Review Article

Potential of Non-Dairy Probiotic Beverages to Modulate Gut Microbiota and Improve Management of Non-Communicable Diseases

Laverdure Tchamani Piame*

Department of Human Biology, Faculty of Health Sciences, Walter Sisulu University, Mthatha, South Africa.

Abstract | This review aims to explore the efficacy of probiotic supplementation in non-dairy beverages on the management of non-communicable diseases (NCDs). The pre-March 2025 study selected eight articles from electronic databases such as Web of Science, Scopus, PubMed, and Embase. These studies involved a variety of plant matrices (*i.e., Astragalus membranaceus*, soy, sorghum, blueberry, gogi berry, raspberry, apple, and lichi) and probiotic strains (bacteria and yeast) in a single or mixed cultures. The impact of consuming fermented beverages on gut microbiota (GM) was examined in relation to several conditions, including hyperuricemia, obesity, diabetes, dysbiosis, and colitis, in addition to healthy control individuals. The results indicate that drinking these probiotized beverages greatly alters the composition of the GM by correcting dysbiosis. These beverages foster a rich environment for beneficial bacteria that are known to produce short-chain fatty acids. These fatty acids play a crucial role in maintaining the health and integrity of the intestinal barrier, supporting immune function, and modulating inflammatory responses within the body. In conclusion, this review highlights the considerable therapeutic potential of non-dairy probiotic beverages in the management of chronic diseases that are associated with dysbiosis of the gut microbiota.

Received | March 06, 2025; **Revised** | March 25, 2025; **Accepted** | April 01, 2025; **Published** | June 18, 2025
***Correspondence** | Laverdure Tchamani Piame, Department of Human Biology, Faculty of Health Sciences, Walter Sisulu University, Mthatha, South Africa; **Email:** ltchamanipiame@wsu.ac.za
Citation | Piame, L.T., 2025. Potential of non-dairy probiotic beverages to modulate gut microbiota and improve management of non-communicable diseases. *Novel Research in Microbiology Journal,* 9(3): 198-213.
DOI | https://dx.doi.org/10.17582/journal.NRMJ/2025/9.3.198.213
Keywords | Non-dairy probiotic beverage, Fermented beverage, Gut microbiota, Dysbiosis, Non-communicable diseases, Biological impact

Introduction

Non-communicable diseases (NCDs), particularly diet-related diseases such as cardiovascular disease, type 2 diabetes (T2D), and metabolic disorders, represent a significant threat to global public health. The World Health Organization (WHO) stated that around 71 % of deaths globally each year are due to these diseases, with 77 % of the cases reported in low- and middle-income countries, resulting in major economic and social consequences (WHO, 2021). Managing these diseases is a complex challenge due to their multifactorial nature, involving interactions between genetic, behavioral, environmental, and socioeconomic factors (Stringhini and Bovet, 2017). Although some NCDs have no treatment, several existing strategies for managing these diseases are proving effective. Still, the associated side effects, and the difficulty of targeting the underlying causes and their accessibility remain real challenges (Zaid *et al*., 2022).

Numerous studies have revealed a relationship between the imbalance of the intestinal microbiota (GM) and the genesis of various NCDs (Castillo-Rodriguez *et al*., 2018; Szeligowski *et al*., 2020). GM is a complex group of microorganisms, including bacteria, lower eukaryotes, archaea, and viruses living in symbiosis and actively participating in the organism's functioning (Zhang *et al*., 2024). An imbalance in this complex commonly leads to obesity, cardiovascular disease and T2D, and colitis disease (Liu *et al*., 2021; Ofosu *et al*., 2023). Therefore, microorganisms able to confer a beneficial health effect on their hosts when ingested in sufficient quantities, named probiotics (FAO/WHO, 2002), come as a promising alternative for modulating the microbiota and improving the management of NCDs. Traditionally probiotics incorporated into dairy-based food matrices, which are often expensive and inaccessible, limits their access to low-income populations, particularly those in Asia and Africa. These constraints are leading to a rush to assess the suitability of non-dairy food matrices such as fruit juices (pineapple, mango, orange, apple, grape, golden apple etc.), vegetable juices (sorrel), cereal-based beverages (maize, sorghum, millet) as probiotic vehicles (de Oliveira *et al*., 2021; Tchamani *et al*., 2023; Foko *et al*., 2023, 2024).

The particular feature of the latter is that they are better suited to all classes of the population and perhaps to the dietary requirements of people with delicate health. Moreover, they have common nutrients such as dietary fibre, vitamins, antioxidants, minerals, and bioactive molecules (Basnayake *et al*., 2022), which are all fundamental for maintaining the body and the GM's health (Beane *et al*., 2021). Fermenting non-dairy matrices with probiotics not only lowers the glycemic index but also enhances the production of beneficial bioactive compounds (Tchamani *et al*., 2023). While various studies have shown that these probiotics positively impact gut health, it is crucial to address the ongoing debate about their effectiveness in managing the non-communicable diseases (NCDs). Consensus on their role could unlock significant health benefits for many individuals. The outstanding question concerns the efficacy of probiotised non-dairy food matrices on the specific modulation of the GM and the tangible repercussion on managing pathophysiological processes associated with NTMs. To date, there have been fragmented and incomplete research studies on this subject. While several studies have indicated the beneficial effects on the composition of the microbiota and the reduction of inflammatory markers (Wen *et al*., 2020; El-Sayed *et al*., 2021), others report less clear results, suggesting that the diversity of probiotic strains and the specificities of non-dairy formulations might influence their efficacy (Suez *et al*., 2022). As a result, the precise mechanism of action of non-dairy probiotics in NCDs remains unclear and requires further investigation. Exploring the available data from preclinical studies, the objective of this review is to present the efficacy of probiotic supplementation in non-dairy beverages on the management of NCDs.

Use of previous studies on non-dairy probiotics

This review is based on a descriptive analysis and use of the existing literatures on the effect of consumption of non-dairy probiotic fermented beverages on the GM and its implication in alleviating or treating the NCDs. Therefore, a literature search has been conducted referring to electronic databases (*i.e*., Web of Science, PubMed, Scopus, and Embase) and a search engine (Google Scholar). Original articles that evaluate the effects of the non-dairy probiotic beverages on the GM and the various metabolic parameters have been included, whereas studies involving dairy matrices (completely or partially), multiple probiotic strains, or unidentified microorganisms have been excluded.

Non-dairy probiotic beverages

The changing eating habits and lifestyles of people living in urban areas predispose them to developing chronic diseases. For this reason, a diet-based approach to combating chronic diseases suggests the consumption of foods that are beneficial to health, such as functional foods or probiotics, to come closer to Asian eating habits, which include drinks, basic foods, and very few dairy products (Vasudha and Mishra, 2013). The scientific community is therefore very interested in promoting the consumption of probiotics *via* matrices other than dairy products, for reasons pre-mentioned in the section of introduction in this review.

Numerous studies have demonstrated the effectiveness of non-dairy food matrices in carrying probiotics. These matrices are generally inspired by traditional fermented drinks, which add conventional or non-conventional probiotics to improve fermentation. For this purpose, cereals (maize, rice, pearl millet and sorghum), vegetables (*Hibiscus sabdariffa* L. (sorrel) calyx, *Astragalus membranaceus*), legumes (*i.e.*, soy), and fruits (apple, golden apple, pineapple, blueberry, raspberry, cranberry, lichi, pomegranate, orange etc.) (Panghal *et al*., 2018; Aspri *et al*., 2020) are commonly studied in combination with probiotics belonging to the genera *Lactobacillus, Lactococcus, Bifidobacterium, Enterococcus* etc. (Foko *et al*., 2023). Foko *et al.* (2023, 2024) demonstrated an increase in the viability of the *Lactiplantibacillus plantarum* LO3 strain in golden apple juice, and an increase in the antioxidant capacity as well without affecting the organoleptic quality. However, in the sorrel + pineapple juice, the viability of the probiotic *L. casei* 62L is close to 10^8 cfu/ ml and the organoleptic quality has been significantly improved after 24 d of storage (Foko *et al*., 2023). Similarly, in orange juice, there has been no significant difference among the viability of the *L. casei* strains, with no negative impact on the overall acceptability of the product (Miranda *et al*., 2019). For the sake of completeness, we note that non-dairy beverages are suitable for ensuring the viability of probiotics and can therefore grow in them. Many studies have shown that fermentation of non-dairy food matrices potentiates their biological effect and improves the product's organoleptic quality and shelf life. Fermentation increases the phenol and flavonoid content and, therefore, the antioxidant activity of golden apple, sorrel juice + pineapple, raspberry, beetroot, and carrot juices (Zamfir *et al*., 2022; Foko *et al*., 2023, 2024). Furthermore, fermentation extends the shelf life of the products by reducing the pH of the medium through organic acids and inhibiting the selective proliferation of spoilage/pathogenic micro-organisms through the synthesis of antimicrobial molecules. Several bacterial genera (*i.e., Lactobabillus* spp., *Lactococcus* spp., and *Enterococcus* spp.) produce bacteriocins, antimicrobial molecules that are more or less stable to chemical and thermal treatment (Qiao *et al*., 2020; Fotso Techeu *et al*., 2022).

Gut microbiota and plasticity

Formerly known as the 'intestinal flora', the GM refers to a complex group of millions of microorganisms residing in the human digestive tract, mainly the colon. The density of this population gradually evolves from the mouth to the colon as the oxygen content decreases. As a result, approximately 99 % of the bacteria residing in the colon are aerobic (Thursby and Judge, 2017) (Figure 1). Scientific advances over the past two decades have highlighted the critical importance of this microbial assemblage to the human health, revealing their fundamental roles in digestion, immunity, inflammation, and even neurocognitive interactions.

