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Systematic Review

The Gut–Brain Axis and Probiotics in Beverages and Liquid Preparations: A PRISMA Systematic Review on Cognitive Function Enhancement

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Abstract: The gut–brain axis links the health of the gut microbiota to cognitive function and mental well-being. Numerous studies suggest that probiotics, particularly strains belonging to *Lactobacillus* spp. and *Bifidobacterium* spp., can positively modulate memory, attention, and executive functions, contributing to the prevention of cognitive decline. However, while the use of probiotic capsules and powders is widely documented, the role of probiotic beverages or liquid preparations in brain health remains poorly explored. This systematic review analyzes studies on the efficacy of probiotics in improving cognitive functions from 2020 to 2025, evaluating the potential of probiotic liquid preparations as a delivery vehicle. The results indicate that fermented beverages or liquid suspensions containing probiotics could improve the bioavailability of beneficial microorganisms, promoting synergistic effects with other bioactive components and facilitating treatment adherence. However, the current literature still has methodological limitations and there is a need for further clinical studies to validate the efficacy of this strategy. Probiotic supplementation through functional beverages could represent a promising innovation to improve cognitive health and counteract neurocognitive decline.

Keywords: gut–brain axis; probiotics; cognitive functions; probiotic liquid preparations; neuroprotection

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1. Introduction

The growing interest in the role of the intestinal microbiota in mental health has led, in recent years, to a better understanding of its influence on cognitive and neurological processes; studies, in fact, have focused on the relationship between probiotic microorganisms and the gut–brain axis [1–5]. This bidirectional crosstalk between the gastrointestinal tract and the central nervous system is now recognized as a key element in the modulation of cognitive, emotional, and behavioral functions [6,7], and appears to be mediated by a series of mechanisms that represent the production of neurotransmitters and neuromodulators by the intestinal microbiota, the regulation of the inflammatory and immune response, and the interaction with the vagus nerve [8].

The concept of psychobiotics, i.e., probiotics that can positively influence cognitive function and mental well-being, has recently emerged in the scientific literature through a

sequence of preclinical and clinical studies that have shown how some bacterial strains, in particular belonging to *Lactobacillus* spp. sensu lato and *Bifidobacterium* spp. [9,10] have been able to promote mood-improving effects through a reduction in stress and anxiety levels and the enhancement of cognitive functions related to memory and attention [11,12]. However, although scientific literature contains evidence on the beneficial effects of probiotic microorganisms on brain function, there is a significant gap in the literature regarding the use of probiotic drinks as tools for improving cognitive performance [6].

Among the varied scientific evidence reported in recent years in numerous clinical studies, it has been demonstrated that the use of probiotics has been able to positively and beneficially support mental health through a significant improvement in mood and a reduction in stress [9,13–15]. Specific examples are attributable to the intake of *Bifidobacterium breve*, for which an improvement in the scores of the hospital anxiety and depression scale (HADS) has been demonstrated in patients with schizophrenia [16], or to the use of *Lacticaseibacillus rhamnosus*, for which a reduction in cortisol levels and an improvement in the regulation of the stress response in healthy subjects has been recorded [12].

Some studies, specifically, have directly explored the effect of probiotics on cognitive performance. A concrete example is that attributable to the probiotic action of *Bifidobacterium longum*, which was able to reduce mental fatigue and improve the response to social stress, modulating brain activity [12]. Similarly, the strain *Lactiplantibacillus plantarum* C29 also improved cognitive abilities in patients with mild cognitive impairment, increasing the levels of brain-derived neurotrophic factor (BDNF), a key protein in neuronal plasticity [17].

Studies such as those cited above suggest that the integration of probiotics into a person's diet may represent a decidedly innovative strategy for improving cognitive function. However, almost all of the studies conducted to date have used probiotic supplements in the form of capsules or powders, neglecting the potential of probiotic drinks as a functional tool for modulating cognition [6,18].

Fermented beverages containing probiotics, such as kefir, kombucha, and liquid yogurt, are known for their positive and beneficial effects on gastrointestinal health and the human immune system [19–21], but their potential effect on cognitive functions has not yet been adequately explored [7].

Considering the characteristics of probiotic drinks, their consumption could represent an innovative turning point in terms of a more effective administration compared to traditional supplements.

First of all, the use of probiotic drinks could facilitate the bioavailability of probiotics, improving the survival of bacterial strains in the intestinal tract, then it could integrate functional nutrients, such as bioactive peptides and prebiotics, significantly amplifying the beneficial effects on cognition, and finally it could promote greater adherence to treatment, being more easily incorporated into the daily diet compared to capsule supplements [22–24].

The growing interest in the gut–brain axis and psychobiotics has oriented, especially in recent years, scientific research on the probiotic potential of new emerging strains towards this new exploratory field, mainly considering the use of supplements in the form of capsules and powders as a priority vehicle [18]. Such an apparent significant gap in the scientific literature regarding the role of probiotic drinks in improving cognitive performance and systematic evaluations of the generic effects of probiotic drinks on cognitive abilities represents an interesting research gap to explore.

Based on what has been described so far, the aim of this study is to investigate the literature regarding the correlation between the use of probiotic beverages and/or probiotic

liquid preparations and cognitive performance, identifying the positive effects and benefits on humans in the fields of brain well-being and mental health.

