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The effectiveness of natural probiotics in food

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Abstract

Introduction and purpose

The term "probiotic" rooted in Latin, signifies 'for life,' reflecting the historical use of fermented products for therapeutic purposes. Defined by the WHO as living microorganisms conferring health benefits when consumed adequately, probiotics, mainly bacteria from *Lactobacillus* and *Bifidobacterium genera*, play a vital role in maintaining gut microbiota balance, regulating digestion, supporting the immune system and influencing mental and cardiovascular health. While browsing many websites devoted to healthy eating or popular science topics, we often came across the topic of probiotic food without any confirmation by scientific research. The aim of this paper is to confirm or exclude the presence of probiotics in popular foods.

Material and method

In our work, we will look at individual products with an emphasis on verifying whether the microorganisms they contain meet the WHO criteria of probiotics.

Results

Our review managed to prove the probiotic effect of almost all presented food, except for miso. By reviewing many articles, we shed a lot of uncertainty on the repeated myth about the lack of probiotic effect of cucumbers preserved in vinegar and what is more, we found scientific assumptions about the probiotic effect of vinegar itself.

Conclusion

Fermented food contains numerous strains of bacteria that are resistant to acid, bile and temperature in the human digestive tract and can be effectively used as a source of probiotics.

What is more, compared with probiotics from the pharmacy, pickles provide not only probiotics, but also nutritional values, valuable fiber and vitamins. They seem to be a versatile supplement for our health.

Keywords: probiotic; fermented food; pickled food; bacteria; gut microbiota;

Introduction

The term probiotic was first used in 1965, comes from Latin and means ‘for life’. Fermented products such as beer, bread, wine, kefir, kumis and cheese had been frequently used for therapeutic purposes a long time before the discovery of microorganisms (1,2).

As defined by WHO probiotics are living microorganisms that, when consumed in adequate amounts, confer health benefits to the host(3). The most commonly utilized probiotics are bacteria, predominantly strains from the Lactobacillus and Bifidobacterium genera(4). Probiotics in food play a crucial role in promoting and maintaining a healthy balance of microorganisms in the digestive system by gut microbiota balance, regulate the digestive system, immune system support, synthesis of nutrients like B or K vitamins, promotion of mental health, cardiovascular health by potential of decreasing cholesterol level, management of allergies by modulating the immune response. There are also opinions about the potential role of probiotics in the prevention of cancer, especially of the gastrointestinal tract(5).

Probiotics are an important concept for health care in the 21st century. The global probiotics market size was valued at USD 77.12 billion in 2022. In Asia and Europe, probiotics are widely used as health foods and medicines. In the global probiotic market, the European market is the largest and the fastest growing with an average annual growth rate of around 20% (6).

Purpose

The purpose of this study is to examine and provide evidence regarding the effectiveness, or lack thereof, of commonly consumed food products advertised as sources of probiotics. The aim of this work is to provide valuable information on the potential health benefits of popular probiotic-rich foods by analyzing the scientific literature and relevant studies. The study aims to shed light on the practical implications of incorporating these foods into your dietary regimen, offering a nuanced look at their impact on overall health.

Material and methods

The term probiotics is regulated by WHO, candidates to receive it must meet the following criteria(7):

1. They must be living at the moment of administration and must be microorganisms
2. They must be administered in a dose which is sufficiently high to have a health promoting effect. The recommended effective dose is strictly connected with the clinical documentation on which it must be based
3. Microorganisms administered must have a beneficial effect on the host

In our work, we will look at individual products with an emphasis on verifying whether the microorganisms they contain meet the criteria of probiotics. For this purpose, We browsed publicly available article databases such as PubMed and Google Schoolar.

Results

Our review managed to prove the probiotic effect of almost all presented food, except for miso. By reviewing many articles, we shed a lot of uncertainty on the repeated myth about the lack of probiotic effect of cucumbers preserved in vinegar and what is more, we found scientific assumptions about the probiotic effect of vinegar itself.

