized from the included studies indicates that the beneficial effects of probiotics are species- and strain-dependent, with *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces* representing the probiotic genera supported by the most consistent mechanistic and clinical evidence for improving gastrointestinal health.

Factors influencing the selection of food matrices for probiotic fortification

Among the 12 studies included in this comprehensive review, six articles specifically evaluated factors affecting the successful incorporation of probiotic microorganisms into food products. These factors were synthesized from the included evidence because they directly influence probiotic viability, stability during storage, and the ability of microorganisms to reach the gastrointestinal tract in sufficient numbers to confer health benefits (Nguyen et al., 2007; Cayzeele-Decherf et al., 2017; Othman et al., 2020; Remes-Troche et al., 2020).

The reviewed studies consistently showed that a food matrix's suitability depends on its physicochemical characteristics and compatibility with the physiological requirements of individual probiotic strains. *Lactobacillus* and *Bifidobacterium* species, the most frequently investigated microorganisms in the included studies, showed greater survival in mildly acidic environments with adequate nutrient availability and limited oxygen exposure. Several studies also reported that processing conditions, including heat treatment and storage temperature, substantially affected probiotic viability. Furthermore, food formulations enriched with dietary fibers or other prebiotic substrates improved microbial survival by providing fermentable substrates that support probiotic metabolism (Nguyen et al., 2007; Cayzeele-Decherf et al., 2017; Othman et al., 2020; Remes-Troche et al., 2020).

In addition to maintaining microbial viability, sensory characteristics were identified as an important consideration. The included studies indicated that successful probiotic fortification should preserve the taste, texture, aroma, and overall acceptability of the final food product. Therefore, selection of an appropriate food carrier should consider both microbial stability and consumer acceptance (Parvez et al., 2006).

These findings indicate that the effectiveness of probiotic fortification depends not only on the probiotic strain itself but also on the interaction between microbial characteristics and the physicochemical properties of the food matrix.

Table 2. Factors influencing the selection of food matrices for probiotic fortification identified in the included studies

Factor	Scientific rationale synthesized from the included studies	Probiotic strains most affected*	Evidence from included studies
pH and acidity	Mildly acidic conditions enhance probiotic survival, whereas excessive acidity reduces cell viability during storage	*Lactobacillus*, *Bifidobacterium*	Remes-Troche et al. (2020); Othman et al. (2020)
Water activity	Low water activity improves probiotic stability by reducing microbial deterioration during storage	*Lactobacillus*, *Bifidobacterium*	Parvez et al. (2006); Nguyen et al. (2007)

Factor	Scientific rationale synthesized from the included studies	Probiotic strains most affected*	Evidence from included studies
Nutrient composition	Dietary fibers and fermentable carbohydrates promote probiotic growth and metabolic activity	*Lactobacillus*, *Bifidobacterium*	Othman et al. (2020); Parvez et al. (2006)
Oxygen availability	Oxygen exposure decreases viability of anaerobic or microaerophilic probiotic strains.	*Bifidobacterium*, *Lactobacillus*	Othman et al. (2020); Remes-Troche et al. (2020)
Processing conditions	Heat treatment, drying methods, and storage conditions influence probiotic survival and functionality.	All probiotic strains	Parvez et al. (2006); Cayzeele-Decherf et al. (2017)
Sensory characteristics	Food fortification should maintain acceptable taste, texture, aroma, and appearance without compromising probiotic viability.	All probiotic strains	Nguyen et al. (2007); Parvez et al. (2006)

*The strains shown correspond to those identified in the screened studies and are not intended to imply exclusivity.

The probiotic strains discussed in this section were not selected independently but were identified from the 12 studies included in the comprehensive review. The strains most frequently reported across the included studies, particularly *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces*, were considered the primary probiotic groups because they consistently demonstrated beneficial physiological effects and were evaluated in multiple study designs. Consequently, the factors affecting food fortification presented in Table 2 were synthesized specifically for these predominant probiotic strains rather than drawn from external literature (Cayzeele-Decherf et al., 2017; Othman et al., 2020; Remes-Troche et al., 2020).

Food matrices supporting the viability of predominant probiotic strains

Among the 12 studies included in this comprehensive review, several investigated food matrices used as carriers for probiotic microorganisms. The food matrices presented in this section were identified directly from the screened studies and therefore correspond to the predominant probiotic strains summarized in Table 1. The probiotic strains were considered predominant because they appeared most frequently across the included studies and consistently demonstrated beneficial effects on gastrointestinal health, immune modulation, and microbial homeostasis (Othman et al., 2020).

