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REVIEW ARTICLE

GENERAL INSIGHTS INTO FRUITS AND VEGETABLES LACTIC FERMENTATION - A MINIREVIEW

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Abstract: Fermentation, besides being a preservation method and of major economic importance, could also reflect a growing focus on the environment. It offers solutions to reduce waste by producing novel types of protein, lipids, and carbohydrates, and to increase global food production. This mini-review aims to address specific issues related to the lactic fermentation of fruits and vegetables, as well as the nutritional and health benefits of their consumption. The industrial revolution in fermentation should include an emerging understanding of the synergies between microorganisms throughout their life cycle. Fermented fruits and vegetables are a natural source of probiotics and bio-preservatives, making them valuable to the food industry for supporting human health. Moreover, modern fermentation technology involves processes designed to produce specific compounds using selected microbial strains, which generate useful metabolites (such as lactic acid, bacteriocins, etc.). However, further paraclinical and clinical studies are still necessary to evaluate the *in vivo* effects of consuming fermented fruits and vegetables.

Keywords: lactic acid bacteria, fermentation, fruits, vegetables

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1. Introduction

Fermentation is a traditional process with ancient origins. It is typically used in the preservation of perishable foods (Tan *et al.,* 2024a). As a natural, ecological process, lactic fermentation generates broader taste and nutritional value enhancer. It continues to gain more attention and popularity among worldwide consumers' diets.

Several fermented foods and alcoholic beverages are produced from a variety of substrates metabolised by a different microorganism, either through spontaneous or by controlled lactic flora (Viridiana *et al.*, 2018).

1.1. Fermentation types

Two types of lactic fermentation are broadly recognised, namely: homofermentative and heterofermentative.

Homofermentative fermentation is based on the transformation of glucose into lactic acid as the primary by-product by homofermentative lactic acid bacteria (LAB), including *Lactococcus* spp. (Ghazi Al-Shawi & Jaafir Aziz Alneamah, 2021).

Heterofermentative LAB (rarely used as dairy starter cultures, more common in milk and dairy products), notable for their ability to degrade both hexoses and pentoses, ferment glucose with lactic acid, ethanol/acetic acid, and carbon dioxide (CO_2) as by-products. This type of fermentation could be a proper solution for food flavouring and texture enhancement, but it also could lead to food spoilage if they are not carefully managed (Wang *et al.*, 2021).

1.2. Microorganisms involved in lactic fermentation

Both bacteria and yeasts could be involved in vegetal fermentation.

LAB constitute a group of Gram-positive bacteria exhibiting special characteristics like: aerotolerance, resistance to acidic conditions, and immobility. Their distinctive property is the production of lactic acid (Aguirre-Garcia *et al.*, 2024a).

Lactic acid bacteria act on the vegetal substrate and produce glycosyl hydrolase, esterase, decarboxylase, and phenolic acid reductase, which convert phenolic compounds into physiologically active metabolites (Filannino *et al.*, 2015).

Hetero and homofermentative species belonging to *Leuconostoc*, *Lactobacillus*, *Weissella*, *Enterococcus*, *Pediococcus*, and *Bifidobacterium* genera were identified in fermented vegetables. The most frequently identified in fruit and vegetable fermentations were *Weissella* *cibaria/confusa* and the ubiquitous *Lactobacillus plantarum*, both recognised as metabolically versatile (Mozzi *et al.*, 2016).

Yeasts

Fruit microbiota is mainly dominated by yeasts and fungi, and yeasts often anticipate the colonisation by fungi due to their faster growth (Di Cagno *et al.*, 2013). Even undesirable yeasts could be part of secondary lactic fermentation, which leads predominantly to spoilage, resulting in excessive softening of fruits and vegetables, off-flavours, and other defects.

Saccharomyces boulardii is an example of a lactic acid fermentation yeast, whose probiotic properties have been debated for a long time, due to its intrinsic opportunistic nature and the possibility of transferring antimicrobial resistance genes (Ljungh & Wadström, 2006).

Pichia spp. and *Candida* spp. are beneficial members of fruit fermentation, especially olives, with an important impact on flavour generation through the production of esters and volatile compounds and texture improvement through pectinase activity (Wei *et al.*, 2025).