Therefore, this investigation was guided by the formulation of some research questions. Firstly, the inquiry sought to determine whether the existing scientific literature contains studies that directly examine the relationship between the consumption of probiotic beverages or probiotic liquid preparations and cognitive performances. Secondly, attention was directed toward assessing whether previous research has established any correlations between specific probiotic strains—potentially suitable for inclusion in probiotic beverages—and outcomes related to cognitive functioning and abilities. Finally, this study aimed to explore whether either probiotic beverages/liquid preparations or the probiotic strains which could be potentially incorporated into such formulations may be considered valuable strategies for supporting cognitive performance, brain health, and overall mental well-being.

2. Materials and Methods

This systematic review was conducted according to the methodological framework Prisma 2020 [25] to ensure comprehensive and transparent reporting of our methods and findings, as detailed in the following sections.

2.1. Information Sources and Search Strategy: Steps for Article Selection

The literature review was performed on papers published between 2020 and 2025.

The selection of articles was carried out in accordance with these criteria, and bibliographic analyses were performed on three databases, Scopus, Science Direct, and Web of Science, from the 25 February 2025 to the 30 April 2025, to identify relevant publications combining the use of probiotic beverages or potentially usable probiotics in beverages or liquid preparations and cognitive performance.

The selection of these databases was based on their internationally recognized impact indices [26,27].

The search strategy was based on the use of core concepts regarding the subject of the study ((probiotic beverage OR probiotic drinks OR psychobiotic beverages OR psychobiotic drinks) AND (cognitive functions OR cognitive performance OR cognitive enhancement) AND gut–brain axis) and the research questions utilizing Boolean operators (AND, OR) with simple operators using parentheses in the search string [28].

In a screening phase, the strings have been limited to the presence of search terms in the titles, abstracts, and keywords of the articles. Only studies published between 2020 and 2025, which are open access, and written in English were considered.

All identified articles were collected. Initially, the search returned 680 articles, and no duplicates and retracted publications were found, so the final number was 680 studies included in the analysis; all articles were independently reviewed by two authors, and only retained for the screening phase if deemed eligible by both parties.

The second step was the screening phase; articles were further reviewed (title and abstracts) according to the inclusion and exclusion criteria (Table 1), thus leading to us selecting 55 papers. Finally, a second selection was performed by focusing on the whole papers and only articles available as full-texts were included in the meta-analysis.

A confirmatory step for the literature search was also performed on PubMed, but the search returns the same outputs of the other databases.

The process is detailed in Figure 1. The PRISMA checklist is available in the Supplementary Materials.