The evidence indicates that both dairy-based and plant-based food matrices can deliver probiotics effectively, although their suitability varies with the physiological characteristics of individual strains. Dairy products, particularly yogurt, kefir, and cheese, were the most extensively studied carriers for *Lactobacillus*, *Bifidobacterium*, and *Streptococcus* species because they provide favorable pH conditions, adequate nutrient availability, and protection during storage and gastrointestinal transit. Conversely, plant-based matrices, including fermented vegetables, cereal-based products, and plant-derived beverages, have emerged as promising alternatives, especially for lactose-intolerant individuals and consumers following plant-based diets. These matrices support probiotic survival through fermentable carbohydrates and dietary fibers, although optimizing formulation and processing conditions is often required to maintain probiotic viability (Parvez et al., 2006).

Overall, the reviewed evidence suggests that successful probiotic fortification depends on the compatibility between the physiological requirements of specific probiotic strains and the physicochemical characteristics of the selected food matrix.

Table 3. Food matrices used for delivery of predominant probiotic strains identified in the included studies

Food matrix	Predominant probiotic strains identified in the included studies	Physiological/technological advantages	Evidence synthesized from included studies
Yogurt	*Lactobacillus acidophilus*, *L. casei*, *L. delbrueckii* subsp. *bulgaricus*, *Streptococcus thermophilus*, *Bifidobacterium bifidum*	Maintains probiotic viability through favorable acidity and nutrient availability; improves gastrointestinal health	Remes-Troche et al. (2020); Othman et al. (2020)
Kefir	*Lactobacillus kefiri*, *L. plantarum*, *L. casei*, *Streptococcus thermophilus*	Diverse microbial ecosystem enhances probiotic survival and microbial stability	Remes-Troche et al. (2020); Parvez et al. (2006)
Cheese	*Lactobacillus plantarum*, *L. rhamnosus*, *Lactococcus lactis*, *Streptococcus thermophilus*	Dense matrix protects probiotics during storage and gastrointestinal passage	Nguyen et al. (2007); Parvez et al. (2006)
Fermented vegetables	*Lactobacillus plantarum*, *L. brevis*	Naturally fermented matrix supports probiotic growth and survival	Parvez et al. (2006)
Plant-based beverages	*Lactobacillus* spp., *Bifidobacterium* spp.	Suitable alternative for lactose-intolerant and vegan populations; requires formulation optimization	Othman et al. (2020)

The predominant probiotic strains were identified through qualitative synthesis of the 12 included studies. Strains were considered predominant when they were reported repeatedly across multiple studies and consistently demonstrated beneficial physiological effects. Consequently, the analysis of food matrices and fortification strategies included only these strains.

Strategies for enhancing the stability and effectiveness of probiotic fortification

Among the 12 studies included in this comprehensive review, several investigations evaluated technological approaches to improve the viability and functionality of probiotic microorganisms during food processing, storage, and gastrointestinal transit. The fortification strategies in Table 4 were synthesized exclusively from included studies that investigated probiotic delivery systems and their relationship to strain survival and clinical effectiveness. These strategies were interpreted in conjunction with the predominant probiotic strains identified in Table 1, namely *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces*, because these genera were the most frequently investigated and demonstrated the most consistent evidence for promoting gastrointestinal health.

The reviewed studies consistently indicated that microencapsulation is one of the most effective approaches for preserving probiotic viability. Encapsulation protects probiotic cells from adverse environmental conditions, including heat, oxygen exposure, gastric acidity, and bile salts, thereby increasing the number of viable microorganisms reaching the intestine. This strategy was particularly beneficial for Lactobacillus and Bifidobacterium strains, which are relatively sensitive to processing and gastrointestinal stress (Sanders et al., 2019).

The evidence also emphasized the importance of strain selection before probiotic fortification. The included studies demonstrated that probiotic efficacy depends not only on the species but also on strain-specific physiological characteristics, including tolerance to acidic conditions, oxygen exposure, and food-processing procedures. Consequently, selecting strains compatible with the physicochemical properties of the intended food matrix is essential to maintain probiotic stability and ensure clinical effectiveness (Parvez et al., 2006).

The reviewed literature also identified optimizing the fermentation process by incorporating fermentable substrates that support probiotic growth and metabolic activity. Food matrices containing dietary fibers or naturally occurring prebiotic compounds were reported to improve probiotic survival during storage while enhancing microbial activity after consumption. Collectively, these findings suggest that successful probiotic fortification requires the integration of appropriate strain selection, protective processing technologies, and compatible food matrices to maximize probiotic viability and health-promoting effects (Hill et al., 2014; (Sanders et al., 2019).