1.3. Factors

LAB fermentation depends on several factors, such as raw and auxiliary materials (salts, aromatic herbs, spices, etc.) composition, temperature, time, pH, and antagonistic microorganisms.

Internationally, almost all vegetal materials could be subjected to fermentation. (Güleç & Yılmaz, 2024) mention an impressive number of vegetables and fruits used to obtain pickles: from the popular cucumber, white cabbage, and peppers, to the less known as cranberry, unripe almonds, cherries, or apricots. Anyway, they are mentioned mostly as a cultural gastronomic heritage rather than as a scientific investigation into the fermentation process or the functional properties of the products. In this regard, sauerkraut or fermented white cabbage is one of the most studied. Thus, its health-promoting properties have been investigated and attributed to their content in phytochemicals (phenolic compounds, phytosterols, and carotenoids) and organosulfur compounds (Kim *et al.*, 2022; Özer & Kalkan Yıldırım, 2019; Pires-Cabral *et al.*, 2025). Another popular fermented vegetable is cucumber, which is appreciated for its taste and texture. (Moore *et al.*, 2022) investigated the changes in the free amino acid profile of pickled cucumber during lactic acid fermentation, identifying a series of amino acids (lysine, arginine, tryptophane, phenylalanine, tyrosine) with high impact on health promotion (essential for muscle development, emphasizing the energy provision, maintaining the integrity of skin, hair, and nails, hormone stimulation) and consumer acceptance.

Fermentation has a determinant role in the manufacturing of table olives, defining their sensorial characteristics (Erdogan *et al.*, 2018). According to Anagnostopoulos & Tsaltas (2022), besides their economic importance, olives are considered among the most health-promoting products due to their content of bioactive compounds, like organic acids, vitamins, trace elements, and polyphenols with important antimicrobial and antioxidant capacities. On the other hand, fresh olives contain oleuropein, which is responsible for the bitter taste. This compound is hydrolysed during fermentation, leading to a product suitable for consumption.

To fully extract nutritional content from plants and raw materials, they should include carbon, nitrogen, salts, trace elements, and vitamins, all of which are essential for LAB growth. Polymer derivatives like cellulose, hemicellulose are enzymatically degraded, leading to a better digestion of these polymers. The bioavailability of simple sugars or polysaccharides, proteins, free fatty acids, and iron is enhanced by the critical function of enzymatic hydrolysis (Sharma *et al.*, 2020). One of the auxiliary materials used in pickle preparation is pepper, which could be used fresh or dried (red chilli pepper powder). It is added for its content of capsaicinoids involved in microorganisms' inhibition, as well as in taste development (Kim *et al.*, 2022). According to the same authors, a similar role in taste development could be attributed to onion, garlic, mustard leaves, or ginger.

Mustard leaves have anti-atherogenic effects, red chilli pepper reduces the viability of norovirus, and ginger has anti-influenza effects. All these important properties support the LAB fermentation functionality.

The possible residues from pesticides could negatively influence the fermentation microorganism's growth and sometimes their survival (Tan *et al.*, 2024a).

Seasonings, in addition to influencing the aroma and preservation of vegetables, can also affect metabolite production and microbial community dynamics during fermentation.

Among the most important materials in vegetable fermentation is salt. Beyond its well-known preservative role, many studies are concerned about the relationship between concentration and the type of salt. Added as such or in brine, salt plays a crucial role in LAB fermentation. It also mediates the extraction of nutrients from fruits and vegetables, such as sucrose, glucose, and fructose.

The traditional salt used in vegetable fermentation is sodium chloride, with a definite role in taste and texture development, as well as in enzyme and microorganism control. In recent years, due to its health-related issues, sodium chloride has been replaced with other salts. Panagou *et al.* (2011) studied the influence of NaCl reduction in the fermentation profile of Conservolea natural black olives. They replaced the NaCl with five different combinations of natrium, potassium, or calcium salts and concluded that only the variant 4% NaCl and 4% KCl could finally produce olives with lower sodium content and good sensorial attributes. (Mahdi, 2020) evaluated the sensorial and microbiological characteristics of Armenian cucumber fermented with potassium chloride. They reported that a combination of 3.6% NaCl and 4.4% KCl was the most successful in NaCl substitution. The influence of NaCl being replace with KCl was also studied by (Li *et al.*, 2022) in sauerkraut production, concluding significant differences in fermentation kinetics as well as in LAB development. When NaCl is replaced by KCl, lower amounts of lactic acid are produced while LAB present a better viability. Bautista-Gallego (2013) identified KCl, $MgCl_2$, $CaCl_2$, and $ZnCl_2$ as chloride salt replacers in vegetable fermentation, owing to their similarities in chemical structure and their effects on microorganism and sensorial characteristics. In addition, their use is permitted under legislation in both Europe and the United States of America.