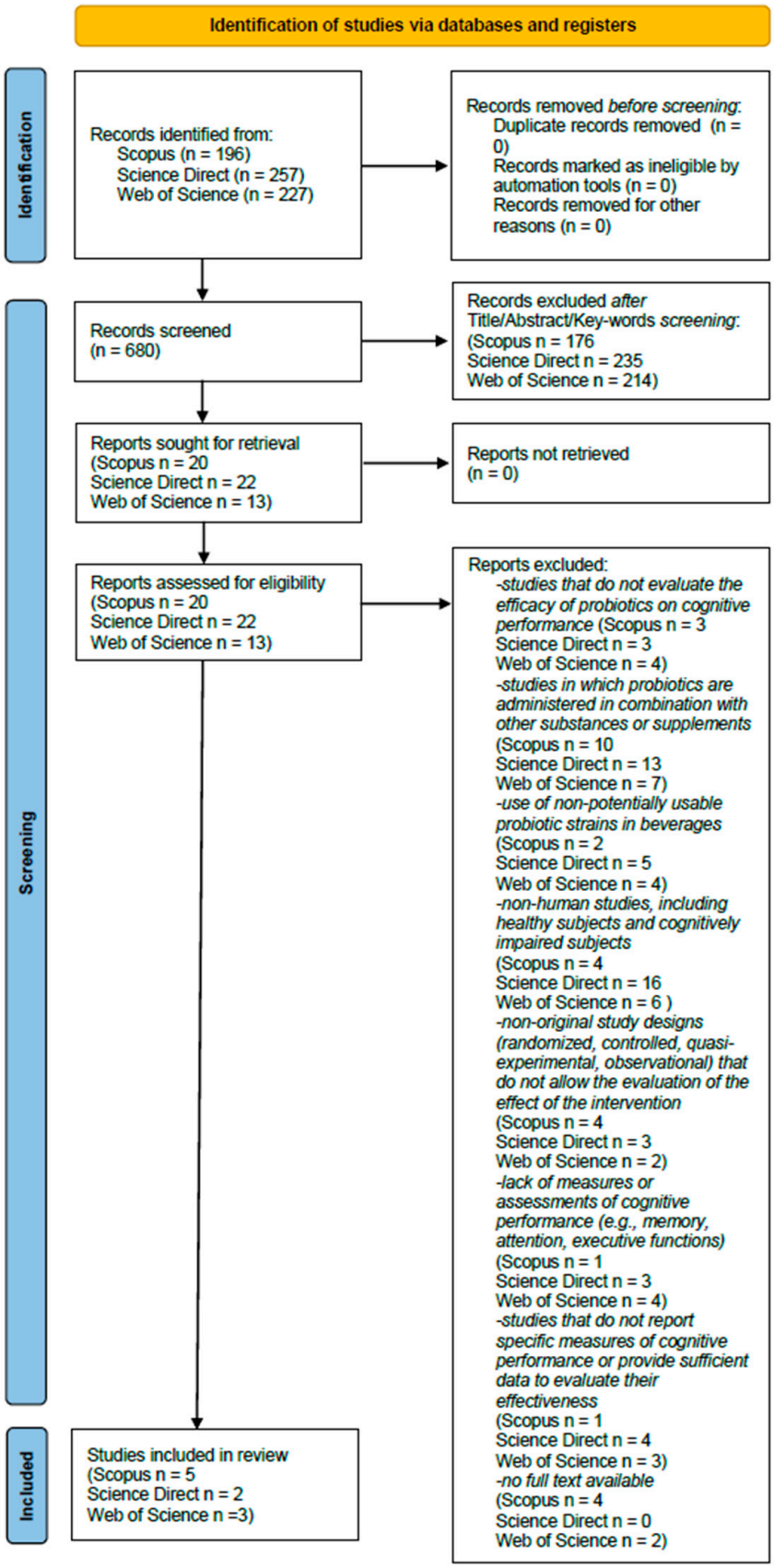


Figure 1. PRISMA 2020 flow diagram.

Table 1. Inclusion criteria used in the screening and inclusion phase.

Inclusion Criteria	Exclusion Criteria
Studies evaluating the efficacy of probiotics on cognitive performance	Articles not complying with inclusion criteria
Probiotic in beverages or liquid preparations or usable in these systems	Duplicate articles
Measures or assessments of cognitive performance (e.g., memory, attention, executive functions)	Articles not written in English
Studies conducted on humans, including healthy subjects and subjects with cognitive impairment, or if conducted on models with results applicable to humans	Proceedings of congresses, conference papers, books, book chapters, and other nonpeer-reviewed publications
Original study designs (randomized, controlled, quasi-experimental, and observational) that allow the evaluation of the effect of the intervention	Articles written before 2020
Studies in which probiotics are NOT administered in combination with other substances or supplements	Narrative reviews and/or meta-analyses which do not strictly adhere to the inclusion criterion on reviews
Studies that report specific measures of cognitive performance or that provide sufficient data to evaluate their effectiveness	
Reviews or meta-analyses if they clearly report specific outcomes, demonstrate with well-defined parameters an effect on cognitive functions, and focus on probiotic species which could be used in beverages or liquid preparations	

2.2. Quality and BIAS Assessment

The methodological quality of studies was assessed using the Newcastle–Ottawa scale (NOS). This instrument rates studies across the following three domains: selection of participants (maximum 4 stars), comparability of study groups (maximum 2 stars), and ascertainment of either the exposure or the outcome (maximum 3 stars). The assessments were carried out independently by two reviewers and disagreements were resolved by consensus. Studies scoring 7–9 stars were rated as high quality, those with 5–6 stars as moderate quality, and those with fewer than 5 stars as low quality. Table 2 details the studies included in this paper and their NOS evaluation.

Table 2. Papers included in systematic literature review. Na, not assessed.

Author	Title	Journal	NOS Score
Zheng et al. [29]	Probiotic *Clostridium butyricum* ameliorates cognitive impairment in obesity via microbiota–gut–brain axis	*Brain Behaviour and Immunity* **2024**, *115*, 565–587	7
Lof et al. [30]	The health effect of probiotics on high-fat diet-induced cognitive impairment, depression, and anxiety: A cross-species systematic review	*Neuroscience and Biobehavioural Reviews* **2022**, *136*, 104634	na

Table 2. *Cont.*

Author	Title	Journal	NOS Score
Kou et al. [31]	Evaluation of improvement of cognitive impairment in older adults with probiotic supplementation: A systematic review and meta-analysis	*Geriatric Nursing* **2023**, *54*, 155–162	na
Kikuchi-Hayakawa et al. [32]	Effects of *Lacticaseibacillus paracasei* strain Shirota on daytime performance in healthy office workers: A double-blind, randomized, crossover, placebo-controlled trial	*Nutrients* **2023**, *15*, 5159	7
Abdelhamid et al. [33]	Protective effects of *Bifidobacterium breve* MCC1274 as a novel therapy for Alzheimer's disease	*Nutrients* **2025**, *17*, 558	na
Aljumaah et al. [34]	The gut microbiome, mild cognitive impairment, and probiotics: A randomized clinical trial in middle-aged and older adults	*Clinical Nutrition* **2022**, *41*, 2565–2576	8
Cannavale et al. [35]	Consumption of a fermented dairy beverage improves hippocampal-dependent relational memory in a randomized, controlled cross-over trial	*Nutritional Neuroscience* **2022**, *26*, 265–274	8
Gaougaou et al. [36]	Acceptability and safety of a probiotic beverage supplementation (Bio-K+) and feasibility of the proposed protocol in children with a diagnosis of autism spectrum disorder	*Research Square* **2025**, 1–38	8
Yang et al. [37]	Effect of *Lacticaseibacillus paracasei* strain Shirota supplementation on clinical responses and gut microbiome in Parkinson's disease	*Food and Function* **2023**, *14*, 6828–6839	8
Pereira et al. [38]	The emerging scenario of the gut–brain axis: the therapeutic actions of the new actor Kefir against neurodegenerative diseases	*Antioxidants* **2021**, *10*, 1845	na

3. Results

The search produced 10 results which fulfil the inclusion criteria (Table 2); the details on the type of study conducted, objective of the study, type of microorganisms used and studied, and their type of administration are in Table 3, whilst evaluation of a potential use of probiotic microorganisms in beverages and/or liquid systems, and type of beneficial effect on cognitive performance and brain well-being are in Table 4.