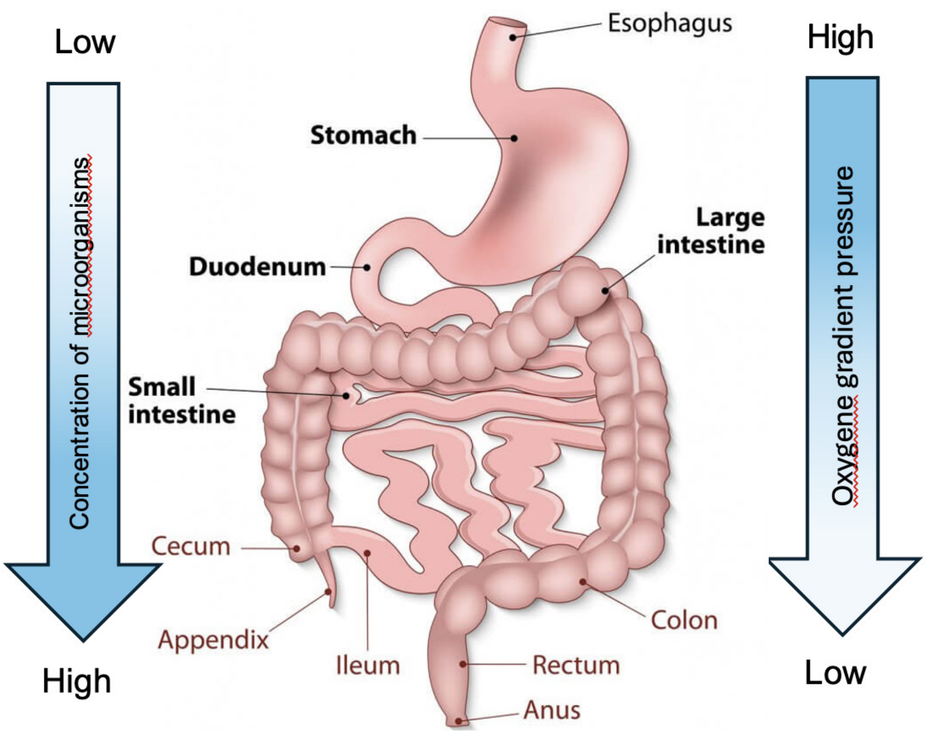

Figure 1: *Gradient in the concentration of microorganisms according to the oxygen content in the digestive tract. The concentration of micrsoorganisms (mainly bacteria) increases from the mouth to the anus, while the concentration of oxygen decreases in the opposite direction, as depicted by Thursby and Judge (2017).*

The gut microbiota is a highly dynamic system that continually reacts to environmental changes and is characterized mainly by its plasticity defined according to Grembi *et al.* (2020) as the variability of microbiota structure and composition (measured by β-diversity), on such short time scales as a day. This plasticity is based on the ability of microbial populations to regulate each other and adapt their metabolism according to the host's nutritional intake and physiological conditions. For example, a fibre-rich diet encourages the proliferation of the bacteria producing short-chain fatty acids, such as Bacteroidetes and Firmicutes, which play a key role in regulating the inflammation and the energy metabolism (Chandrasekaran *et al.*, 2024). Conversely, a high-calorie and low-fibre diet enriches pro-inflammatory species, which can lead to a state of dysbiosis (Yao *et al.*, 2023).

Gut microbiota-host interaction

The GM and host maintain a constant dialogue mediated by complex mechanisms involving signaling molecules and immune interactions. Short-chain fatty acids (SCFA) and polyamines, which modulate intestinal permeability and regulate the activity of local immune cells, act as chemical mediators (Ramos-Molina *et al.*, 2019). By binding to specific receptors on epithelial cells, SCFA inhibit the production of pro-inflammatory cytokines (Fonseca *et al.*, 2022) and the action of histone deacetylase, thereby promoting gene regulation by increasing its accessibility to transcription factors (Fawad *et al.*, 2022). In return, the host immune system regulates the microbial composition by producing antimicrobial peptides and modulating inflammatory responses (Ma *et al.*, 2022). This bi-directional dialogue is essential for maintaining intestinal homeostasis and preventing immune dysregulation that could lead to autoimmune or chronic inflammatory diseases. In a recent investigation, Yu *et al.* (2019) have employed male C57 BLKS db/ db mice as experimental models, uncovering notable shifts in the β-diversity and relative abundance of the gut bacteria in these db/db mice. Additionally, significant alterations in metabolic parameters have been observed when the GM from db/ db mice was transplanted into pseudogerm-free mice. These findings indicate that the GM of diabetic mice harbors transmissible elements, suggesting that the transfer of an imbalanced GM may play a role in the onset of Type 2 Diabetes (T2D). These observations are similar in several pathologies, including obesity, liver disease, colon disease, and mental illness, where a disturbance in the microbiota is being associated (Gurung *et al.*, 2020; Ridaura *et al.*, 2013).

Maintaining a permanent balance in the composition of the microbiotic communities is essential. Several studies have highlighted the importance of a healthy diet rich in dietary fibre in increasing the relative diversity and the abundance of phyla of interest in restoring the microbiota in individuals suffering from chronic diseases. A meta-analysis of twelve randomized controlled trials (RCTs) in overweight and obese adults has found that soluble fibre supplementation, compared to placebo, reduced BMI, body weight, and body fat (Bozzetto *et al.*, 2018). An in-depth analysis of twenty one randomized clinical trials involving 1037 patients with NAFLD (nonalcoholic fatty liver disease) revealed that probiotic intervention significantly improved liver function, blood lipid profiles, glucose levels, and insulin concentrations, thus reducing hepatic steatosis. However, this intervention showed no significant effect on body mass index, inflammatory markers or insulin resistance as assessed by the Homeostatic Model Assessment for Insulin Resistance (Zhou *et al.*, 2023). This testifies to the effectiveness of probiotics, whose consumption should be encouraged in both healthy and sick people to prevent the burden of chronic diseases. The addition of probiotics to plant- or fruit-based beverages is of interest since plant matrices potentially provide prebiotics, which intestinal probiotics use to promote their metabolism, reproduction, and production of bioactive metabolites (You *et al.*, 2022).

Non-dairy probiotic fermented beverages and non-communicable diseases

Managing non-communicable diseases can be tricky because they require intervention over a long period and, in most cases, are incurable and require lifelong monitoring (Budreviciute *et al.*, 2020). Developing less burdensome strategies and therapeutic agents with very low toxicity would be imperative to achieve this, hence the interest in probiotics. The medium used to transport probiotics is crucial, as it facilitates their consumption and sometimes potentiates their effects through symbiosis (Kamdem *et al.*, 2016). According to the available studies, consuming drinks fermented with recognized probiotics undoubtedly impacts MG and improves the mice's recovery and health (Figure 2). Interestingly, we observed a common effect in GM modulation according to the consumed probiotic drink. Changes in microbiotic composition have a direct influence on the host's state of health (Wang *et al*., 2024). Consuming probiotic beverages made from plants, fruit or seeds selectively modifies the intestinal microflora. *Astragalus membranaceus* and raspberry probiotic drinks promote the proliferation of a group of bacteria, mainly *Butyricimonas synergistica*, *Odoribacter splanchnicus*, *Collinsella tanakaei*, and *Akkermansia*, respectively, which produce SCFAs. The best known of these metabolites are butyrate, acetate, and propionate (Mortensen *et al*., 1996). Although GM usually produces these SCFAs, our food can influence the quantity produced. An intake of non-digestible polysaccharides (i.e., dietary fibre and resistant starch), which fruits contain in sufficient amounts, is degraded by a type of microbiota that produce SCAFs (Garcia-Mantrana *et al*., 2018). Thus, administration of these probiotics *via* a plant-based drink would play a crucial role in the production of SCFAs, acting as chemical mediators between GM and DNA and therefore modulating gene function. Through their actions, probiotics ensure the proper functioning of several levels of the body by preserving the permeability of the intestinal barrier, regulating the nervous system's pathways and the decarboxylation of histones, and neuro-inflammation, hence their involvement in the management of several chronic diseases (*i.e.*, ulcerative colitis, diabetes, hyperuricemia, obesity, and antibiotic induced diarrhea) (Mirzaei *et al*., 2021; Wang *et al*., 2022; Ofosu *et al*., 2023).