Compared to *Lactobacillus* spp., which is not directly affected by different salt types or concentrations, *Pediococcus, Leuconostoc, Weissella, Sporobolomyces, Azospirillum, Klebsiella, Acinetobacter*, and *Cladosporium* have a close correlation with salt concentration during vegetable fermentation (Liang *et al.*, 2020).

Usually, LAB fermentation is based on a mixture of warm temperatures (20°C–30°C) for about 7–21 days.

Lactic acid bacteria grow and develop in an acidic environment (pH 3.8-4), thus ensuring the microbiological stability of the products by inhibiting the development of unfavourable and pathogenic bacteria (Miszczak *et al.*, 2024). The pH value could regulate or stimulate the bacteriocin production or the enzymatic reactions (Abbasiliasi *et al.*, 2017).

Lactic acid, one of the most important compounds produced by both heterofermentative and homofermentative LAB fermentations, presents two enantiomers: D-lactic and L-lactic, with notable possible applications in food and the pharmaceutical industry (Aguirre-Garcia *et al.*, 2024b).

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The direct effect of pH reduction is attributed to the Gram-negative bacteria from the plant and the antimicrobial properties of the organic acids. Lactic acid led to cytoplasmic acidification, inducing proton motive force disruption in sensitive bacteria. The antimicrobial effects of lactic acid depend on intrinsic and extrinsic factors such as temperature, pH, dissolved oxygen, and bacterial strains (Sun *et al.*, 2021).

A pH value above 4.6 encourages the germination of *Clostridium botulinum* spores, which can spoil the pickles (Ghazi Al-Shawi & Jaafir Aziz Alneamah, 2021).

The antagonistic effect of LAB microorganisms against undesired microbes induces the inhibition of food spoilage-related organisms. Notably, specific LAB fermentation metabolites, such as bacteriocins, organic acids, are involved in preventing the proliferation of undesirable microorganisms (Cirat *et al*., 2024) and effectively enhancing the sensorial properties of pickles by imparting distinctive fruity or floral flavours through the production of esters, ketones, alcohols, and terpenes (Sevindik *et al*., 2022).

1.4. Vegetable fermentation options

Worldwide, the amount of fermented fruits and vegetables is extensive and ongoing. Whether raw or sun-dried, unsalted, dry-salted, or brined, and whether whole or shredded, vegetables can undergo fermentation and produce important compounds with benefits to human health.

Other possible options to vegetable fermentation include spontaneous and controlled fermentation. Traditionally, pickles are obtained by spontaneous fermentation, without using starter cultures, under genuine conditions. The spontaneous fermentation of fruits and vegetables consists of a succession of hetero and homofermentative lactic acid bacteria, in the presence or the absence of yeasts. In the traditional fermentation process of vegetables, their microbial community is closely related to the ingredients, their origin, climate, and type of container, which will further affect the quality of fermented vegetables.

Regarded as an affordable method, it is widely used both in households and industry. Without an important care for hygiene and specific conditions for a proper LAB fermentation, several pathogenic microorganisms could survive and grow in fermented vegetables, such as enterotoxigenic and enterohemorrhagic (*Escherichia coli, Shigella* spp., *Salmonella* spp., *enterotoxigenic Staphylococcus aureus, Listeria monocytogenes*, and *Bacillus cereus*) (Skowron *et al*., 2022).

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Notwithstanding the reliable feature of the spontaneous fermentation, the controlled fermentation promises more safety and uniformity in the consumption of pickles and superior nutritional and sensorial conditions. In fruit and vegetable-controlled fermentation, the most frequently used are: *Lactiplantibacillus plantarum, Lacticaseibacillus casei, Lactobacillus helveticus, Lacticaseibacillus zeae, Lactobacillus delbrueckii subsp. bulgaricus, Lacticaseibacillus paracasei, Lacticaseibacillus rhamnosus and Lactobacillus acidophilus* (Yuan *et al*., 2024).