Probiotics in fermented food

Kimchi

Kimchi is a dish originating from Korean cuisine. The first mentions of consuming fermented vegetables in Korea date back 2000 years. The composition of kimchi may vary depending on the region, affluence, and ingredient availability. The most common ingredients in kimchi include *baechu* cabbage, radish, red pepper powder, garlic, ginger, fermented anchovy juice, sugar, green onion, salt, mustard, pear, apple, pine nut, chestnut, ginkgo nut, cereals, fishes, and crabs.(8,9) It contains high levels of vitamin C, b-carotene, vitamin B complex and minerals like Na, Ca, K, Fe, and P.(8)

Bacterial composition varies depending on the stage of fermentation. Bacteria present in the product include *Leuconostoc mesenteroides*, *Lactobacillus sakei*, *Lactobacillus plantarum*, *Leuconostoc citreum*, *Leuconostoc gasicomitatum*, *Leuconostoc gelidum*, and *Lactobacillus brevis, Akkermansia muciniphila*.(8,10–12)

The health benefits of consuming kimchi have a wide range. It exhibits anti-cancer properties, prevents obesity, regulates digestive function, reduces cholesterol levels, combats free radicals, acts as an anti-aging agent, positively affects the brain, immune system, and skin.(8,12,13)

Sauerkraut

Sauerkraut is one of the oldest and most popular forms of preserving cabbage, the first historical traces of consumption date back to 4th century BC. Production is based on a process of lacto-fermentation, where cabbage is fermented by lactic acid bacteria (14). These bacteria, particularly strains of Lactobacillus, thrive in the fermentation process and are responsible for transforming the sugars in the cabbage into lactic acid. What is more, sauerkraut is considered to be low-calorie, high-fiber food that provides essential nutrients such as vitamin C, vitamin K, and various antioxidants (14).
In their comprehensive study Touret T. et al. analyzed 114 sauerkraut samples. Their findings revealed a diverse microbial landscape, with 52% of the identified bacteria belonging to the Lactobacillus spp. genus and 33% to the Leuconostoc spp. genus. Remarkably, 88% of the bacteria exhibited bile resistance, showcasing their ability to withstand the difficult conditions of the digestive system. Additionally, 20% of the bacteria demonstrated survival capabilities in the acidic environment, highlighting their potential to endure the stomach's low pH (15). This result suggests that at least 16% of the bacteria present in the sauerkraut samples may possess the capability to establish themselves in the intestinal environment.

It's common to hear that not all store-bought sauerkraut may contain live probiotics because some commercial varieties are pasteurized, which kills the beneficial bacteria. It's hard to disagree about the bactericidal effect of pasteurization, but is sauerkraut devoid of its beneficial effect? Maybe it's not just live probiotics that have a positive effect on our bodies? - This is the question asked by researchers from Norway. They divided people suffering from irritable bowel syndrome (IBS) into two groups. One group received pasteurized sauerkraut

(PS) and the other group received sauerkraut that was not subjected to any preservation processes (UPS). Both groups experienced significant improvements in IBS symptoms in IBS-Symptom Severity Score (IBS-SSS), group with UPS achieved a result that was 48% better on the point scale, but there was no statistically significant difference in symptom improvement between the pasteurized and unpasteurized sauerkraut groups. What is important the sauerkraut intervention, regardless of pasteurization, led to significant changes in gut microbiota composition confirmed by 16S rRNA gene amplicon sequencing of feces samples.(16) To sum up if we expect probiotic use of sauerkraut, the only option is to use UPS, the long-term effect of PS remains questionable.

Pickled “fermented” cucumbers

None of the foods we have presented have caused as much confusion as cucumbers.
First of all, we must point out the problems of the English nomenclature, in which "pickled cucumber" means its preservation in both salted and vinegar water (17). This is not without significance, as it turns out, only cucumbers conserved in salted water take full advantage of lactic fermentation. To make a clear distinction, we divide cucumbers preserved with vinegar into pickled ones, and those preserved with salt into fermented ones. Both fermented and pickled cucumbers are preserved but the process is different. The pickled cucumber is preserved in vinegar, so it’s not fermented. The vinegar marinade retains some of the cucumber's nutrients, but is not believed to provide any of the probiotic benefits of fermented cucumber. While reviewing the literature, we did not find many articles assessing pickled cucumbers, but in those in which the microbiota of cucumbers with vinegar was checked, lactic acid bacteria were detected.
One work that counters this myth is an extensive analysis comparing cucumbers prepared with different concentrations of vinegar and salt. Yekta Gezginç and Özge İnanç showed that even a solution containing 10% vinegar has a level of lactic acid bacteria comparable to a solution consisting of 8% salt (18). Other researchers in work published in early 2024 also came to interesting conclusions (19). They discovered a presence of lactic acid bacteria represented by six genera and 26 species in almost all types of vinegar. Moreover, they hypothesized that vinegar itself may have probiotic properties. However, we have not found any more research confirming this thesis, it is certainly a very interesting topic that requires further exploration and research.