The 10 articles included in this systematic review can also be grouped on the basis of the following characteristics:

- Human-tested studies [29,32,34–37];
- Studies using probiotics delivered through drinks [32,35];
- Studies using probiotics delivered through liquid suspensions [29];

- Studies using bacteria which is potentially usable in beverages, even if in some cases the main way of delivery in the study was through capsules. They were included due to the possibility of using the particular strain in a liquid preparation or because it is used in probiotic drinks [29,32,34,35];
- clinical studies [29,32,34,35];
- systematic reviews, included if they offer hypotheses, evidence, and data strictly connected to the main goal of the paper, based on well-defined parameters and clinical outcomes [30,31,33,38].

Table 3. Characterizing elements of the articles included in the systematic review (type of the study, objectives of the study, and microorganisms used and studied).

Author	Type of the Study	Objectives of the Study	Microorganisms Used and Studied
Zheng et al. [29]	Combined study (observational analysis on human subjects and experiments on a mouse model)	To investigate the potential neuroprotective effect of *C. butyricum* on obesity-induced hippocampal cognitive deficits	*C. butyricum*
Lof et al. [30]	Systematic review (one human study and sixteen animal studies)	To evaluate the efficacy of probiotic intervention in alleviating cognitive impairment, depression, and anxiety induced by a high-fat diet (HFD)	*Lactobacillus* spp. *Bifidobacterium* spp. *Akkermansia* spp.
Kou et al. [31]	Systematic review and meta-analysis	To assess the effects of probiotics on the cognitive levels, psychological symptoms, and oxidative stress levels of elderly people To investigate the impact of disease type, different cognitive rating scales, and types of probiotics	*Lactobacillus* spp. *Bifidobacterium* spp.
Kikuchi-Hayakawa et al. [32]	Double-blind, randomized, crossover, placebo-controlled study	To explore the possible efficacy of *Lacticaseibacillus paracasei* strain *Shirota* (LcS) in improving daytime performance	*Lcb. paracasei* strain *Shirota* (LcS)
Abdelhamid et al. [33]	Review	Examining the beneficial effects of *Bifidobacterium breve* MCC1274 on Alzheimer's disease (AD)	*B. breve* MCC1274
Aljumaah et al. [34]	Randomized, placebo-controlled, double-blind clinical trial	To identify differences in gut microbiota composition and predicted microbial functional pathways between middle-aged and older adults with mild cognitive impairment (MCI) compared to neurologically healthy individuals To investigate the impact of supplementation with the probiotic *Lcb. rhamnosus* GG (LGG) on the composition of the intestinal microbiota	*Lacticaseibacillus rhamnsosus* GG (LGG)

Table 3. *Cont.*

Author	Type of the Study	Objectives of the Study	Microorganisms Used and Studied
Cannavale et al. [35]	Randomized, controlled, cross-over clinical trial	To assess the effects of probiotics on mood states, stress, and hippocampal-dependent memory performance in healthy adults.	*Lactobacillus* spp.
Gaougaou et al. [36]	Acceptability, safety and feasibility, open-label, and non-randomized	To evaluate the acceptability and safety of a probiotic drink (Bio-K+) in autistic children aged 4 to 11 years To evaluate the feasibility of the proposed research protocol to measure the impact of supplementation on behaviors and comorbidities To collect preliminary data to evaluate the impact of probiotic drink supplementation on behaviors, as well as gastrointestinal symptoms and sleep disturbances	*Lactobacillus acidophilus* CL1285 *Lccb* LBC80R *Lcb. rhamnosus* CLR2
Yang et al. [37]	Randomized, double-blind, placebo-controlled trial	To investigate the effect of *Lcb. paracasei* strain Shirota (LcS) supplementation on clinical outcomes and intestinal microbial homeostasis in neo-patients with Parkinson's disease	*Lcb. paracasei* strain Shirota (LcS)
Pereira et al. [38]	Review	Discuss the data available in the last two decades regarding the therapeutic benefits of the probiotic kefir on oxidative stress and inflammation (contributors to chronic neuronal disorders). Promote the development of programs for the next steps needed to obtain confirmation through clinical studies on the breadth of the effects of kefir on large samples	*Lactobacillus* spp. *Lactococcus* spp. *Leuconostoc* spp. *Acetobacter* spp. *Kluyveromyces* spp. *Saccharomyces* spp.

Table 4. Characterizing elements of the articles included in the systematic review (type administrations, potential use of microorganisms in beverages/liquid preparations, and type of beneficial effect on cognitive performance and brain well-being).