The antagonistic aspect in the secondary stage of controlled fermentation of fruits and vegetables could be sustained by *Pichia kudriavzevii,* which will minimise the effect of pectinolytic yeasts' activity.

Compared to spontaneous fermentation, controlled fermentation also entails the reduction of nitrite formation (Shah & Singhal, 2017).

2. Changes of biological components in fermented vegetables and their benefits for human health

2.1. Positive aspects

Known as a boundary of probiotics, LAB fermented fruits and vegetables possess health-related features associated with probiotic microorganisms that are inexhaustible.

Probiotics are mainly recognised for the production of valuable compounds, stimulation and regulation of immune response, and antagonist activity towards pathogenic bacteria. Probiotics should demonstrate good resistance to acids, the disintegration effect of biliary salts, and remain alive in gastrointestinal and intestinal conditions (Castellone *et al.*, 2021).

Regular ingestion of fermented food can therefore contribute in many ways to homeostasis and organism functions. LAB fermented vegetables could be a support in digestive processes, prevention of irritable bowel syndrome, gastric, enteric, Crohn’s disease, and urinary tract diseases, or inhibitory for endogenous or exogenous pathogens.

Moreover, the consumption of LAB fermented vegetables could have a positive impact on improving the human body's resistance to allergies, preventing respiratory diseases and stimulating the innate immunity (Swain *et al.*, 2014).

Even useful in bacterial infections, antibiotics could generate unbalances in the human body that lead to the need for using probiotics to populate the affected mucous membranes.

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LAB fermentations can enhance the digestibility of foods, improve lactose metabolism, and provide health benefits, in addition to their preservation role by reducing the risk of degradation associated with unwanted microorganism activity (Aguirre-Garcia *et al.*, 2024b).

Historically, LAB remains the safest used health-related bacteria in food fermentation and not only. They can be used as food or food supplements, being listed as Qualified Presumption of Safety (QPS) by the European Food Safety Authority (EFSA), or as Generally Regarded as Safe (GRAS) by the United States Food and Drug Administration (FDA) (Martín & Langella, 2019).

Not only do probiotics from fermented vegetables have specific functional characteristics, but their metabolic compounds also result in active substances (antioxidants, phenolic compounds, flavonoids, bacteriocins, probiotics) or precursors to active substances (vitamins and minerals). Thus, microorganisms convert carbohydrates and proteins into biologically active metabolites, such as simple sugars, short-chain fatty acids, organic acids, free amino acids, and volatile compounds, highlighting the nutritional and sensory value of fruits and vegetables. (Yuan *et al.*, 2023).

Fermentation could change the nutritional and bioactive qualities of fruits and vegetables due to the synergic effects of the raw material's enzymatic activity and microorganism metabolism (Filannino *et al.*, 2015).

The most common antioxidants present in fruits and vegetables are mostly polyphenols, especially flavonoids, which constitute the most abundant class of compounds, with important biological activities: anti-inflammatory, hepatoprotective, anticancer, antithrombotic, and antiallergic. Often, the increment in antioxidant activity is directly related to the presence of polyphenols (Gunawardena *et al.*, 2024).

An enhancement in total phenolic content and antioxidant capacity during LAB fermentation can occur in two ways:

- by releasing the phenolic compounds from the plant matrices into the juices or extracts
- The biotransformation of the native phenolic compound into derivatives (Galena *et al.*, 2022).

The availability of calcium, phosphorus, iron, and vitamin D absorption could be increased by lactic acid content. The multitude of enzymes could play an essential role in digestion and other human metabolic processes.

One of the most important classes of compounds released during LAB fermentation is bacteriocins, known as low molecular weight proteins with antimicrobial potential. A special ribosomal mechanism is used by the bacteria to synthesise polypeptides, proteins, or protein complexes, which are recognised as bacteriocins. These are compounds with a fundamental role in antimicrobial activity, inhibiting the growth and reproduction of various bacteria.