Traditionally fermented cucumbers have many studies confirming their probiotic properties. One of the most important for our methodology is the 2015 study conducted in Poland. Dorota Zielińska and her colleagues isolated 38 different strains from fermented cucumbers and exposed them to temperature, high and low pH and bile (20). Of the isolated strains, as many as 17 were Lactic acid bacteria, of which 10 strains tolerated the conditions prevailing in the human digestive system, which meets the WHO definitions for probiotics.

Fermented cucumbers contain not only bacteria from the lactobacillus family, in 2018 researchers S. Talebi et al. isolated three new strains of bacteria belonging to the Bacillus family. The bacteria showed high resistance to acidic pH and bile. They exhibited antagonistic activity against various pathogens. Antioxidant activity, auto- and co-aggregation ability as well as their surface hydrophobicity and attachment capacity to the Caco-2 cells were in the range of other well-known probiotic strains. They were susceptible to various antibiotics. (21)

It is through the action of these bacteria that fermented products show their probiotic activity, animal studies show also that lactic acid bacteria contained in fermented cucumbers can even reduce blood cholesterol levels (22) which may have an invaluable impact on the control of metabolic diseases such as heart failure or NAFLD.

However, many commercially produced pickles are heat-processed or pasteurized after fermentation to prolong shelf life and ensure food safety. Unfortunately, this heat treatment kills the live bacteria, including the probiotics, in the pickles. As a result, most store-bought pickles do not contain significant amounts of live probiotics.

Yogurt

Its history date back as far as 5000 BC Mesopotamia, although it was found out independently in many places around the world. Yogurt is made through the process of fermentation in temperature between 30°C and 45°C, most commonly by *Lactobacillus bulgaricus, Streptococcus thermophilus*, and *Lactobacillus acidophilus.* Although for it to be considered prebiotic it should contain additional strains of *Lactobacilli: L. casei, L. rhamnosus*, as well as strains of *Bifidobacteria: B. bifidum, B. lactis.* (23) Yogurt is thought to improve intestine health by enhancing innate and adaptive immune responses, intestinal barrier function, lipid profiles, and by regulating appetite which leads to reducing chronic inflammation. (24). Promising results have been observed in patients with type 2 diabetes and obesity. In meta-analysis by Gijsbers et. al. it was proven that yogurt consumption was

associated with lower risk of type 2 diabetes. (25) It has proven to have antidiabetic properties, decreasing fasting and postprandial glucose, and improving insulin sensitivity and lipid profile. (26) Those features may lead to improvement of overall cardiovascular health of individuals consuming probiotic yogurt. The most common species found in yogurts, *L. acidophilus* apart from lowering cholesterol levels in blood, has been associated in reduction of developing colon cancer. (27)

Kefir

Kefir is a probiotic beverage made of fermented milk in temperature between 10 °C and 25°C by strains of bacteria and yeasts, which include among others *Lactobacillus kefiri, L. kefiranofaciens, Lactobacillus kefirgranum*, *Lactobacillus parakefir, Candida kefyr.* In spite of its North Caucasian origins and stardom in Eastern Europe, the name *kefir* originates from Old Turcic meaning “happiness” or “satisfaction”. It is a good source of various vitamins like A, B1, B2, B6, B12, D, B11, B3 as well as calcium and magnesium. Kefir does not contain lactose, which widens the scope of potential consumers, moreover Hertzler & Clancy have shown it improves lactose digestion and tolerance in those with lactose intolerance. (28) The improvement of life expectancy was proven over a century ago. Strains contained in kefir can have antifungal and antibacterial activity as they can compete with harmful pathogens. (29) The benefits are also viable to the cardiovascular system. In clinical trials it has shown to have strong improvement in serum lipid profile as well as serum apolipoprotein A1 levels in overweight or obese individuals. In mice it showed to be able to decrease levels of triglycerides and uric acid. 10.1007/s00253-023-12630-0 The benefits in hypertension have been shown, although if it is valid remains controversial (30,31) It is important to highlight that the compositions of strains in a product is a key factor, as the commercial kefir can contain poorer composition to the one made by traditional methods. Which in result can lead to lesser health benefits. Bourrie showed that traditional kefir has a greater impact on lowering LDL cholesterol and plasma markers of inflammation than commercial kefir. (32) The anti-inflammatory properties are explained by ability to activate macrophages, increasing production of cytokines, phagocytosis and immunoglobulins in gut.(33)