Author	Type of Administration	Potential Use of Microorganisms in Beverages/Liquid Preparations	Type of Beneficial Effect on Cognitive Performance and Brain Well-Being
Zheng et al. [29]	Oral in aqueous solution (21 weeks, 5×10^8 CFU/mL)	Yes	Alleviation of cognitive impairment Improved behavioral performance Attenuation of the deficit of hippocampal neuritis growth and synaptic ultrastructure Prevention of intestinal microbiota dysbiosis, colonic barrier damage, and inflammation Attenuation of endotoxemia

Table 4. *Cont.*

Author	Type of Administration	Potential Use of Microorganisms in Beverages/Liquid Preparations	Type of Beneficial Effect on Cognitive Performance and Brain Well-Being
Lof et al. [30]	Oral gavage, added to water or mixed with food (various conditions depending on the target)	Yes	Alleviation of cognitive impairment
Kou et al. [31]	Supplements, capsules, and milk as a supplement (various conditions depending on the target)	Yes	Improvement of cognitive symptoms, particularly on memory and global cognitive function Reduction in oxidative stress levels
Kikuchi-Hayakawa et al. [32]	Fermented milk containing viable LcS (4 weeks, 1.0×10^{10} CFU/mL)	Yes	Improved daytime attention Reduction in theta power on an EEG in the afternoon Tendency towards shorter reaction times Increased level of arousal Effect on the autonomic nervous system
Abdelhamid et al. [33]	Oral gavage (various conditions, depending on the target)	Yes	Immediate and delayed memory improvement Improved MMSE (mini-mental state examination) scores Potential slowing of the progression of brain atrophy in patients with suspected mild cognitive impairment (MCI) Reduction in symptoms of anxiety and depression
Aljumaah et al. [34]	Vegetarian capsules containing microcrystalline cellulose (1×10^{10} CFU *Lcb. rhamnosus*, 90 days)	Yes	Improved cognitive performance in participants with mild cognitive impairment (MCI) Cognitive score improvement
Cannavale et al. [35]	Milk drink (kefir) (3×10^{10} live microorganisms, 4 weeks)	Yes	Improved performance in two parameters of hippocampal-dependent relational memory
Gaougaou et al. [36]	Bio-K+ Probiotic Drink (5×10^{10} CFU of probiotics, 14 weeks)	Yes	Improved Autism-related behaviors, sensory/cognitive awareness, cognitive performance, and brain well-being
Yang et al. [37]	Fermented milk containing live LcS cells (1×10^{10} CFU of probiotics, 12 weeks)	Yes	Significant improvement in non-motor symptoms (NMSs) including depression and anxiety
Pereira et al. [38]	Oral gavage Milk drink (kefir) (various conditions; generally probiotic at least 10^{8}–10^{9} CFU/mL or g; some weeks)	Yes	Therapeutic action against degenerative diseases Reduction in oxidative stress and inflammation Restoration/preservation of the intestinal microbiota Enhanced global cognitive performance, with notable gains in immediate and delayed memory

Regarding the experimental study design category: (i) The study conducted by Zheng et al. [29] describes experiments on murine models in which the diet (control vs. hyperlipidic and fiber-deficient) and *C. butyricum* supplementation (yes/no) are manipulated. It also includes fecal microbiota transplantation (FMT) experiments with control and manipulation groups; (ii) The study conducted by Aljumaah et al. [34] is a randomized, double-blind, placebo-controlled clinical trial that examined the impact of *L. rhamnosus* GG (LGG) supplementation on cognitive function in middle-aged and older adults. Participants were randomly assigned to the probiotic and placebo groups; (iii) The study conducted by Kikuchi-Hayakawa et al. [32] is a double-blind, randomized, placebo-controlled, crossover study that evaluated the effect of *L. paracasei* strain *Shirota* (LcS) on daytime performance in healthy office workers with impaired sleep quality. The crossover design involves each participant receiving both the active treatment and the placebo at different times; (iv) The

study conducted by Abdelhamid et al. [33] describes an experiment on AppNL–G–F mice in which they were randomly assigned to receive saline or *B. breve* MCC1274 for four months, followed by cognitive tests; (v) Yang et al. [37] focuses on the effect of *Lcb. casei* Shirota in patients affected by Parkinson disease.

The research of Gaougaou et al. [36] is in the quasi-experimental study design category, while the study conducted by Aljumaah et al. [34] falls into the cross-sectional observational category and also includes a cross-sectional observational analysis. At the baseline of the experimental study, the composition of the gut microbiota was compared between participants with and without mild cognitive impairment (MCI). This analysis does not involve manipulation but rather observes associations between variables at a given point in time.

The category of longitudinal studies includes studies of: (i) Zheng et al. [29] as the measurements and interventions were performed over a prolonged period of time (21 weeks for the dietary intervention); (ii) Aljumaah et al. [34] as participants were assessed at baseline and after three months of intervention; (iii) Kikuchi-Hayakawa et al. [32] due to the intervention and washout periods; (iv) Abdelhamid et al. [33] as the intervention lasted four months and the evaluations were performed before and after.

The systematic reviews included in this study are those conducted by Lof et al. [30], Kou et al. [31], and Pereira et al. [38].

The first one clearly describes a systematic review and meta-analysis of the literature on the effect of probiotics on cognition in animal models of high-fat diet-induced obesity and a human study, while the second one conducts a literature review on probiotic supplementation for the treatment of cognitive impairment in older adults, followed by a meta-analysis. The paper of Pereira et al. [38] collects some evidence on a wide range of microorganisms.