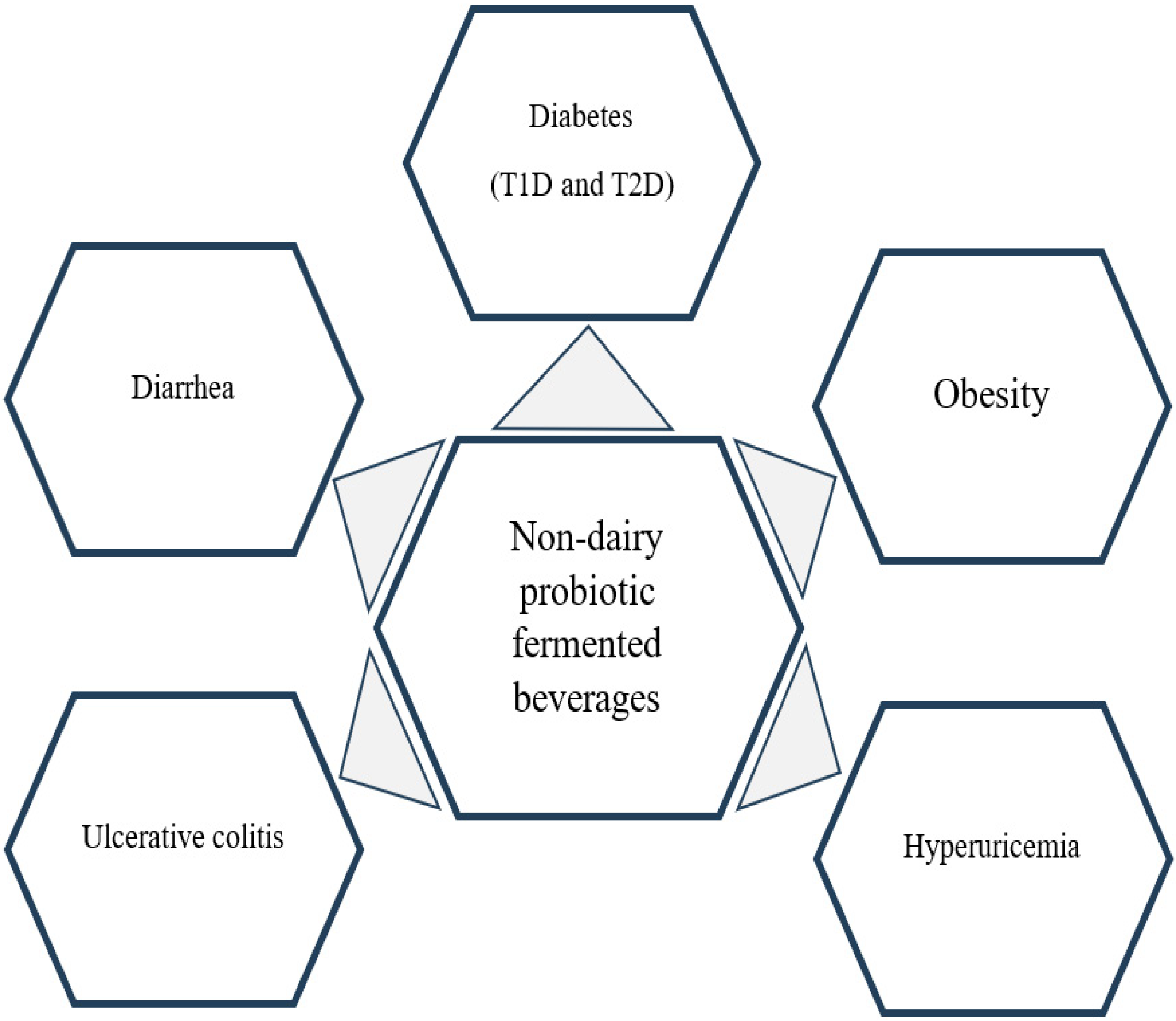

Figure 2: *Some non-communicable diseases on which probiotic-based fermented non-dairy beverages have a significant impact, depicted by Mirzaei et al. (2021), Wang et al. (2022), Ofosu et al. (2023).*

Effect of probiotised soy juice on obesity

Numerous studies have demonstrated that consumption of probiotics influences weight loss in obese people. Probiotics improve coordination of the microbiota-intestine-brain axis *via* the production of SCFs, leading to a reduction in body fat in juvenile iberian pigs (Zeltser *et al*., 2020). A little-known probiotic, heat-killed *Enterococcus faecalis* 2021, was administered orally to obese mice. After 6 weeks, the level of obesity in the experimental mice decreased at doses of 3 mg/ kg or 30 mg/ kg, suggesting a regulatory effect in mice with high-fat diet-induced obesity (HFD). *E. feacalis* 2021 exerts an anti-obesity effect by inhibiting lipid accumulation in the 3T3-L1 cells, the insulin signalling pathway, and the expression of C/EBP-α and PPAR-γ (adipogenic transcription factors) (Lee *et al*., 2022). *E. faecium* SF68 has been shown to reduce excessive weight gain induced by obesogenic diets and preserves a balanced gut microbiota. Certain strains of *Enterococcus* are known for their ability to reduce serum cholesterol. Similarly, *Lactobacillus helveticus* CD6 has been shown to effectively reduce hyperlipidemia and weight gain induced by a high-fat diet, while maintaining a normal liver histology (Holzapfel *et al*., 2018). In contrast, in healthy overweight or obese adults, supplementation with *Bacillus longum* strain APC1472 does not significantly affect primary outcomes, such as BMI or waist-to-hip ratio; however, a beneficial effect has been observed on the secondary result of fasting blood glucose levels (Schellekens *et al*., 2020).

The above-mentioned probiotic strains (*E. feacalis, L. helveticus*, and *B. longum*) have been used as fermenting agents for soy milk in obese mice. In the previous study conducted by de Carvalho Marchesin *et al*. (2018), the administration of soy milk fermented with the three probiotic strains mentioned above influenced the composition of the GM and the reduction of body fat in obese mice. After 70 d, there is a remarkable increase in *Bifidobacterium* levels, a reduction in lipid accumulation (reduction in adipocyte surface area) and blood sugar levels, and an increase in non-inflammatory interleukins (IL-6 and IL-10) (Table 1). The effects noted are mainly associated with probiotics, as anti-obesity effects are not associated with soy milk. A meta-analysis conducted by Akhlaghi *et al*. (2017), including 24 RCTs, has shown that soy has no significant impact on improving anthropometric parameters in obese subjects, whereas a positive effect on weight loss in overweight and obese non-menopausal women have been observed, this effect is thought to be justified by soy's isoflavone and fibre content (Mu *et al*., 2019).

Effect of probiotised Goji berry juice on ulcerative colitis

Ulcerative colitis is a chronic inflammatory bowel disease (IBD) mainly affecting the colon and rectum. It is characterized by persistent inflammation of the intestinal mucosa, leading to the formation of ulcers and causing symptoms such as abdominal pain, bloody diarrhoea, intense fatigue, and weight loss (Kuenzig *et al*., 2022). Disruption of the intestinal barrier, alteration of the microbiota, and a dysregulated immune response are significant factors in the development and progression of this disease. Widely recognized for their ability to reverse related dysbiosis, probiotics are emerging as a promising solution for combating ulcerative colitis. Studies have shown that certain probiotic strains play a remarkable role in maintaining and repairing the intestinal barrier. For example, the *Limosilactobacillus reuteri* D8 strain promotes the intestinal stem cell regeneration by increasing the number of Paneth cells in the intestinal crypts, thereby contributing to intestinal mucosal repair (Hou *et al*., 2018). Similarly, administration of *Akkermansia muciniphila* for 4 weeks accelerated the proliferation of Lgr5+ intestinal stem cells and supported the differentiation of Paneth cells and caliciform cells in the small intestine (Kim *et al*., 2021). In patients with ulcerative colitis, increased intestinal permeability and decreased tight junction proteins are key disease markers. A probiotic formulation combined with dexamethasone (a corticosteroid having anti-inflammatory and immunosuppressive properties) enhanced intestinal barrier integrity by blocking LPS translocation and inhibiting the TLR4/ NF-κB pathway, thereby alleviating symptoms in a mouse model of autoimmune hepatitis (Liu *et al*., 2021). In addition, probiotics can increase taurine levels, which stimulate TJ protein expression, reducing intestinal permeability and preventing leaky gut (Liu *et al*., 2021). These mechanisms are promising for the treatment of the ulcerative colitis, as they directly target the restoration of the intestinal barrier and the reduction of chronic inflammation.

Lactobacillus plantarum, L. reuteri, and *S. thermophilus* are used to ferment Goji berry juice and then tested in mice suffering from dextran sodium sulphate-induced ulcerative colitis. In this context, a positive modification of the GM is observed, marked by an

Table 1: *Effect of consuming probiotic fermented beverages on a number of non-communicable diseases.*