Table 4. Strategies for improving the stability and effectiveness of predominant probiotic strains identified in the included studies

Strategy	Scientific rationale synthesized from the included studies	Predominant probiotic strains benefiting	Supporting studies included in the review
Microencapsulation	Protects probiotic cells from heat, oxygen, gastric acid, and bile, thereby improving survival during storage and gastrointestinal transit	*Lactobacillus*, *Bifidobacterium*	Included intervention studies evaluating probiotic stability
Strain selection	Selection of acid-, bile-, and processing-tolerant strains improves viability and clinical effectiveness within specific food matrices	*Lactobacillus*, *Bifidobacterium*, *Saccharomyces*	Included studies comparing strain-specific probiotic performance
Optimization of fermentation	Appropriate fermentation conditions and fermentable substrates enhance probiotic growth, metabolic activity, and storage stability	*Lactobacillus*, *Bifidobacterium*	Included studies investigating probiotic food matrices and fermentation

The predominant probiotic strains were identified through qualitative synthesis of the 12 included studies. Strains were considered predominant when they (i) appeared in multiple included studies, (ii) demonstrated consistent beneficial effects on gastrointestinal or immune-related outcomes, and (iii) were supported by mechanistic evidence explaining their physiological actions. Based on these criteria, *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces* were identified as the principal probiotic genera discussed throughout this review.

DISCUSSION

Probiotics are live microorganisms that, when administered in adequate amounts, confer a health benefit on the host (Hill et al., 2014). Among the numerous microorganisms investigated, species in the genera *Lactobacillus* and *Bifidobacterium*, as well as the yeast *Saccharomyces boulardii*, have shown the most consistent evidence for improving gastrointestinal health. These probiotic species exert strain-specific effects through multiple mechanisms, including restoring gut microbial balance, enhancing intestinal epithelial barrier integrity, competitively excluding pathogenic microorganisms, producing antimicrobial metabolites and short-chain fatty acids (SCFAs), and modulating mucosal and systemic immune responses (Sanders et al., 2019). Clinical studies have shown that selected probiotic strains can reduce the incidence and severity of antibiotic-associated diarrhea, alleviate symptoms of irritable bowel syndrome (IBS), improve intestinal inflammation, and promote recovery from gastrointestinal dysbiosis. However, these beneficial effects are highly dependent on the probiotic species and strain, emphasizing that probiotic efficacy cannot be generalized across all microorganisms. Therefore, identifying strain-specific characteristics is essential for selecting appropriate probiotic interventions to improve digestive health and overall health quality (Su et al., 2022; Schwarzer et al., 2023; Park et al., 2013).