4. Discussion

4.1. Microbiota Modulation, Cognitive Effects, and Stress Regulation

Recent years have seen a growing interest in the role of the intestinal microbiota in regulating brain function, leading scientific research to focus on the study and identification of specific beneficial microorganisms with potential neuroprotective effects [39–43].

The aim of this systematic review was to investigate whether the literature contained studies that analyzed the correlation between the use of probiotic drinks or probiotic microorganisms potentially usable and transportable in drinks with the improvement of cognitive performance and brain well-being.

Comparative analysis of the studies included in this systematic review suggests that probiotics play a promising role in improving cognitive functions, promoting brain health in different populations [29,33].

Experimental studies conducted on humans have demonstrated how the consumption of fermented milk drinks containing probiotics can exert beneficial effects on relational memory in healthy adults [35]. In particular, it has been demonstrated how a drink containing different live and active cultures of kefir was able to improve the precision in remembering spatial positions and in the association between objects and their location [44–46].

In parallel, research conducted on animal models, in particular on murine models, has highlighted how the integration of specific probiotics can counteract the cognitive decline associated with particular risk conditions such as obesity [29]. In fact, it has been demonstrated that the oral intake of *C. butyricum* has significantly alleviated cognitive deficits in obese mice, improving performance in behavioral tests related to spatial memory and recognition. At the neuronal level, this probiotic, in particular, has contributed to

preserving synaptic integrity, promoting neuritic growth and modulating the expression of key proteins for synaptic plasticity in the hippocampus [47]. The mechanism of action seems to involve the remodulation of the intestinal microbiota, as confirmed by fecal transplant systems [48,49].

Even in randomized controlled clinical trials conducted on adults with mild cognitive impairment (MCI), probiotic supplementation such as *Lcb. rhamnosus* GG (LGG) has shown significant positive correlations with the improvement of cognitive scores [34]. It has been demonstrated that in these experimental conditions a decrease in specific bacterial genera, such as *Prevotella* and *Dehalobacterium*, was associated with cognitive improvement in participants who had received probiotic supplementation [50–52].

The experimental study by Kikuchi-Hayakawa et al. [32] conducted on humans explored the effect of *Lcb. paracasei* strain *Shirota* (LcS) on the daytime performance of individuals with impaired sleep quality, observing an improvement in attention in the afternoon in those who had consumed the fermented beverage containing the probiotic [53].

The potential of *B. breve* MCC127 has also been observed in a highly significant way against neurodegenerative diseases such as Alzheimer's, at least in animal models [33], in which a contrast in the progression of the disease was observed. Although the mechanism of action still needs further clarification, it would seem that this probiotic acts through the gut–brain axis, positively influencing neuroinflammation and oxidative stress [54,55]. Studies on individuals with MCI have also recorded cognitive improvements in specific cognitive subscales following the intake of *B. breve* MCC1274 [56].

The meta-analyses of the literature included in this paper further confirm the beneficial potential of probiotics for cognitive health. In particular, the cross-species systematic review conducted by Lof et al. [30] highlighted how probiotics can alleviate cognitive impairment and anxiety induced by high-fat diets, especially in studies on animal models, with *Lactobacillus* spp. emerging as particularly promising in this field of action [57,58]. The meta-analysis conducted by Kou et al. [31], instead, focused on elderly people with cognitive deterioration, concluding that probiotic supplementation can effectively improve cognitive symptoms, including memory and general cognitive function, and reduce oxidative stress levels [59,60]. Interestingly, this meta-analysis suggests that a probiotic mix might be more effective than a single probiotic at improving general cognition [61,62].

The body of evidence from experimental studies in humans and animal models, as well as from systematic reviews, suggests that different probiotic strains may exert positive effects on cognitive performance and brain well-being through mechanisms involving the gut–brain axis [33].

These effects include improved memory, attention, general cognitive function, and potential protection from cognitive deficits associated with conditions such as obesity and age-related cognitive decline. However, it is important to note that efficacy may vary significantly depending on the specific probiotic, dose, duration of intervention, and characteristics of the population studied. Therefore, further research is needed to fully understand the underlying mechanisms and optimize the use of probiotics for human cognitive health [19,63].

A synopsis of the most important and documented effects on cognitive functions is in Figure 2.

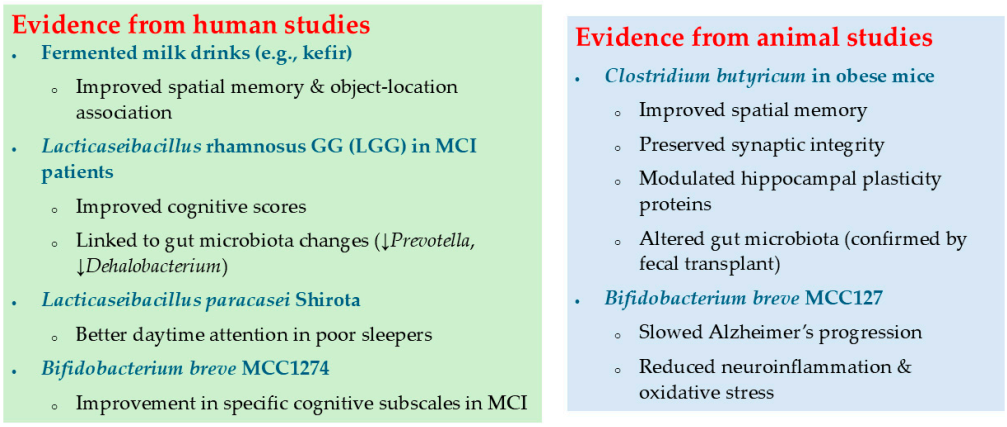


Figure 2. Key-points on the effects of probiotic on some cognitive functions.