References	Raw material used to produce beverage	Probiotic (source)	Dose	Duration of intervention	Type of subject	Effect on gut microbiota	Other pertinent results
de Carvalho Marchesin *et al.* (2018)	Soy	*Enterococcus faecium* CRL183 and *Lactobacillus helveticus* 416 *Bifidobacterium longum* ATCC15707	1.0% of body weight (8.0 log CFUml^{-1} of probiotic microorganisms)	70 d	Diet-induced obese male mice with SPF	Significant ↑ in *Bifidobacterium*	↓ in body weight compared to the obese control group. ↓ in adipocyte surfaces. Significant ↑ in interleukin levels (IL-6, IL-10) and a non-significant ↓ in fasting glycaemia in obese group.
Wen *et al.* (2020)	Litchi	Lactobacillus casei	0,2 ml/10 g of body weight	30 d	Male BALB/c mice free of specific pathogens	↑ in the relative abundance of beneficial bacteria (*Faecalibaculum, Lactobacillus* and *Akkermansia* genera and Firmicutes phylum). ↓ in the relative abundance of the Bacteroidetes.	Improved indices of immune organs (spleen and thymus). Improved antioxidant capacity. ↑ secretion of cytokines (IL-2, IL-6) and immunoglobulins (*i.e.*, IgA, IgG, and SigA).
Liu *et al.* (2021)	Goji berry	*Lactobacillus plantarum, Lactobacillus reuteri* and *Streptococcus thermophilus*	20 ml/kg/d	30 d	Dextran Sodium sulfate (DSS)-induced ulcerative colitis mice	↓ of relative abundance of Bacteroidetes and Firmicutes ↑ of Proteobacteria, Verrucomicrobia and Epsilonbacteraeota in contrast to healthy controls. DDS group, the number of colon crypts disappeared and a large number of globet cells were preserved.	↓ in pro-inflammatory cytokines and total superoxide dismutase in serum and colon tissue. ↑ of anti-inflammatory cytokines, myeloperoxidase and glutathione peroxidase. ↓ bloody diarrhoea and shortening of the colon.
Wu *et al.* (2021)	Raspberry	*Lactobacillus case*i (CICC 20280)	Supplemented in the feed to 3, 6 and 9%	30 d	Male Kun Ming mice	↑of beneficial bacteria (*Lactobacillus* and *Akkermansia*). ↑ production of short-chain fatty acids (acetic, butyric and isovaleric acids). At 9%, the population of Akkermansia significantly reduces the number of harmful bacteria (*Escherichia* spp. and *Shigella* spp.).	Fermentation ↑ the phenolic compound content and antioxidant activity.
Guo *et al.* (2022)	Apple		4 g/kg/d, 0.27 g/ml)	7 d	ICR mice with antibiotic-induced diarrhoea	Evolution of phyla towards a healthier microbiome. ↓ the relative abundance of pathogenic bacteria (*Enterococcus* and *Clostridium*). ↑ of beneficial bacteria such as *Lactobacillus* and *Prevotella*.	Improvement in the height of intestinal villi and the ratio of villi height to crypt depth. ↑ in the expression of tight junction proteins (*i.e.*, ZO-1, Occludin and Claudin-1)
Wang *et al.* (2022)	Astragalus membranaceus	*Bacillus subtilis* (Shanghai Litong Biochemical Products Co., ltd.)	0.25, 0.5 and 1 g/kg *A. membranaceus* and 10^8 cfu/ml *Bacillus subtilis*	6 weeks	Hyperuricemia (HUA) ICR male mice with Specific Pathogen Free	↓ in the hyperuricemia. Significant changes in GM composition (↑ of beneficial bacteria such as *Lactobacillus intestinalis* and *Bacillus mycoides*). ↑ butyrate-producing bacteria (*Butyricimonas synergistica*, *Odoribacter splanchnicus*, and *Collinsella tanakaei*)	Not significantly on body weight or feed intake between the BFA and control groups. Lachnospiraceae, Mycoplasmataceae and Spirocheaceae were positively correlated with glycaemia. Expression proteins GLUT9 and URAT1 in mouse kidneys was significantly ↑ in the HUA group compared with the NC group.
Ofosu *et al.* (2023)	Sorghum	*Pediococcus acidilactici* OHFR1	100, 500 and 1000 mg/kg/bw fermented sorghum	7 weeks	High-fat diet-streptozotocin-induced diabetic mice	Reversing dysbiosis (↑ of firmicutes and ↓ in Bacteroidetes). ↓ of opportunistic pathogens and ↑ of beneficial bacteria.	↑ glucose tolerance and insulin sensitivity. ↓ of glycated haemoglobin levels. ↓ level of deleterious metabolites (p-cresol and indole lactate) and ↑ level of beneficial metabolites (phenylpropionate and bile acids).

increase in the relative diversity of bacteroidetes and firmicutes and a progressive disappearance in the number of colon crypts. Meanwhile, a large number of globet cells are preserved. At the same time, there is an increase in the level of pro-inflammatory cytokines, myeloperoxidase, and glutathione, thus reducing the systemic inflammation and the level of oxidative stress; associated with a reduction in the length of the colon and a reduction in the bloody diarrhoea (Liu *et al*., 2021). These effects cannot be attributed solely to the action of probiotics, but also to Goji berry juice, which has properties favorable to the reduction of ulcerative colitis (Sun *et al*., 2022). In addition to their carotenoid and polyphenol content, *L. barbarum* polysaccharides (LBPs) are the main active components, recognized for their protective effects against oxidative stress, inflammation, and neuro-degeneration (Sun *et al*., 2022). These properties may also be of interest in the fight against diarrhoea.

Effect of probiotised apple juice on antibiotic induced diarrhoea

Different studies demonstrate that *Lactiplantibacillus plantarum* plays a major role in improving intestinal morphology and intestinal barrier function (Wang *et al*., 2019), fighting pathogenic infections (Wang *et al*., 2018), and reducing incidence of *Clostridioides difficile* infections (Dudzicz *et al*., 2018). Due to its ability to restore or steer the gut flora towards a healthier microbiota, *L. plantarum* contributes to reversing dysbiosis. For instance, administration of the apple drink fermented with *L. plantarum* CICC21809 resulted in an increase in the height of the intestinal villi and the ratio between the height of the villi and the depth of the crypts in mice suffering from antibiotic-induced diarrhoea, thereby optimizing intestinal absorption attributed to a larger contact surface (Table 1). In addition, intestinal integrity is enhanced by increased expression of tight junction proteins such as ZO-1, Occludin, and Claudin-1 (Guo *et al*., 2022). Consequently, there is a reduction in the relative abundance of the pathogenic bacterial genera such as *Enterococcus* and *Clostridium*, accompanied by an increase in the beneficial bacteria such as *Lactobacillus* and *Prevotella* (Guo *et al*., 2022). Furthermore, it has been recently shown that *L. plantarum* ELF051 can modulate inflammatory signaling pathways involving TLR4/MyD88/NF-κB (Toll-like receptor/myeloid differentiation primary response 88/nuclear factor kappa B) and phosphatidylinositol 3-kinase/protein kinase B/NF-κB (PI3K/AKT/NF-κB), thereby enhancing intestinal defense mechanisms (Liang *et al*., 2024). Finally, *L. plantarum* ELF051 attenuates pathological alterations in the colonic tissues, reduces the expression of interleukin (IL)-1β and tumour necrosis factor (TNF-α), while increasing the expression of IL-10 and the level of SCFAs in the intestine (Figure 3) (Wang *et al*., 2019).

Effect of Astragalus membranaceus probiotised drink on hyperuricemia

Poor metabolism of the purines synthesized by the body or provided by the diet, inevitably leads to an increase in the level of uric acid in the blood (hyperuricemia), an early transitional step in gout. However, there are anti-hyperuricemic drugs (*i.e*., allopurinol, febuxostat, probenecid, and benzbromarone) which are avoid of consequences for vital organs such as the liver and the kidney. The research community is now actively looking for alternative treatments. Fermented *Astragalus. membranaceus* drink administered to hyperuricemic mice positively impacted GM and uricemia (Table 1). *L. intestinalis* and *B. mycoides* are abundant, as were butyrate-producing bacteria (*Butyricimonas synergistica*, *Collinsella tanakaei*, and *Odoribacter splanchnicus*). This drink has significantly increased the expression of enzymes involved in the elimination of ammonia from the body (*i.e*., urease and ornithine amino transferase) in the group of mice that consumed it (Wang *et al*., 2022). It is therefore plausible that the microbiota *via* the chemical mediators it produces, could increase the flow of ammonia out of the body so that the *de novo* or purine recovery pathway becomes oriented towards the long cycle. Abnormal fluctuations in GM are thought to be linked to the development of hyperuricemia and gout (Chu *et al*., 2021). A metagenomic study highlighting the microbiotic composition of the intestinal flora of mice demonstrated that hyperuricemia alters the composition of the microbiota (Xu *et al*., 2019) and considerably reduces the population having the ability to metabolize the purines. Multiple studies have focused on screening, selecting, and supplying of purines degrading probiotics to control uricemia in animal models.

In those hyperuricemia mice which have been given oral *L. plantarum* WCFS1, uric acid levels have been significantly reduced compared to healthy control mice (Li *et al*., 2014). *Lacticaseibacillus paracasei* MJM60396, a potential probiotic, administered for

3 weeks to male C57BL mice has reduced uric acid levels to normal. Three mechanisms are involved in this case: it absorbs purines (100 %), down-regulates xanthine oxidase activity (81 %) by reducing their quantity, and increasing urate transporters' excretion (Lee *et al*., 2022). Wu *et al*. (2021) demonstrated that hyperuricaemic mice fed with the *Limosilactobacillus fermentum* JL-3 strain have reversed the intestinal dysbiosis induced by hyperuricemia, significantly reducing blood uric acid levels, but restoring levels of biochemical markers associated with oxidative stress and inflammation (*i.e*., malone-dialdehyde, creatinine, interleukin-1β, blood urea nitrogen). These studies alone demonstrate the efficacy of probiotics in the prevention/ management of hyperuricemia. Further studies should be carried out to confirm the clinical effects in humans and promote the consumption of these probiotics by including them in low-cost food matrices that are available, acceptable, and without risk of causing metabolic disorders in the consumer.