Kvass

Kvass is a popular drink common in the Slavic cuisine in Eastern European countries. It is made in a process of dry bread fermentation, with the usage of brewing yeast and lactic acid bacteria. The result of the process is a reddish-brown drink with an appearance similar to beer, however the alcohol content usually does not exceed 1% volume. The beverage is popular as a natural, soft-drink alternative to beer. It contains amino acids, vitamins, and other nutrients beneficial to the gastrointestinal system.

In a study conducted on rats by Shao and Zhong, Kvass has been observed to improve functional dyspepsia. The intake of Kvass increased the level of pepsin and decreased the gastric residual rate in the treatment group. A high dose of Kvass increased the level of ghrelin, motilin and gastrin in the blood plasma and decreased the level of the vasoactive intestinal peptide. The proposed mechanism was the regulation of the expression of short-chain fatty acids in the colon.(34)

Miso

Miso, produced through the fermentation of soybean paste, stands as a key seasoning in Japanese culinary traditions since ancient times.(35) Miso undergoes a two-phase fermentation procedure. In the initial stage, *koji* is created usually by introducing spores of the filamentous fungi *Aspergillus ozyrae* species onto a growth substrate, although *Saccharomyces cerevisiae* and lactic acid bacteria may also be employed in the process.(36,37) During the second phase, the *koji* undergoes a blending process with an additional growth substrate and salt. This mixture is then placed into crocks or vats and left to ferment at room temperature. The taste of miso is subject to variation based on factors such as the type and proportion of raw materials used, the amount of salt added, and the duration of the fermentation period. (36)

The fermented product encompasses bioactive compounds and diverse nutrients such as soy proteins and isoflavones, that exhibit potential therapeutic properties. (35) Genistein and daidzein represent the primary isoflavones found in soy. These isoflavones derived from soy function as antioxidants and inhibitors of tyrosine kinase, offering preventive effects against conditions like cardiovascular diseases, post-menopausal issues such as osteoporosis, and cancer. (38–40) A study conducted on mice also showed that miso could prevent the progression of obesity and fatty liver. (38) Another research presents a hypothesis that long-

termin miso intake, despite its high salt concentration, does not increase daytime blood pressure, meanwhile reducing nighttime blood pressure. (41,42)

It has been found that genistein, obtained from natural food sources, demonstrates its anti-carcinogenic effects through a multifaceted molecular mechanism, showing promise as a therapeutic agent. However, further investigation through both fundamental and clinical research in the growing domain of isoflavones is anticipated to provide valuable insights for its eventual utilization in the field of cancer.(43)

As of now, two studies assessed the examination of microbial communities in commercially bought Japanese miso. In one study, prevalent fungal species identified in the miso samples were *Aspergillus oryzae* and the yeast *Zygosaccharomyces rouxii*. Additionally, the two most frequently observed bacterial species were *Tetragenococcus halophilis* and *Staphylococcus gallinarum*. (44) However, the study did not provide information on factors such as fermentation duration, ingredients, manufacturer details, pre-purchase storage conditions, or expiration dates for these samples. In the second study, *T. halophilus* and the nonhalophilic (moderately salt-tolerant) *Enterococcus faecium* species were identified as the predominant lactic acid bacteria (LAB) in the ultimate miso product. The presence of *E. faecium* species is noteworthy in miso fermentation, as the bacteriocins produced by this species have been shown to exhibit antibacterial effects against spoilage bacteria in miso. (45)

Further research is warranted to thoroughly explore the microbial population in miso. As of now, there have been no published studies that have measured the quantity of microorganisms in *koji* or miso, nor have they determined whether these microorganisms possess a consistent microbial profile indicative of the presence of probiotic microorganisms. Consequently, in accordance with the definition provided by the World Health Organization (WHO), neither *koji* nor miso can be classified as probiotic. (36)