4.2. Probiotic Drinks as a Vector for Cognitive Enhancement

An emerging aspect of particular interest, and which acts as a common thread for the work carried out in this review and to all the articles included, is the potential applicability of the microorganisms analyzed in the various scientific works in probiotic drinks, a form of administration that could broaden the accessibility and effectiveness of these intervention strategies. The possibility of conveying these probiotics through probiotic drinks marks, therefore, a turning point of considerable interest in this sense.

The microorganisms studied in these works (*C. butyricum*, *Lcb. rhamnosus* GG, *Lcb. paracasei* strain *Shirota*, and *B. breve* MCC1274) are already used in fermented products or could be easily adapted to functional beverages, improving their bioavailability and promoting a more practical daily administration. The work of Zheng et al. [29], for example, although not specifying whether the microorganism was used in beverages, was, however, dissolved in water and further used in a suspension in PBS (phosphate-buffered saline) for fecal transplantation. From the cross-species systematic review conducted by Lof et al. [30] it emerges that probiotics were mainly delivered via oral gavage or added to drinking water, therefore many of the microorganisms used could potentially be used in beverages. In particular, one of the studies analyzed in the review [64] used a multi-strain probiotic delivered as psychobiotic oral suspension (POS); in fact, the participants took a 3 g sachet of POS or placebo per day via self-administration. Although it is not explicitly stated whether the contents of the sachet were dissolved in a beverage prior to ingestion, the definition of "oral suspension" suggests that the probiotic in powder form was likely mixed with a liquid (water or another beverage) at the time of ingestion, making the delivery method similar to use in beverages.

In the systematic review conducted by Kou et al. [31] most of the studies describe the intervention in the experimental group of "probiotic supplementation", and specifically, in the study by Yun-Ha Hwang et al. [17] *Lcp. plantarum* C29 fermented soybean (DW2009) was used, which implies the potential use of fermented soybean in liquid or semi-liquid form. In some studies, moreover, the control group received a milk supplementation which therefore suggests the administration of microorganisms through milk-based drinks.

This approach would be particularly beneficial for the elderly population or for individuals with high levels of stress and intense lifestyles.

The positive effects of these probiotics on the microbiota and cognitive functions suggest that probiotic beverages/liquid preparations could represent an innovative strategy for the prevention of cognitive decline, especially in high-risk groups such as the elderly or individuals exposed to high work stress. Regular consumption of beverages containing

these probiotics could help maintain optimal brain function, improving quality of life and preventing neurodegenerative diseases.

The studies of Kikuchi-Hayakawa et al. [32] and Cannavale et al. [35] clearly report the use of probiotic microorganisms in fermented beverages. In the first study the probiotic bacterium *Lcb. paracasei* strain *Shirota* (LcS) was delivered through fermented milk containing viable LcS, whilst in the second study the microorganisms were delivered through the consumption of a fermented milk-based beverage.

The study by Gaougaou et al. [36] highlights the fundamental importance of the gut–brain axis, understood as a bidirectional connection employing neural, immunological, and neuroendocrine pathways (with the vagus nerve identified as a crucial link), in the pathophysiology of various neurological and neuropsychiatric conditions, including neurodegenerative diseases such as Parkinson's disease (PD) and neurodevelopmental conditions such as Autism spectrum disorder (ASD). In this context, modulating the composition and function of the gut microbiota emerges as a potentially therapeutic strategy to influence brain health and function.

Specific interventions based on the modulation of the microbiota, such as probiotic supplementation or the consumption of fermented beverages such as kefir, can exert positive effects on different dimensions that intersect with cognitive function and the regulation of stress and mood [36–38].

In particular, it was observed that the intake of the probiotic strain *Lcb. paracasei Shirota* (LcS) had favorable effects on non-motor symptoms (NMSs) in patients with PD, significantly contributing to the improvement of neuropsychiatric symptoms such as depression and anxiety [37]. Previous studies have suggested that the same LcS strain could have a positive impact on mood disorders in the elderly, and could cause a reduction in anxiety symptoms in individuals with chronic fatigue syndrome. In parallel, a specific probiotic drink has been studied in children with ASD; although preliminary data from a non-randomized feasibility study require further confirmation due to the potential placebo effect [36], they suggest a potential beneficial impact on autistic behaviors assessed by ATEC, including dysphoria and social interaction, and on gastrointestinal symptoms.

Regarding cognitive function, modulation of microbiota has been associated with the influence on cognitive processes of learning and memory [38]. Specifically, the review on kefir highlights how supplementation with probiotic kefir has led to significant improvements in global cognitive function, memory (immediate and late), and constructive skills in patients with Alzheimer's disease. In the case of Rasmussen's encephalitis, the use of probiotic kefir has been linked to less cognitive impairment.