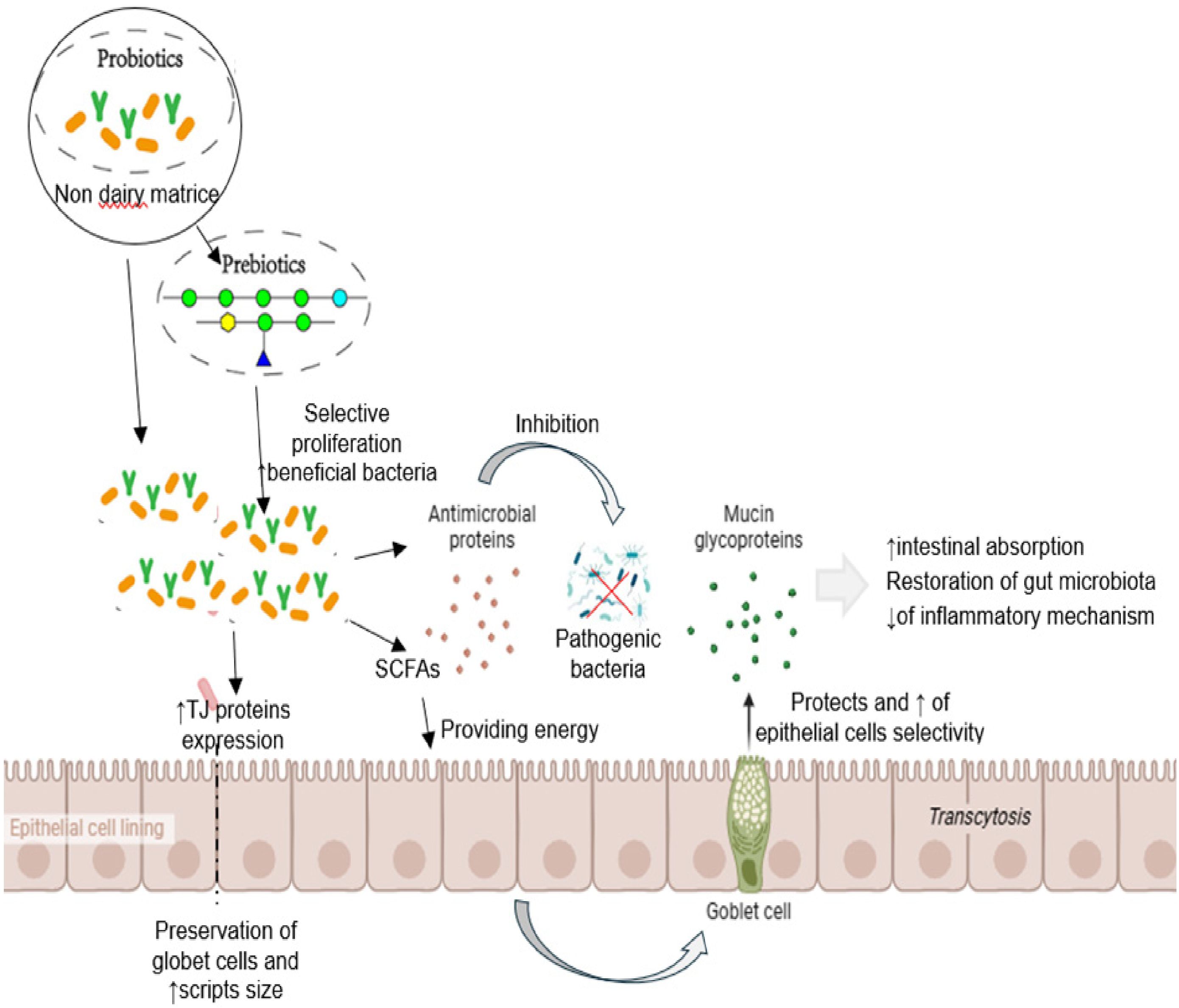

Figure 3: *Regulation of the gut microbiota by dietary probiotics, depicted by Guo et al. (2022). Probiotics taken in the diet (i.e., non-dairy drinks) act on the microbiota via several mechanisms. Brought into the digestive tract in large quantities, probiotics exert a competitive effect on substrate consumption, depriving pathogenic bacteria of energy sources, thus reducing their numbers. Due to their ability to adhere to the epithelial cells, they occupy space to the detriment of the other microorganisms. They produce antimicrobial substances that exert selective inhibition. By degrading the dietary fibres, they produce SCFAs, which not only serve as a source of energy for the colonocytes but also act on the regulation of genes (TJ proteins, TLR4, NF-kβ, etc.), thereby modulating the intestinal membrane integrity.*

Links Researchers

Effect of Sorghum probiotic drink on diabetes

Research into probiotics has opened up new perspectives in the management of diabetes; particularly T2D, and *Pediococcus acidilactici* has shown itself to be a promising agent due to its various metabolic actions. The anti-diabetic activity of this bacterium is mainly based on its ability to inhibit the enzymes that hydrolyze carbohydrates, such as α-glucosidase and α-amylase, limiting the absorption of sugars in the intestine and reducing postprandial glucose peaks (Fachrial *et al*., 2023).

The effects on glucose regulation have been demonstrated in rodent models of induced diabetes. The administration of specific strains of *P. acidilactici* has been shown to significantly reduce blood sugar levels, with some results even surpassing those achieved with metformin (Fachrial *et al*., 2023). One identified mechanism for this effect is the inhibition of α-glucosidase, an enzyme that slows the digestion of complex carbohydrates into simple glucose, ultimately reducing postprandial hyperglycemia. Its action has no deleterious effect on vital organs; however, it does improve liver and kidney function and lipid profiles. The impact on the pancreas is remarkable following a histological observation of the pancreatic tissue, revealing an improvement in the structure of Langerhans islets and acinous cells in the diabetic mice treated with *P. acidilactici*, suggesting protection of insulin-producing β cells (Fachrial *et al*., 2023). This preservation of β cells could be linked to a reduction in oxidative stress and inflammation, generally involved in the destruction of the pancreatic cells (Shen *et al*., 2024) and the reduction of the low-grade inflammation in the diabetic context (Ahmadi *et al*., 2020).

Ofosu *et al*. (2023) have shown that sorghum drink fermented with *P. acidilactici* OHFR1 positively affects the diabetic mice (Table 1). This drink reverses dysbiosis by encouraging the proliferation of firmicutes and the reduction of bacteroidetes, with a decrease in the number of potentially pathogenic opportunistic bacterial genera (*Oscillibacter, Acetatifacter*m and *Allobaculum*) and an increase in the number of beneficial bacteria (*Phocaeicola, Parabacteroides*, and *Muribaculum*). These results are unanimously supported by several researchers who assert that probiotic consumption restores biochemical parameters to normal in diabetic patients (Ofosu *et al*., 2023; Wang *et al*., 2024; Zhong *et al*., 2024). A meta-analysis conducted by Zhong *et al*. (2024) demonstrated the efficacy of *L. plantarum* supplementation in improving the management of glucose and lipid metabolism. Biochemical parameters relating to diabetes, namely fasting glycaemia, glucose tolerance, insulinemia, insulin resistance, and glycated haemoglobin (HbA1c) levels in diabetic mice are closely correlated with *Oscillibacter, Roseburia, Acetivibrio, Helicobacter, Flintibacter, Millionella, Lachnoclostridium, Acetatifactor, Enterocloster*, and *Ruminiclostridium* spp. (Ofusun *et al*., 2023).

Probiotic effect of raspberry and lichi fermented juices in healthy mice

The blueberry fermented drink supplemented with cricket protein hydrolysates, such as the raspberry fermented drink, has impacted the relative abundance of the probiotic genera in healthy patients (Table 1). In particular, raspberry juice fermented with the *L. casei* strain increased the abundance of bacteria belonging to the *Lactobacillus* and *Akkermansia* genera and promoted the synthesis of SCFAs (acetic, butyric, and isovaleric acids). A similar effect is observed with the fermented lichi drink that has been fermented with a strain of the same species (Wen *et al*., 2020) (Table 1). This would suggest that the impact on GM depends mainly on the nature of the probiotic and that the matrix acts merely as a carrier agent. Nevertheless, the effect of the matrix on the health is not negligible.

However, a non-beneficial effect has been observed when this drink is administered at a concentration of 9 %, with a decrease in the population of *Akkermansia* and an increase in harmful enterobacteria, including *Escherichia* spp. and *Shigella* spp. and bacteroidetes. At the same time, the antioxidant activity has increased markedly after fermentation, as it did in the fermented litchi juice (Wu *et al*., 2021). In addition to the previously mentioned effects, litchi fermented juice improves the performance of the immune organ indices; in this case the spleen and thymus, and increases the secretion of the cytokines (IL-2, IL-6) and the immunoglobulins, mainly IgA, IgG, and SigA.

Limitations and future direction

While pre-clinical and animal studies show promising results, clinical data supporting the use of probiotics in humans for managing non-communicable diseases (NCDs) remains limited, and the long-term effects are not well understood. Differences in outcomes among various probiotic strains, dietary contexts, and individual traits make standardizing protocols more challenging. In addition, there are potential risks to vulnerable populations such as immunocompromised patients or those undergoing chemotherapy due to opportunistic infections. Future research must rigorously assess the efficacy and safety of probiotic beverages in large-scale clinical trials in patients with NCD, explore their molecular mechanisms, and optimize formulations to improve their bioavailability and effectiveness. The study of synergies between different probiotic strains, their interactions with functional foods, and individual microbial diversity is essential for customizing therapies. The integration of probiotic beverages into affordable and accessible nutrition strategies could expand their use for sustainable management and prevention of NCDs on a global scale.

Conclusions and Recommendations

This review highlights the promising therapeutic potential of the non-dairy probiotic beverages in managing and treating the diet-related non-communicable diseases through their modulatory effects on the gut microbiota. Indeed, their ability to positively influence microbiotic composition and promote the production of beneficial metabolites, such as SCFs, represents key mediators in the management of chronic pathologies, including diabetes, ulcerative colitis, hyperuricemia, and diarrhoea. Furthermore, probiotic beverages improve biochemical, functional, and histological parameters, demonstrating the plausible link of a balanced microbiota in modulating the inflammatory, the immune responses, and the intestinal integrity. Nonetheless, more scientific evidence are recommended; according to the type of disease, in order to specifically measure the efficacy of non-dairy probiotic beverages, using harmonized protocols.