Gut-brain axis

Food rich in natural probiotics can significantly reduce body weight and serum levels of pro-inflammatory cytokines. Healthy bacteria intake can lead to reduction of the high fat diet(HFD)- induced inflammation caused by activation of astrocytes and microglial cells,

resulting in damage in the hypothalamus region. Furthermore the IgG accumulation test revealed that probiotics can lead do decrease blood-brain barrier (BBB) damage caused by HFD by enhancing the expression of tight junction molecules in cerebral endothelial cells.(12) Silage may exert beneficial effects in preventing and alleviating obesity and associated neuroinflammation by altering the composition of gut microbiota and the production of short-chain fatty acids.(12,46) *Lactobacillus* and *Bifidobacterium* are commonly found in pickled products are currently used to treat depression. Natural probiotics could be used as enhancer in depression therapy by improving mood through the gut-brain axis.(46–48)

Discussion

Gastrointestinal diseases have become increasingly prevalent in modern society due to a combination of lifestyle factors, dietary changes, and environmental influences. The adoption of Western dietary habits, characterized by high levels of processed foods, refined sugars, and low fiber intake, has been linked to an elevated risk of gastrointestinal disorders (49). The lack of dietary fiber can compromise the condition of the gut microbiota, leading to imbalances such as irritable bowel syndrome (IBS) and inflammatory bowel diseases (IBD) (50). Sedentary lifestyles and high-stress levels further compound the issue, as physical inactivity and chronic stress can negatively impact digestive function. Environmental factors, including the widespread use of antibiotics and exposure to pollutants, may also disrupt the delicate balance of the gut microbiome, predisposing individuals to gastrointestinal issues. Moreover, an increase in the prevalence of certain risk factors like obesity and the overuse of medications, such as nonsteroidal anti-inflammatory drugs (NSAIDs), contribute to the rising incidence of gastrointestinal diseases in the modern era. Addressing these lifestyle factors and promoting a more balanced and gut-friendly approach to diet and well-being is crucial in mitigating the prevalence of gastrointestinal diseases in contemporary society.

Lactic acid bacteria play a crucial role in maintaining a healthy balance in the digestive system. These microorganisms are naturally present in the human body, particularly in the gastrointestinal tract, where they contribute to various essential functions. Incorporating probiotics into the diet is vital for several reasons.

First and foremost, probiotics aid in the digestion and absorption of nutrients. Their enzymes help in the digestion process of complex carbohydrates, proteins, and fats, facilitating their absorption and utilization of essential vitamins and minerals from food. This digestive support not only promotes nutrient absorption but also helps prevent digestive issues such as bloating, gas, and constipation.

Probiotics are integral to maintaining a balanced gut microbiota. The gut microbiome plays a crucial role in supporting the immune system and protecting against harmful pathogens. Probiotics contribute to this microbial diversity, preventing the overgrowth of harmful bacteria and promoting a healthy environment in the gut.

Research suggests that a well-balanced gut microbiome may have positive effects on mental health, as the gut-brain axis influences mood and cognitive function. Probiotics can potentially help regulate this axis, contributing to improved mental well-being.

In addition to their digestive and immune benefits, probiotics may also aid in managing certain health conditions, such as irritable bowel syndrome (IBS), inflammatory bowel diseases (IBD), and allergies. While more research is needed to fully understand the extent of their therapeutic effects, the evidence so far suggests a promising role for probiotics in supporting various aspects of human health.

To incorporate probiotics into the diet, individuals can consume fermented foods like kimchi, sauerkraut, pickled vegetables, yogurt, kefir, kvass and kimchi. Additionally, probiotic supplements are available for those who may have difficulty obtaining an adequate amount through food alone. Including these sources of probiotics in the diet can contribute to overall health and well-being by fostering a harmonious relationship between the body and its microbial inhabitants.

Conclusion

Fermented food contains numerous strains of bacteria that are resistant to acid, bile and temperature in the human digestive tract and can be effectively used as a source of probiotics. Natural probiotics represent a fascinating area of research in medicine, offering potentially

novel approaches to the treatment and prevention of various health conditions. Despite promising results, further studies are necessary to precisely define the mechanisms of action, optimal dosages, and probiotic strains for effective utilization in clinical practice. The evolving field of probiotics holds significant promise for the future of medical interventions, emphasizing the importance of ongoing research and development.