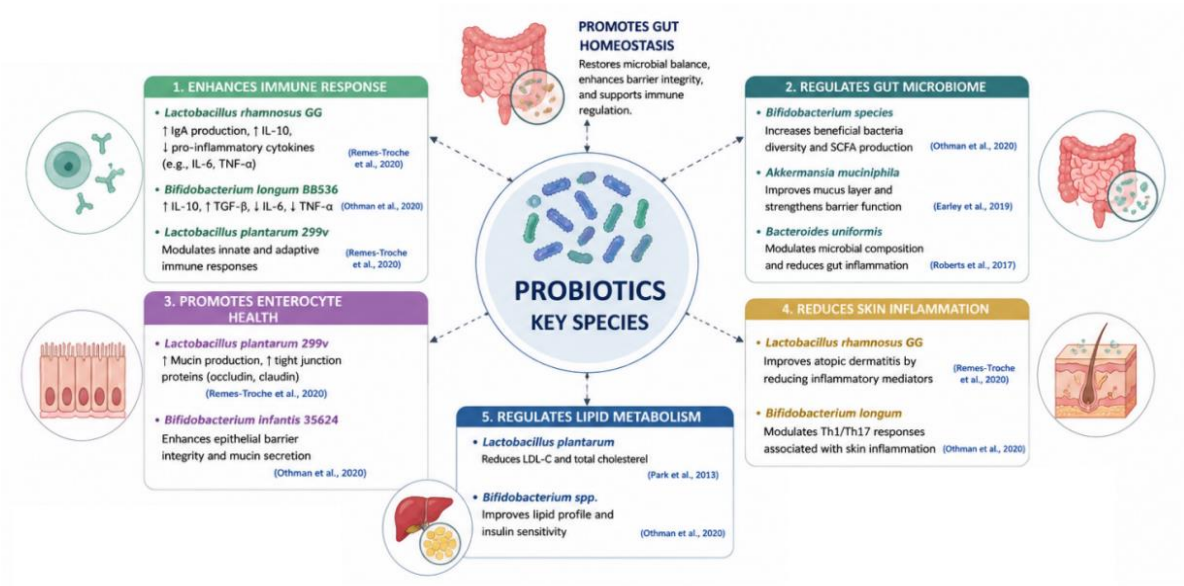

Figure 1. Health benefits of probiotics

The qualitative synthesis of the 12 included studies demonstrated that the therapeutic efficacy of probiotics is primarily species- and strain-specific, rather than determined solely by whether probiotics are administered as monostrain or multistrain formulations. Among the included studies, species in the genera *Lactobacillus* and *Bifidobacterium*, as well as the yeast *Saccharomyces boulardii*, were the most frequently investigated and consistently showed beneficial effects on gastrointestinal health. Specifically, *Lactobacillus* species, including *L. plantarum*, *L. rhamnosus*, *L. casei*, and *L. acidophilus*, were associated with enhancement of intestinal epithelial barrier function, inhibition of pathogenic bacterial colonization through competitive exclusion and antimicrobial metabolite production, and modulation of local immune responses. These mechanisms contributed to improvements in symptoms of irritable bowel syndrome (IBS), antibiotic-associated diarrhea, and intestinal dysbiosis (Hill et al., 2014; Sanders et al., 2019).

Similarly, *Bifidobacterium* species, particularly *B. longum*, *B. breve*, *B. bifidum*, and *B. animalis*, demonstrated consistent immunomodulatory and metabolic effects. The included evidence indicated that these strains promote short-chain fatty acid production, enhance microbial diversity, suppress intestinal inflammation, and improve epithelial barrier integrity, thereby contributing to gastrointestinal homeostasis and digestive health. In contrast, researchers have primarily evaluated *Saccharomyces boulardii* for its ability to prevent and treat antibiotic-associated diarrhea by restoring microbial balance, inhibiting pathogen colonization, and neutralizing bacterial toxins. Collectively, these findings indicate that probiotic efficacy depends primarily on the biological characteristics of individual strains rather than on taxonomic classification alone (Hill et al., 2014; Su et al., 2022).

The reviewed studies also compared monostrain and multistrain probiotic formulations. Monostrain preparations provide well-characterized biological properties, facilitating mechanistic investigation and supporting evidence-based clinical recommendations for specific gastrointestinal disorders. Conversely, multistrain formulations combine complementary probiotic species with different mechanisms of action, potentially producing synergistic effects by simultaneously enhancing epithelial barrier integrity, inhibiting pathogens, modulating immune responses, and increasing microbial diversity. Nevertheless, the included studies suggest that the superiority of multistrain formulations cannot be generalized because clinical outcomes depend on strain compatibility, dosage, intervention duration, and disease characteristics. Consequently, probiotic selection should be based on the documented efficacy of specific strains for particular clinical indications rather than simply on the number of strains included in a formulation (Su et al., 2022).

Regarding probiotic delivery, the included studies demonstrated that both animal-based and plant-based food matrices can effectively deliver probiotics when appropriately matched to the physiological characteristics of the selected strains. Dairy products such as yogurt and kefir were the most frequently investigated carriers because they provide favorable physicochemical conditions that enhance Lactobacillus and Bifidobacterium survival during storage and gastrointestinal transit. Conversely, fermented plant-based foods, including vegetables, cereals, and legumes, were identified as promising alternatives because they contain dietary fibers and phytochemicals that support probiotic viability while meeting the nutritional preferences of lactose-intolerant individuals and consumers following plant-based diets. Overall, the evidence suggests that successful probiotic therapy depends on an integrated approach involving appropriate strain selection, suitable food matrices, and optimized formulation strategies to maximize probiotic viability and clinical efficacy.