Bacteriocin's system of bio preservation is based on a mechanism that involves interaction with the cell content brokered by the cell wall, with nucleic acid and protein synthesis (Kumariya *et al.*, 2019).

LAB also synthesises other antimicrobial compounds, besides bacteriocins, such as hydrogen peroxide, reuterin, and reutericyclin (Admassie, 2018).

Another beneficial aspect is related to the removal or detoxification during the fermentation process of some genuine plants' antinutrients, considered toxic, such as oxalate, protease, and α-amylase inhibitors, lectins, condensed tannins, and phytic acid (Swain *et al.*, 2014).

Some of the fermented raw materials contain coloured pigments (flavonoids, anthocyanins, carotenoids found in all yellow to orange vegetables, and glucosinolates abundantly found in Brassicaceae, capsaicinoids – found in chili peppers, chlorophylls – found in all green fruits and vegetables), which act as antioxidants fighting against free radicals implicated in degenerative diseases and ageing (Tufail *et al.*, 2025).

As a way of obtaining biologically available compounds with functional value, carotenoids derived from lactic acid fermentation led to an increase in cis-lycopene content.

2.2. Negative aspects

Although strongly recommended and widely recognised for their special benefits as functional foods, they could also pose potential risks for human health. These include high salt content, which could contribute to cardiovascular diseases; nitrite content responsible for carcinogenic properties; biogenic amines, and pathogens that may occur during vegetable processing.

Not being exposed to thermal treatment before consumption, possible pathogenic microorganisms could induce a risk of foodborne infection (Tan *et al.*, 2024b).

The major concerns related to the microbial safety of fermented vegetables came from the poor quality of starting raw materials and ingredients, improper handling and sanitation of equipment, or contamination during fermentation or processing, leading to the growth of spoilage or pathogenic microorganisms (Skowron *et al.*, 2022).

Therefore, biogenic amines, known for their toxic potential, which could affect both the central and peripheral nervous systems, are formed from the decarboxylation of specific amino acids or by the transamination of aldehydes and ketones (Alan, 2019).

3. Conclusions

This review highlights the huge potential of LAB fermentation applied to vegetables and the importance of antimicrobial attributes and human health benefits.

Market demand for fermented vegetables has increased due to pickles' specific sensorial characteristics, being safe products, a source of probiotics, and at least nutritive.

A better understanding of lactic acid fermentation of vegetables could help the industrial sector to improve the existing processes and to develop other types of fermentation by using novel substrates or fermentation media. As a rich source of prebiotics, fruits and vegetables may be considered a suitable substrate for probiotics growth with a significant impact on the prevention of several diseases.

Additionally, the probiotic properties of several LAB make them valuable for promoting gastrointestinal health. The performance of LAB fermentation can also have a significant impact on sustainability and a green perspective by minimising the food waste through the release of bioactive compounds.

References

1. Abbasiliasi, S., Tan, J. S., Tengku Ibrahim, T. A., Bashokouh, F., Ramakrishnan, N. R., Mustafa, S., Ariff, A. B. (2017). Fermentation factors influencing the production of bacteriocins by lactic acid bacteria: A review. *RSC Advances*, 7(47), pp. 29395–29420. https://doi.org/10.1039/c6ra24579j
2. Admassie, M. (2018). A Review on Food Fermentation and the Biotechnology of Lactic Acid Bacteria. World Journal of Food Science and Technology, *2*(1), 19. https://doi.org/10.11648/j.wjfst.20180201.13
3. Aguirre-Garcia, Y. L., Nery-Flores, S. D., Campos-Muzquiz, L. G., Flores-Gallegos, A. C., Palomo-Ligas, L., Ascacio-Valdés, J. A., Sepúlveda-Torres, L., & Rodríguez-Herrera, R. (2024a).