Acknowledgments

The author is deeply grateful to Walter Sisulu University for providing him access to the various electronic databases as part of this bibliographic review.

Novelty Statement

This overview summarises scientific evidence which supports non-dairy probiotic fermented beverages' potential in the management of non-communicable diseases associated with dysbiosis.

Funding

This work did not receive any funding.

Ethical approval

Not applicable.

Conflict of interests

The author has declared no conflicts of interest.

References

Ahmadi, S., Wang, S.H., Nagpal, R., Wang, B., Jain, S., Razazan, A., Mishra, S.P., Zhu, X.W., Wang, Z., Kavanagh, K. and Yadav, H., 2020. A human-origin probiotic cocktail ameliorates aging-related leaky gut and inflammation via modulating the microbiota/taurine/tight junction axis. JCI Insight, 5: 132055. https://doi.org/10.1172/jci.insight.132055

Akhlaghi, M., Zare, M., Nouripour, F. 2017. Effect of soy and soy isoflavones on obesity-related anthropometric measures: A systematic review and meta-analysis of randomized controlled clinical trials. Adv. Nutr., 8(5):705-717.

Aspri, M., Papademas, P. and Tsaltas, D., 2020. Review on non-dairy probiotics and their use in non-dairybasedproducts.Fermentation,6(1):30. https://doi.org/10.3390/fermentation6010030

Basnayake, B.S.G.M., Jemziya, M.B.F., Rambodagalla, R.T.B. and Rikasa, A.M., 2022. Development of Ambarella (*Spondias dulsis*) fruit pulp incorporated ice cream. Food Sci. J., pp. 39–43.

Beane, K.E., Redding, M.C., Wang, X., Pan, J.H., Le, B., Cicalo, C., Jeon, S., Kim, Y.J., Lee, J.H., Shin, E.C., Li, Y., Zhao, J. and Kim, J.K., 2021. Effects of dietary fibers, micronutrients, and phytonutrients on gut microbiome: A review. Appl. Biol. Chem., 64(36). https://doi.org/10.1186/s13765-021-00605-6

Bozzetto, L.E., Costabile, G., Della Pepa, G., Ciciola, P., Vetrani, C., Vitale, M., Rivellese, A.A. and Annuzzi, G., 2018. Dietary fibre as a unifying remedy for the whole spectrum of obesity-associated cardiovascular risk. Nutrients, 10(7): 943. https://doi.org/10.3390/nu10070943

Budreviciute, A., Damiati, S., Sabir, D.K., Onder, K., Schuller-Goetzburg, P., Plakys, G., Katileviciute, A., Khoja, S. and Kodzius, R., 2020. Management and prevention strategies for noncommunicable diseases (NCDs) and their risk factors. Front. Public Health, 8: 574111. https://doi.org/10.3389/fpubh.2020.574111

Castillo-Rodriguez, E., Fernandez-Prado, R., Esteras, R., Perez-Gomez, M.V., Gracia-Iguacel, C., Fernandez-Fernandez, B., Kanbay, M., Tejedor, A., Lazaro, A., Ruiz-Ortega, M., Gonzalez-Parra, E., Sanz, A.B., Ortiz, A. and Sanchez-Niño, M.D., 2018. Impact of altered intestinal microbiota on chronic kidney disease progression. Toxins, 10(7): 300. https://doi.org/10.3390/toxins10070300

Chandrasekaran, P., Weiskirchen, S. and Weiskirchen, R., 2024. Effects of probiotics on gut microbiota: An overview. Int. J. Mol. Sci., 25: 6022. https://doi.org/10.3390/ijms25116022

Chu, Y., Sun, S., Huang, Y., Gao, Q., Xie, X., Wang, P., Li, J., Liang, L., He, X., Jiang, Y., Wang M., Yang, J., Chen, X., Zhou, C., Zhao, Y., Ding, F., Zhang, Y., Wu, X., Bai, X., Wu, J., Wei, X., Chen, X., Yue, Z., Fang, X., Huang, Q., Wang, Z. and Huang, R., 2021. Metagenomic analysis revealed the potential role of gut microbiome in gout. NPJ Biofilms Microbiomes, 7: 66. https://doi.org/10.1038/s41522-021-00235-2

de Carvalho Marchesin, J., Celiberto, L.S., Orlando, A.B., de Medeiros, A.I., Pinto, R.A., Zuanon, J.A., Spolidorio, L.C., dos Santos, A., Taranto, M.P. and Cavallini, D.C., 2018. A soy-based probiotic drink modulates the microbiota and reduces body weight gain in diet-induced obese mice. J. Funct. Foods, 48: 302–313. https://doi.org/10.1016/j.jff.2018.07.010

de Oliveira, S.P., do Nascimento, H.M., Rodrigues, N.P., Sampaio, K.B., dos Santos Lima, M., da Conceição, M.L. and Leite de Souza, E., 2023. Different parts from the whole red beet (*Beta vulgaris* L.) valorization with stimulatory effects on probiotic lactobacilli and protection against gastrointestinal conditions. Food Biosci., 52: 102439. https://doi.org/10.1016/j.fbio.2023.102439

Dudzicz, S., Kujawa-Szewieczek, A., Kwiecień, K., Więcek, A. and Adamczak, M., 2018. Lactobacillus plantarum 299v reduces the incidence of Clostridium difficile infection in nephrology and transplantation ward: Results of one year extended study. Nutrients, 10(11): 1574. https://doi.org/10.3390/nu10111574

El-Sayed, N.S., Kandil, E.A. and Ghoneum, M.H., 2021. Enhancement of insulin/PI3K/Akt signaling pathway and modulation of gut microbiome by probiotics fermentation technology, a kefir grain product, in sporadic Alzheimer's disease model in mice. Front. Pharmacol., 12: 666502. https://doi.org/10.3389/fphar.2021.666502

Fachrial, E., Ismawati, I., Nugroho, T.T. and Saryono, S., 2024. α-glucosidase inhibitory activity of probiotic isolate LBSU9 isolated from traditional food "Trites": A preliminary study. IJOBAS, 12(4): 138–147. https://doi.org/10.35335/ijobas.v12i4.293

FAO/WHO (Food and Agriculture Organization/World Health Organization), 2002. Guidelines for the evaluation of probiotics in food, Ontario, Canada, pp. 1-11.

Fawad, J.A., Luzader, D.H., Hanson, G.F., Moutinho, T.J. Jr., McKinney, C.A., Mitchell, P.G., Brown-Steinke, K., Kumar, A., Park, M., Lee, S., Bolick, D.T., Medlock, G.L., Zhao, J.Y., Rosselot, A.E., Chou, C.J., Eshleman, E.M., Alenghat, T. Hong, C.I., Papin, J.A. and Moore, S.R. 2022. Histone deacetylase inhibition by gut microbe-generated short-chain fatty acids entrains intestinal epithelial circadian rhythms. Gastroenterology, 163: 1377–1390.e11. https://doi.org/10.1053/j.gastro.2022.07.051

Foko Kouam, E.M., Kaktcham, P.M., Maffo, B., Tchamani Piame, L., Fotso Techeu, U.D. and Zambou Ngoufack, F., 2023. Development of a non-dairy probiotic beverage based on sorrel and pineapple juices using *Lacticaseibacillus paracasei* 62L. J. Agric. Food Res., pp. 100688.

Foko Kouam, E.M., Tchamani Piame, L., Kouteu, S.S., Temgoua, J.B., Zambou Ngoufack, F. and Kaktcham, P.M., 2024. Probiotic characterization of *Lactiplantibacillus plantarum* LO3 and use in the development of a golden apple-based non-dairy probiotic beverage. Syst. Microbiol. Biomanuf., 4(3): 869–881. https://doi.org/10.1007/s43393-024-00251-1

Fonseca, J.R., Lucio, M., Harir, M. and Schmitt-Kopplin, P., 2022. Mining for active molecules in probiotic supernatant by combining non-targeted metabolomics and immunoregulation testing. Metabolites, 12: 35. https://doi.org/10.3390/metabo12010035

Fotso Techeu, T., Daquain, U., Kaktcham, P.M., Momo, H.K., Foko Kouam, E.M., Tchamani Piame, L., Ngouenam, R.J. and Ngoufack, F.Z., 2022. Isolation, characterization, and effect on biofilm formation of bacteriocin produced by Lactococcus lactis F01 isolated from Cyprinus carpio and application for biopreservation of fish sausage. BioMed. Res. Int., 2022: 8437926. https://doi.org/10.1155/2022/8437926

Garcia-Mantrana, I., Selma-Royo, M., Alcantara, C. and Collado, M.C., 2018. Shifts on gut microbiota associated to mediterranean diet adherence and specific dietary intakes on general adult population. Front. Microbiol., 9: 890. https://doi.org/10.3389/fmicb.2018.00890

Grembi, J.A., Nguyen, L.H., Haggerty, T.D., Gardner, C.D., Holmes, S.P. and Parsonnet, J., 2020. Gut microbiota plasticity is correlated with sustained weight loss on a low-carb or low-fat dietary intervention. Sci. Rep., 10(1): 1405. https://doi.org/10.1038/s41598-020-58000-y

Guo, X., Wang, J., Niu, R., Li, R., Wang, J., Fan, X., Wang, X. and Sun, Z., 2022. Effects of apple juice fermented with *Lactobacillus plantarum* CICC21809 on antibiotic-associated diarrhea of mice. J. Funct. Foods, 99: 105334. https://doi.org/10.1016/j.jff.2022.105334