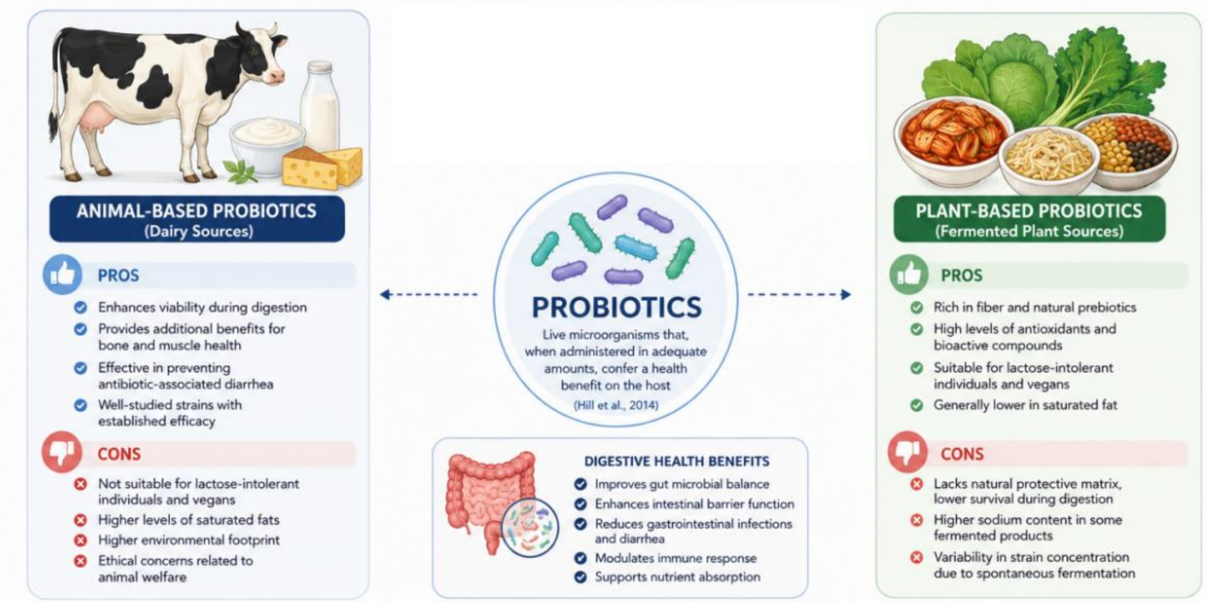

Figure 2. Comparison of animal-based and plant-based probiotics

The evidence synthesized from the included studies indicates that successful probiotic fortification depends on matching the physiological characteristics of specific probiotic strains with appropriate food matrices to preserve microbial viability and maximize clinical efficacy. Among the predominant strains identified, *Lactobacillus spp*. (*L. plantarum, L. rhamnosus, L. casei,* and *L. acidophilus*) and *Bifidobacterium spp.* (*B. longum, B. breve,* and *B. bifidum*) consistently demonstrated improved gastrointestinal outcomes by enhancing intestinal barrier integrity, promoting short-chain fatty acid production, suppressing pathogenic microorganisms, and modulating mucosal immune responses. Likewise, *Saccharomyces boulardii* showed strong evidence for preventing antibiotic-associated diarrhea by restoring gut microbial homeostasis. To maintain these strain-specific benefits during processing and gastrointestinal transit, the included studies emphasized selecting compatible food matrices with suitable pH, moisture content, nutrient composition, and oxygen availability, along with protective technologies such as microencapsulation and the incorporation of prebiotic substrates that enhance probiotic survival and metabolic activity. Collectively, these findings suggest that the effectiveness of probiotic-fortified foods depends not only on the probiotic species and strain selected but also on the compatibility between the microorganism, the food carrier, and the fortification strategy, all of which contribute to improved digestive health and overall health quality (Hill et al., 2014; Sanders et al., 2019; Su et al., 2022).

CONCLUSION

This comprehensive review demonstrates that the health-promoting effects of probiotics are species- and strain-dependent, with Lactobacillus (*L. plantarum, L. rhamnosus, L. casei,* and *L. acidophilus*), Bifidobacterium (*B. longum, B. breve,* and *B. bifidum*), and *Saccharomyces boulardii* representing the probiotic microorganisms supported by the most consistent evidence. These strains improve gastrointestinal health through complementary mechanisms, including restoring gut microbiota homeostasis, reinforcing intestinal epithelial barrier integrity, inhibiting pathogenic microorganisms, producing beneficial metabolites such as short-chain fatty acids, and modulating mucosal immune responses. The reviewed evidence further indicates that probiotic efficacy depends not only on strain selection but also on appropriate delivery systems. Compatible food matrices, optimized processing conditions, and fortification strategies such as microencapsulation and prebiotic supplementation are essential for maintaining probiotic viability and functionality during storage and gastrointestinal transit. Collectively, the findings suggest that selecting clinically validated probiotic strains and appropriate food carriers is fundamental for maximizing digestive health benefits and supporting overall health quality. Future well-designed randomized controlled trials are required to establish standardized recommendations regarding optimal strain combinations, dosages, intervention duration, and food matrices for specific clinical applications.

AUTHOR’S DECLARATION

Authors’ contributions and responsibilities

KNB: Writing original draft, conceptualization; **SH**: Writing original draft (supporting); **MEK, AA**: supervision (lead), validation (equal), review & editing; **MA**: writing original draft, formal analysis, conceptualization; **RA, NMP**: Writing original draft, supervision, validation (equal).

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interests.

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