These effects appear to be mediated through various mechanisms along the gut–brain axis [36]. It is hypothesized that modulation of the microbiota may influence the synthesis of neurotransmitters crucial for mood, behavior, and cognitive functions, such as acetylcholine, dopamine, serotonin, and noradrenaline [38]. In the case of the LcS study in PD patients, an increase in plasma concentration of L-tyrosine, a precursor of dopamine and noradrenaline, was observed, suggesting a possible link with improved mood and cognitive functions [37]. Furthermore, modulation of the gut microbiota and supplementation with probiotics or kefir appear to contribute to the reduction in oxidative stress and inflammation, processes well-known for their role in neurodegenerative diseases [37]. Last but not least, the improvement of gastrointestinal symptoms, such as constipation, often concomitant in conditions such as PD and ASD, represents in itself a favorable aspect that may impact on quality of life and indirectly on mood [36,37].

As a final step a mind map (Figure 3) with the most important outcomes retrieved from the literature was prepared; the figure offers a synopsis of the most important points discussed in this section on microorganisms, effects, and target populations.

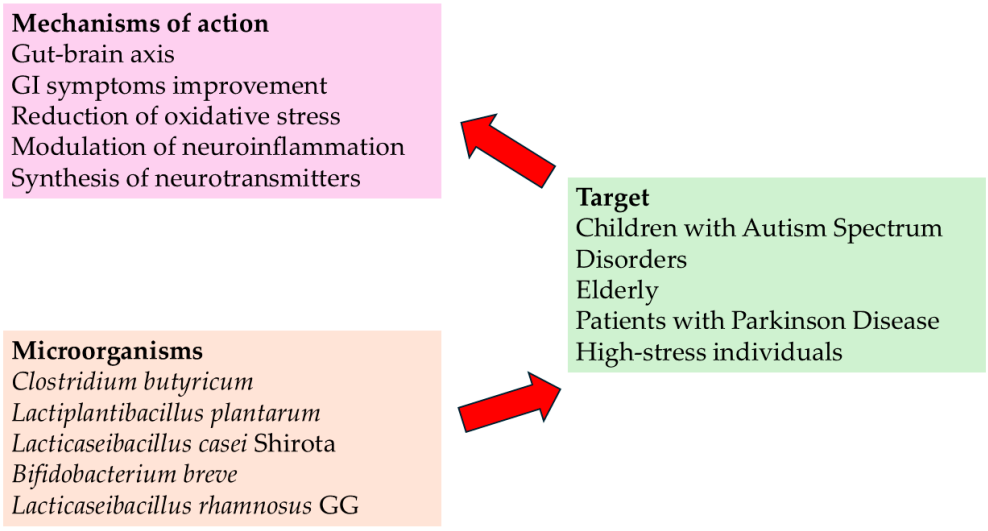


Figure 3. Microorganisms, target populations, and mechanisms for probiotic drinks and cognitive enhancement.

4.3. Limitations of the Study

The limitations of the present study include the low number of analyzed results and the exclusion criteria.

Another limitation could arise from the general trait of systematic reviews in general, as pertains to the restriction of included studies, particularly in instances where studies exhibit divergent quality standards (i.e., inadequate experimental design, limited participant sample size which may impede the generalizability of conclusions, and the absence of comprehensive analysis of the impact of varying doses and treatment durations). The authors are aware of these limits and aim to continue this research to collect more data and evidence.

5. Study Implications and Recommendations

The present review consolidates the emerging evidence indicating the potential of probiotics, especially when delivered through fermented beverages or in liquid formulations, as a novel strategy for sustaining brain function and managing stressful situations. The research studies presented suggest that particular strains of *Lcb. paracasei* Shirota, *C. butyricum*, *Lcb. rhamnosus* GG, and *B. breve* MCC1274 may impact positively on memory, attention, and mood. This might occur because of an influence of these probiotics on the gut–brain axis, their involvement in the mechanisms of neurotransmission, or the ability to decrease oxidative stress and improve the function of synapses.

Not only is the consumption of fermented beverages with probiotics confirmed as an easy and practical way of taking these microorganisms, particularly in the elderly or among people who experience a high level of stress or present risk for at least one neurodegenerative disease, but the habit of ingesting these probiotics regularly as part of a diet could also qualify as a very easy but a potential way of maintaining the health of the brain and preserving cognitive function.

Still, the current literature is characterized by a substantial heterogeneity in the use of probiotics, with different study designs, dosages, durations of treatment, and characteristics of participants all hampering the drawing of clear indications. To be able to refer to more certain evidence on this subject and given the inconsistency that still perdures, further research should be undertaken. Future investigations should be inclined to concur in study protocols, examine the various manners in which different probiotics intervene along the

way from the intestines to the brain, and observe if the results persist through time and in different groups of people.

However, the variability in strains, dosages, durations, and study populations highlights the need for caution in generalizing the findings. Therefore, it is recommended that future research prioritize the following: (i) well-designed randomized controlled trials with standardized probiotic formulations; (ii) studies exploring dose–response relationships and optimal treatment durations; (iii) longitudinal research to evaluate long-term cognitive outcomes; (iv) investigations into strain-specific mechanisms of action along the gut–brain axis.

Such studies will be essential to establish evidence-based guidelines for the clinical application of probiotic beverages in cognitive health promotion.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/beverages11030085/s1. Reference [65] is cited in Supplementary Materials.

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