Gurung, M., Li, Z., You, H., Rodrigues, R., Jump, D.B., Morgun, A. and Shulzhenko, N., 2020. Role of gut microbiota in type 2 diabetes pathophysiology. EBioMedicine, 51: 102590. https://doi.org/10.1016/j.ebiom.2019.11.051

Holzapfel, W., Arini, A., Aeschbacher, M., Coppolecchia, R. and Pot, B., 2018. Enterococcus faecium SF68 as a model for efficacy and safety evaluation of pharmaceutical probiotics. Beneficial Microbes, 9: 375–388. https://doi.org/10.3920/BM2017.0148

Hou, Q., Ye, L., Liu, H., Huang, L., Yang, Q., Turner, J.R. and Yu, Q., 2018. Lactobacillus accelerates ISCs regeneration to protect the integrity of intestinal mucosa through activation of STAT3 signaling pathway induced by LPLs secretion of IL-22. Cell Death Differentiation, 25: 1657–1670. https://doi.org/10.1038/s41418-018-0070-2

Kaktcham, P.M., Tchamani Piame, L., Sandjong Sileu, G.M., Foko Kouam, E.M., Temgoua, J.-B., Zambou Ngoufack, F. and Pérez-Chabela, M.L., 2019. Bacteriocinogenic Lactococcus lactis subsp. lactis 3MT isolated from freshwater Nile tilapia: Isolation, safety traits, bacteriocin characterization, and application for biopreservation in fish pâté. Arch. Microbiol., 201: 1249–1258. https://doi.org/10.1007/s00203-019-01690-4

Kamdem Bemmo, U.L., Moumita, S., Jayabalan, R. and Zambou Ngoufack, F., 2016. Honey, probiotics and prebiotics: Review. Res. J. Pharma. Biol. Chem. Sci., 7(5): 2428.

Khlaghi, M., Zare, M. and Nouripour, F., 2017. Effect of soy and soy isoflavones on obesity-related anthropometric measures: A systematic review and meta-analysis of randomized controlled clinical trials. Adv. Nutr., 8(5): 705–717. https://doi.org/10.3945/an.117.015370

Kim, S., Shin, Y.C., Kim, T.Y., Kim, Y., Lee, Y.S., Lee, S.H., Kim, M.N., O.E., Kim, K.S. and Kweon, M.N., 2021. Mucin degrader *Akkermansia muciniphila* accelerates intestinal stem cell-mediated epithelial development. Gut Microbes, 13: 1–20. https://doi.org/10.1080/19490976.2021.1892441

Kuenzig, M.E., Fung, S.G., Marderfeld, L., Mak, J.W.Y., Kaplan, G.G., Ng, S.C., Wilson, D.C., Cameron, F., Henderson, P., Kotze, P.G., Bhatti, J., Fang, V., Gerber, S., Guay, E., Jayawarden, S.K., Kadota, L., Maldonado, F.D., Osei, J.A. Sandarage, R., Stanton, A., Wan, M. and Benchimol E.I., 2022. Twenty-first century trends in the global epidemiology of pediatric-onset inflammatory bowel disease: Systematic review. Gastroenterology, 162: 1147–1159.e4. https://doi.org/10.1053/j.gastro.2021.12.282

Lee, J.H., Woo, K.J., Kim, M.A., Hong, J., Kim, J., Kim, S.H., Han, K.I., Iwasa, M. and Kim, T.J., 2022. Heat-killed Enterococcus faecalis prevents adipogenesis and high fat diet-induced obesity by inhibition of lipid accumulation through inhibiting C/EBP-α and PPAR-γ in the insulin signaling pathway. Nutrients, 14(6): 1308. https://doi.org/10.3390/nu14061308

Lee, Y., Werlinger, P., Suh, J.W. and Cheng, J., 2022. Potential Probiotic *Lacticaseibacillus paracasei* MJM60396 prevents hyperuricemia in multiple ways by absorbing purine, suppressing xanthine oxidase and regulating urate excretion in mice. Microorganisms, 10(5): 851. https://doi.org/10.3390/microorganisms10050851

Li, M., Yang, D., Mei, L., Yuan, L., Xie, A. and Yuan, J., 2014. Screening and characterization of purine nucleoside degrading lactic acid bacteria isolated from Chinese sauerkraut and evaluation of the serum uric acid lowering effect in hyperuricemic rats. PLoS One, 9(9) : e105577. https://doi.org/10.1371/journal.pone.0105577

Liang, W., Gao, Y., Zhao, Y., He, Z. and Li, S., 2024. *Lactiplantibacillus plantarum* ELF051 alleviates antibiotic-associated diarrhea by regulating intestinal inflammation and gut microbiota. Probiot. Antimicrob. Proteins, 16: 1996–2006. https://doi.org/10.1007/s12602-023-10150-x

Liu, Q., Tian, H., Kang, Y., Tian, Y., Li, L., Kang, X., Yang, H., Wang, Y., Tian, J., Zhang, F., Tong, M., Cai, H. and Fan, W., 2021. Probiotics alleviate autoimmune hepatitis in mice through modulation of gut microbiota and intestinal permeability. J. Nutr. Biochem., 98: 108863. https://doi.org/10.1016/j.jnutbio.2021.108863

Liu, Y., Fang, H., Liu, H., Cheng, H., Pan, L., Hu, M. and Li, X., 2021. Goji berry juice fermented by probiotics attenuates dextran sodium sulfate-induced ulcerative colitis in mice. J. Funct. Foods, 83: 104491. https://doi.org/10.1016/j.jff.2021.104491

Ma, D., Jin, H., Kwok, L.Y. and Zhang, H., 2022. Effect of *Lacticaseibacillus casei* Zhang on iron status, immunity, and gut microbiota of mice fed with low-iron diet. J. Funct. Foods, 88: 104906. https://doi.org/10.1016/j.jff.2021.104906

Miranda, R.F.F., de Paula, M.M., da Costa, G.M., Barão, C.E., da Silva, A.C.S., Raices, R.S.L., Gomes, R.G. and Pimentel, T.C.P., 2019. Orange juice added with L. casei: Is there an impact of the probiotic addition methodology on the quality parameters? LWT, 106: 186–193. https://doi.org/10.1016/j.lwt.2019.02.047

Mirzaei, R., Bouzari, B., Hosseini-Fard, S.R., Mazaheri, M., Ahmadyousefi, Y., Abdi, M., Jalalifar, S., Karimitabar, Z., Teimoori, A., Keyvani, H., Zamani, F., Yousefimashouf, R. and Karampoor, S., 2021. Role of microbiota-derived short-chain fatty acids in nervous system disorders. Biomed. Pharmacother., 139: 111661. https://doi.org/10.1016/j.biopha.2021.111661

Mortensen, P.B. and Clausen, M.R., 1996. Short-chain fatty acids in the human colon: Relation to gastrointestinal health and disease. Scand. J. Gastroenterol. Suppl., 216: 132–148. https://doi.org/10.3109/00365529609094568

Mu, Y., Kou, T., Wei, B., Lu, X., Liu, J., Tian, H., Zhang, W., Liu, B., Li, H., Cui, W. and Wang, Q., 2019. Soy products ameliorate obesity-related anthropometric indicators in overweight or obese Asian and non-menopausal women: A meta-analysis of randomized controlled trials. Nutrients, 11(11): 2790. https://doi.org/10.3390/nu11112790

Ofosu, F.K., Elahi, F., Daliri, E.B., Aloo, S.O., Chelliah, R., Han, S.I. and Oh, D.H., 2023. Fermented sorghum improves type 2 diabetes remission by modulating gut microbiota and their related metabolites in high fat diet-streptozotocin induced diabetic mice. J. Funct. Foods, 107: 105666. https://doi.org/10.1016/j.jff.2023.105666

Qiao, X., Du, R., Wang, Y., Han, Y. and Zhou, Z., 2020. Isolation, characterization and fermentation optimization of bacteriocin-producing *Enterococcus faecium*. Waste Biomass Valor., 11: 3173–3181. https://doi.org/10.1007/s12649-019-00634-9

Ramos-Molina, B., Queipo-Ortuño, M.I., Lambertos, A., Tinahones, F.J. and Peñafiel, R., 2019. Dietary and gut microbiota polyamines in obesity- and age-related diseases. Front. Nutr., 6: 24. https://doi.org/10.3389/fnut.2019.00024

Ridaura, V.K., Faith, J.J., Rey, F.E., Cheng, J., Duncan, A.E., Kau, A.L., Cheng, J., Duncan, A.E., Kau, A.L., Griffin, N.W., Lombard, V., Henrissat, B., Bain, James R.M., Muehlbauer, J., Ilkayeva, O., Semenkovich, C.F., Funai, K., Hayashi, D.K., Lyle, B.J., Martini, M.C., Ursell, L.K., Clemente, J.C., Treuren, W.V., Walters, W.A., Knight, R., Newgard, C.B., Heath, A.C. and Gordon J.I., 2013. Gut microbiota from twins discordant for obesity modulate metabolism in mice. Science, 341(6150): 1241214. https://doi.org/10.1126/science.1241214

Schellekens, H., Torres-Fuentes, C., van de Wouw, M., Long-Smith, C.M., Mitchell, A., Strain, C., Berding, K., Bastiaanssen, T.F.S., Rea, K., Golubeva, A.V., Arboleya, S., Verpaalen, M., Pusceddu, M.M., Murphy, A., Fouhy, F., Murphy, K., Ross, P., Roy, B.L., Stanton, C., Dinan, T.G. and Cryan, J.F., 2020. Bifidobacterium longum counters the effects of obesity: Partial successful translation from rodent to human. EBioMed., 63: 103176. https://doi.org/10.1016/j.ebiom.2020.103176