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Author's contribution

Conceptualization, Michał Urbaś, and Dawid Kościołek; methodology, Martyna Kępczyk.; software, Mikołaj Tokarski; check, Michał Urbaś, Jakub Misiak and Mikołaj Tokarski; formal analysis, Kaja Surowiecka and Michał Urbaś; investigation, Konrad Szalbot and Aleksandra Kościołek; resources, Aleksandra Kościołek; data curation, Michał Urbaś ; writing - rough preparation, Kaja Surowiecka and Aleksandra Kościołek; writing - review and editing, Miłosz Ojdana and Jakub Misiak; visualization, Konrad Czchowski; supervision, Mikołaj Tokarski adn Konrad Szalbot; project administration, Michał Urbaś and Dawid Kościołek; receiving funding - no specific funding.
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The authors deny any conflict of interest

References:

1. Ozen M, Dinleyici EC. The history of probiotics: the untold story. Benef Microbes. 2015;6(2):159–65.
2. Gupta V, Garg R. Probiotics. Indian J Med Microbiol. 2009;27(3):202–9.
3. Hill C, Guarner F, Reid G, Gibson GR, Merenstein DJ, Pot B, et al. Expert consensus document. The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. Nat Rev Gastroenterol Hepatol. 2014 Aug;11(8):506–14.
4. Wilkins T, Sequoia J. Probiotics for Gastrointestinal Conditions: A Summary of the Evidence. Am Fam Physician. 2017 Aug 1;96(3):170–8.
5. Yu AQ, Li L. The Potential Role of Probiotics in Cancer Prevention and Treatment. Nutr Cancer. 2016;68(4):535–44.
6. Probiotics Market Size, Share & Growth Analysis Report 2030 [Internet]. [cited 2024 Jan 17]. Available from: https://www.grandviewresearch.com/industry-analysis/probiotics-market
7. Sanders ME. Probiotics: the Concept. WGO Handbook on Gut Microbes. 2014;39.
8. Park KY, Jeong JK, Lee YE, Daily JW. Health Benefits of Kimchi (Korean Fermented Vegetables) as a Probiotic Food. Journal of Medicinal Food. 2014 Jan;17(1):6–20.
9. Patra JK, Das G, Paramithiotis S, Shin HS. Kimchi and Other Widely Consumed Traditional Fermented Foods of Korea: A Review. Front Microbiol [Internet]. 2016 Sep 28 [cited 2024 Jan 18];7. Available from: http://journal.frontiersin.org/Article/10.3389/fmicb.2016.01493/abstract
10. Park WJ, Kong SJ, Park JH. Kimchi bacteriophages of lactic acid bacteria: population, characteristics, and their role in watery kimchi. Food Sci Biotechnol. 2021 Jul;30(7):949–57.
11. Lee ME, Jang JY, Lee JH, Park HW, Choi HJ, Kim TW. Starter Cultures for Kimchi Fermentation. Journal of Microbiology and Biotechnology. 2015 May 28;25(5):559–68.
12. Kim N, Lee J, Song HS, Oh YJ, Kwon MS, Yun M, et al. Kimchi intake alleviates obesity-induced neuroinflammation by modulating the gut-brain axis. Food Research International. 2022 Aug;158:111533.
13. Castellone V, Bancalari E, Rubert J, Gatti M, Neviani E, Bottari B. Eating Fermented:

Health Benefits of LAB-Fermented Foods. Foods. 2021 Oct 31;10(11):2639.

14. Raak C, Ostermann T, Boehm K, Molsberger F. Regular consumption of sauerkraut and its effect on human health: a bibliometric analysis. Glob Adv Health Med. 2014 Nov;3(6):12–8.

15. Touret T, Oliveira M, Semedo-Lemsaddek T. Putative probiotic lactic acid bacteria isolated from sauerkraut fermentations. PLoS One. 2018;13(9):e0203501.

16. Nielsen ES, Garnås E, Jensen KJ, Hansen LH, Olsen PS, Ritz C, et al. Lacto-fermented sauerkraut improves symptoms in IBS patients independent of product pasteurisation - a pilot study. Food Funct. 2018 Oct 17;9(10):5323–35.