Shen, X., Ma, C., Yang, Y., Liu, X., Wang, B., Wang, Y., Zhang, G., Bian, X. and Zhang, N.,

2024. The role and mechanism of probiotics supplementation in blood glucose regulation: A review. Foods, 13(17): 2719. https://doi.org/10.3390/foods13172719

Stringhini, S. and Bovet, P., 2017. Socioeconomic status and risk factors for noncommunicable diseases in low-income and lower-middle-income countries. Lancet Glob. Health, 5(3): e230–e231. https://doi.org/10.1016/S2214-109X(17)30054-2

Suez, J., Cohen, Y., Valdés-Mas, R., Mor, U., Dori-Bachash, M., Federici, S., Zmora, N., Leshem, A., Heinemann, M., Linevsky, R. and Zur, M., 2022. Personalized microbiome-driven effects of non-nutritive sweeteners on human glucose tolerance. Cell, 185(18): 3307–3328. https://doi.org/10.1016/j.cell.2022.07.016

Sun, Q., Du, M., Kang, Y. and Zhu, M.J., 2022. Prebiotic effects of goji berry in protection against inflammatory bowel disease. Crit. Rev. Food Sci. Nutr., 63(21): 5206–5230. https://doi.org/10.1080/10408398.2021.2015680

Szeligowski, T., Yun, A.L., Lennox, B.R. and Burnet, P.W., 2020. The gut microbiome and schizophrenia: The current state of the field and clinical applications. Front. Psych., 11: 156. https://doi.org/10.3389/fpsyt.2020.00156

Tchamani, P.L., Kaktcham, P.M., Foko, K.E.M., Techeu, U.D.F., Ngouenam, R.J. and Zambou, N.F., 2023. Low-cost dehydrated starter production: Protective effect of maize-based carrier materials and its application in a Cameroonian maize-based traditional fermented beverage (Sha'a). J. Agric. Food Res., 15: 100942. https://doi.org/10.1016/j.jafr.2023.100942

Tchamani-Piame, L.T., Kaktcham, P.M., Kouam, E.M., Techeu, U.D., Ngouenam, R.J. and Ngoufack, F.Z., 2024. Low-cost dehydrated starter production: Protective effect of maize-based carrier materials and its application in a Cameroonian maize-based traditional fermented beverage (Sha'a). J. Agric. Food Res., 15: 100942. https://doi.org/10.1016/j.jafr.2023.100942

Thursby, E. and Juge, N., 2017. Introduction to the human gut microbiota. Biochem. J., 474: 1823–1836. https://doi.org/10.1042/BCJ20160510

Vasudha, S. and Mishra, H.N. 2013. Non dairy probiotic beverages. Int. Food Res. J., 20(1):7-15.

Wang, J., Zeng, Y.X., Wang, S.X., Liu, H., Zhang, D.Y., Zhang, W., Wang, Y. and Ji, H., 2018. Swine-derived probiotic Lactobacillus plantarum inhibits growth and adhesion of enterotoxigenic Escherichia coli and mediates host defense. Front. Microbiol., 9: 1364. https://doi.org/10.3389/fmicb.2018.01364

Wang, M., Zhang, Z., Liu, Y., Jian, E., Ye, P., Jiang, H., Yu, X. and Cai, P., 2024. Research trends between childhood obesity and gut microbiota: A bibliometric analysis (2002–2023). Front. Microbiol., 15: 1461306. https://doi.org/10.3389/fmicb.2024.1461306

Wang, Q., Sun, Q., Qi, R.L., Wang, J., Qiu, X.Y., Liu, Z.H. and Huang, J.X., 2019. Effects of *Lactobacillus plantarum* on the intestinal morphology, intestinal barrier function and microbiota composition of suckling piglets. J. Anim. Physiol. Anim. Nutr., 103(6): 1908–1918. https://doi.org/10.1111/jpn.13198

Wang, R., Lin, F., Ye, C., Aihemaitijiang, S., Halimulati, M., Huang, X., Jiang, Z., Li, L. and Zhang, Z., 2022. Multi-omics analysis reveals therapeutic effects of Bacillus subtilis-fermented Astragalus membranaceus in hyperuricemia via modulation of gut microbiota. Food Chem., 399: 133993. https://doi.org/10.1016/j.foodchem.2022.133993

Wang, X., Sun, G., Feng, T., Zhang, J., Huang, X., Wang, T.,Xie, Z., Chu, X., Yang, J., Wang, H., Chang, S., Gong, Y., Ruan, L., Zhang, G., Yan, S., Lian, W., Du, C., Yang, D., Zhang, Q., Lin, F., Liu, J., Zhang, H., Ge, C., Xiao, S., Ding, J. and Geng, M., 2019. Sodium oligomannate therapeutically remodels gut microbiota and suppresses gut bacterial amino acids-shaped neuroinflammation to inhibit Alzheimer's disease progression. Cell Res., 29: 787–803. https://doi.org/10.1038/s41422-019-0216-x

Wen, J., Ma, L., Xu, Y., Yu, Y., Peng, J., Tang, D., Zou, B. and Li, L., 2020. Effects of probiotic litchi juice on immunomodulatory function and gut microbiota in mice. Food Res. Int., 137: 109433. https://doi.org/10.1016/j.foodres.2020.109433

WHO (World Health Organization), 2021. Noncommunicable Diseases. Available online: https://www.afro.who.int/health-topics/noncommunicable-diseases (accessed on 28 February 2025).

World Health Organization (WHO), 2025.

Noncommunicable Diseases. Available online: https://www.afro.who.int/health-topics/noncommunicable-diseases (accessed on 28 February 2025).

Wu, T., Chu, X., Cheng, Y., Tang, S., Zogona, D., Pan, S. and Xu, X., 2021. Modulation of gut microbiota by Lactobacillus casei fermented raspberry juice *in vitro* and *in vivo*. Foods, 10(12): 3055. https://doi.org/10.3390/foods10123055

Xu, D., Lv, Q., Wang, X., Cui, X., Zhao, P., Yang, X., Liu, X., Yang, W., Yang, G., Wang, G., Wang, P., Wang, Z., Li, Z. and Xing, S., 2019. Hyperuricemia is associated with impaired intestinal permeability in mice. Am. J. Physiol. Gastrointest. Liver Physiol., 317: G484–G492. https://doi.org/10.1152/ajpgi.00151.2019

Yao, S., Zhao, Y., Chen, H., Sun, R., Chen, L., Huang, J., Yu, Z. and Chen, S., 2023. Exploring the plasticity of diet on gut microbiota and its correlation with gut health. Nutrients, 15(15): 3460. https://doi.org/10.3390/nu15153460

You, S., Ma, Y., Yan, B., Pei, W., Wu, Q., Ding, C. and Huang, C., 2022. The promotion mechanism of prebiotics for probiotics: A review. Front. Nutr., 9: 1000517. https://doi.org/10.3389/fnut.2022.1000517

Yu, F., Han, W., Zhan, G., Li, S., Jiang, X., Wang, L., Luo, A., Hua, F. and Yang, C., 2019. Abnormal gut microbiota composition contributes to the development of type 2 diabetes mellitus in Db/Db mice. Aging (Albany NY), 11(22): 10454–10467. https://doi.org/10.18632/aging.102469

Zaid, H., Shanak, S. and Tamrakar, A.K., 2022. Computer-aided drug design of natural candidates for the treatment of noncommunicable diseases. Evid. Based Complement. Altern. Med., pp. 9769173. https://doi.org/10.1155/2022/9769173

Zamfir, M., Angelescu, I.R., Voaides, C., Cornea, C.P., Boiu-Sicuia, O. and Grosu-Tudor, S.S., 2022. Non-dairy fermented beverages produced with functional lactic acid bacteria. Microorganisms, 10(12): 2314 https://doi.org/10.3390/microorganisms10122314.

Zeltser, N., Meyer, I., Hernandez, G.V., Trahan, M.J., Fanter, R.K., Abo-Ismail, M., Glanz, H., Strand, C.R., Burrin, D.G., La Frano, M.R., Manjarín, R. and Maj, M., 2020. Neurodegeneration in juvenile Iberian pigs with diet-induced nonalcoholic fatty liver disease. Am. J. Physiol. Endocrinol. Metab., 319(3): E592–E606. https://doi.org/10.1152/ajpendo.00120.2020

Zhang, L., Tuoliken, H., Li, J. and Gao, H., 2024. Diet, gut microbiota, and health: A review. Food Sci. Biotechnol., pp. 1–3. https://doi.org/10.1007/s10068-024-01759-x

Zhong, H., Wang, L., Jia, F., Yan, Y., Xiong, F., Li, Y., Hidayat, K. and Guan, R., 2024. Effects of Lactobacillus plantarum supplementation on glucose and lipid metabolism in type 2 diabetes mellitus and prediabetes: A systematic review and meta-analysis of randomized controlled trials. Clin. Nutr. ESPEN, 61: 377–384. https://doi.org/10.1016/j.clnesp.2024.04.009

Zhou, X., Wang, J., Zhou, S., Liao, J., Ye, Z. and Mao, L., 2023. Efficacy of probiotics on nonalcoholic fatty liver disease: A meta-analysis. Medicine (Baltimore), 102(4): e32734. https://doi.org/10.1097/MD.0000000000032734