17. PICKLED CUCUMBER definition and meaning | Collins English Dictionary [Internet]. 2024 [cited 2024 Jan 19]. Available from: https://www.collinsdictionary.com/dictionary/english/pickled-cucumber

18. Kahramanmaraş Sütçü İmam University, Gezginç Y, Kahramanmaraş Sütçü İmam, İnanç Ö. Chemical, Microbiological and Sensory Properties of Acur (Cucumis Melo Var. Flexuosus) Pickles Produced Using Salt and Vinegar at Different Concentrations. IJIAAR. 2021 Sep 30;5(3):290–302.

19. Leal Maske B, Murawski de Mello AF, da Silva Vale A, Prado Martin JG, de Oliveira Soares DL, De Dea Lindner J, et al. Exploring diversity and functional traits of lactic acid bacteria in traditional vinegar fermentation: A review. International Journal of Food Microbiology. 2024 Feb 16;412:110550.

20. Zielińska D, Rzepkowska A, Radawska A, Zieliński K. In vitro screening of selected probiotic properties of Lactobacillus strains isolated from traditional fermented cabbage and cucumber. Curr Microbiol. 2015 Feb;70(2):183–94.

21. Talebi S, Makhdoumi A, Bahreini M, Matin M m., Moradi H s. Three novel Bacillus strains from a traditional lacto-fermented pickle as potential probiotics. Journal of Applied Microbiology. 2018;125(3):888–96.

22. Anandharaj M, Sivasankari B, Santhanakaruppu R, Manimaran M, Rani RP, Sivakumar S. Determining the probiotic potential of cholesterol-reducing Lactobacillus and Weissella strains isolated from gherkins (fermented cucumber) and south Indian fermented koozh. Research in Microbiology. 2015 Jun 1;166(5):428–39.

23. Mozaffarian D. Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity: A Comprehensive Review. Circulation. 2016 Jan 12;133(2):187–225.

24. Pei R, Martin DA, DiMarco DM, Bolling BW. Evidence for the effects of yogurt on gut health and obesity. Critical Reviews in Food Science and Nutrition. 2017 May

24;57(8):1569–83.

25. Gijsbers L, Ding EL, Malik VS, De Goede J, Geleijnse JM, Soedamah-Muthu SS. Consumption of dairy foods and diabetes incidence: a dose-response meta-analysis of observational studies. The American Journal of Clinical Nutrition. 2016 Apr;103(4):1111–24.

26. Barengolts E. Gut Microbiota, Prebiotics, Probiotics, and Synbiotics in Management of Obesity and Prediabetes: Review of Randomized Controlled Trials. Endocrine Practice. 2016 Oct;22(10):1224–34.

27. Zhang T, Jeong CH, Cheng WN, Bae H, Seo HG, Petriello MC, et al. Moringa extract enhances the fermentative, textural, and bioactive properties of yogurt. LWT. 2019 Mar;101:276–84.

28. Hertzler SR, Clancy SM. Kefir improves lactose digestion and tolerance in adults with lactose maldigestion. Journal of the American Dietetic Association. 2003 May;103(5):582–7.

29. Lopitz-Otsoa F, Rementeria A, Elguezabal N, Garaizar J. Kefir: una comunidad simbiótica de bacterias y levaduras con propiedades saludables. Revista Iberoamericana de Micología. 2006 Jun;23(2):67–74.

30. Fathi Y, Ghodrati N, Zibaeenezhad MJ, Faghih S. Kefir drink causes a significant yet similar improvement in serum lipid profile, compared with low-fat milk, in a dairy-rich diet in overweight or obese premenopausal women: A randomized controlled trial. Journal of Clinical Lipidology. 2017 Jan;11(1):136–46.

31. Bellikci-Koyu E, Sarer-Yurekli BP, Karagozlu C, Aydin-Kose F, Ozgen AG, Buyuktuncer Z. Probiotic kefir consumption improves serum apolipoprotein A1 levels in metabolic syndrome patients: a randomized controlled clinical trial. Nutrition Research. 2022 Jun;102:59–70.

32. Bourrie BCT, Forgie AJ, Makarowski A, Cotter PD, Richard C, Willing BP. Consumption of kefir made with traditional microorganisms resulted in greater improvements in LDL cholesterol and plasma markers of inflammation in males when compared to a commercial kefir: a randomized pilot study. Appl Physiol Nutr Metab. 2023 Sep 1;48(9):668–77.

33. AdıLoğlu AK, Gönülateş N, İŞler M, Şenol A. The Effect of Kefir Consumption on Human Immune System: A Cytokine Study. Mikrobiyol Bul. 2013 Apr 26;47(2):273–81.

34. Shao Z, Zhong J, Fang Y, Ma Y. Effect of Kvass on Improving Functional Dyspepsia in Rats. Ye X, editor. Computational and Mathematical Methods in Medicine. 2022 Jun

28;2022:1–7.

35. Saeed F, Afzaal M, Shah YA, Khan MH, Hussain M, Ikram A, et al. Miso: A traditional nutritious & health-endorsing fermented product. Food Science & Nutrition. 2022 Dec;10(12):4103–11.

36. Allwood JG, Wakeling LT, Bean DC. Fermentation and the microbial community of Japanese *koji* and *miso* : A review. Journal of Food Science. 2021 Jun;86(6):2194–207.

37. Dimidi E, Cox S, Rossi M, Whelan K. Fermented Foods: Definitions and Characteristics, Impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease. Nutrients. 2019 Aug 5;11(8):1806.

38. Kanno R, Koshizuka T, Miyazaki N, Kobayashi T, Ishioka K, Ozaki C, et al. Protection of Fatty Liver by the Intake of Fermented Soybean Paste, Miso, and Its Pre-Fermented Mixture. Foods. 2021 Feb 1;10(2):291.

39. Zuo X, Zhao R, Wu M, Wan Q, Li T. Soy Consumption and the Risk of Type 2 Diabetes and Cardiovascular Diseases: A Systematic Review and Meta-Analysis. Nutrients. 2023 Mar 10;15(6):1358.

40. Yan F, Eshak ES, Shirai K, Dong JY, Muraki I, Tamakoshi A, et al. Soy Intake and Risk of Type 2 Diabetes Among Japanese Men and Women: JACC Study. Front Nutr. 2022 Jan 10;8:813742.

41. Kondo H, Sakuyama Tomari H, Yamakawa S, Kitagawa M, Yamada M, Itou S, et al. Long-term intake of miso soup decreases nighttime blood pressure in subjects with high-normal blood pressure or stage I hypertension. Hypertens Res. 2019 Nov;42(11):1757–67.

42. Ito K. Review of the health benefits of habitual consumption of miso soup: focus on the effects on sympathetic nerve activity, blood pressure, and heart rate. Environ Health Prev Med. 2020 Dec;25(1):45.

43. Banerjee S, Li Y, Wang Z, Sarkar FH. Multi-targeted therapy of cancer by genistein. Cancer Letters. 2008 Oct;269(2):226–42.

44. Kim TW, Lee JH, Park MH, Kim HY. Analysis of Bacterial and Fungal Communities in Japanese- and Chinese-Fermented Soybean Pastes Using Nested PCR–DGGE. Curr Microbiol. 2010 May;60(5):315–20.

45. Onda T, Yanagida F, Uchimura T, Tsuji M, Ogino S, Shinohara T, et al. Analysis of Lactic Acid Bacterial Flora during Miso Fermentation. FSTR. 2003;9(1):17–24.

46. Mörkl S, Butler MI, Holl A, Cryan JF, Dinan TG. Probiotics and the Microbiota-Gut-Brain Axis: Focus on Psychiatry. Curr Nutr Rep. 2020 Sep;9(3):171–82.

47. Snigdha S, Ha K, Tsai P, Dinan TG, Bartos JD, Shahid M. Probiotics: Potential novel

therapeutics for microbiota-gut-brain axis dysfunction across gender and lifespan. Pharmacology & Therapeutics. 2022 Mar;231:107978.

48. Góralczyk-Bińkowska A, Szmajda-Krygier D, Kozłowska E. The Microbiota–Gut–Brain Axis in Psychiatric Disorders. IJMS. 2022 Sep 24;23(19):11245.

49. Nieva C, Pryor J, Williams GM, Hoedt EC, Burns GL, Eslick GD, et al. The Impact of Dietary Interventions on the Microbiota in Inflammatory Bowel Disease: A Systematic Review. Journal of Crohn's and Colitis. 2023 Dec 15;jjad204.

50. Holscher HD. Dietary fiber and prebiotics and the gastrointestinal microbiota. Gut Microbes. 2017 Mar 4;8(2):172–84.