Lactic Acid Fermentation in the Food Industry and Bio-Preservation of Food. Fermentation 10 (3). https://doi.org/10.3390/fermentation10030168

4. Aguirre-Garcia, Y. L., Nery-Flores, S. D., Campos-Muzquiz, L. G., Flores-Gallegos, A. C., Palomo-Ligas, L., Ascacio-Valdés, J. A., Sepúlveda-Torres, L., Rodríguez-Herrera, R. (2024b). Lactic Acid Fermentation in the Food Industry and Bio-Preservation of Food. Fermentation, 10(3). https://doi.org/10.3390/fermentation10030168
5. Alan, Y. (2019). Culture fermentation of Lactobacillus in traditional pickled gherkins: Microbial development, chemical, biogenic amine and metabolite analysis. Journal of Food Science and Technology, *56*(8), 3930–3939. https://doi.org/10.1007/s13197-019-03866-8
6. Anagnostopoulos, D. A., Tsaltas, D. (2022). Current Status, Recent Advances, and Main Challenges on Table Olive Fermentation: The Present Meets the Future. Frontiers in Microbiology, 12. https://doi.org/10.3389/fmicb.2021.797295
7. Bautista-Gallego, J., Rantsiou, K., Garrido-Fernández, A., Cocolin, L., Arroyo-López, F. N.. (2013). Salt reduction in vegetable fermentation: reality or desire? Journal of Food Science, 78(8).
8. Castellone, V., Bancalari, E., Rubert, J., Gatti, M., Neviani, E., Bottari, B. (2021). Eating fermented: Health benefits of lab-fermented foods. Foods, 10 (11). https://doi.org/10.3390/foods10112639
9. Cirat, R., Capozzi, V., Benmechernene, Z., Spano, G., Grieco, F., Fragasso, M. (2024). LAB Antagonistic Activities and Their Significance in Food Biotechnology: Molecular Mechanisms, Food Targets, and Other Related Traits of Interest. Fermentation, 10 (4). https://doi.org/10.3390/fermentation10040222
10. Di Cagno, R., Coda, R., De Angelis, M., Gobbetti, M. (2013). Exploitation of vegetables and fruits through lactic acid fermentation. Food Microbiology, 33(1), 1–10. https://doi.org/10.1016/j.fm.2012.09.003
11. Erdogan, M., Agirman, B., Boyaci-Gunduz, C. P., Erten, H. (2018). Partial replacement of sodium chloride with other chloride salts for the production of black table olives from cv. Gemlik. Quality Assurance and Safety of Crops and Foods, 10(4), 399–410. https://doi.org/10.3920/QAS2018.1314
12. Filannino, P., Bai, Y., Di Cagno, R., Gobbetti, M., & Gänzle, M. G. (2015). Metabolism of phenolic compounds by Lactobacillus spp. During fermentation of cherry juice and broccoli puree. Food Microbiology, *46*, 272–279. https://doi.org/10.1016/j.fm.2014.08.018
13. Galena, A. E., Chai, J., Zhang, J., Bednarzyk, M., Perez, D., Ochrietor, J. D., Jahan-Mihan, A., Arikawa, A. Y. (2022). The effects of fermented vegetable consumption on the composition of

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the intestinal microbiota and levels of inflammatory markers in women: A pilot and feasibility study. *PLoS ONE*, *17*. https://doi.org/10.1371/journal.pone.0275275

14. Ghazi Al-Shawi, S., & Jaafir Aziz Alneamah, S. (2021). Cucumber Pickles and Fermentations. In *Cucumber Economic Values and Its Cultivation and Breeding*. IntechOpen. https://doi.org/10.5772/intechopen.96052
15. Güleç, H., & Yılmaz, İ. (2024). A gastronomical product in Bursa Cuisine; Orhangazi Gedelek pickles. *International Journal of Gastronomy and Food Science*, *35*. https://doi.org/10.1016/j.ijgfs.2023.100857
16. Gunawardena, S., Nadeeshani, H., Amarasinghe, V., & Liyanage, R. (2024). Bioactive properties and therapeutic aspects of fermented vegetables: a review. In *Food Production, Processing and Nutrition* (Vol. 6, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s43014-023-00176-7
17. Kim, S., Park, H., Kim, J., & Moon, B. K. (2022). Effect of main vegetable ingredient on the glucosinolate, carotenoids, capsaicinoids, chlorophylls, and ascorbic acid content of kimchis. *Journal of Food Composition and Analysis*, *110*. https://doi.org/10.1016/j.jfca.2022.104523
18. Kumariya, R., Garsa, A. K., Rajput, Y. S., Sood, S. K., Akhtar, N., Patel, S. (2019). Bacteriocins: Classification, synthesis, mechanism of action and resistance development in food spoilage causing bacteria. Microbial Pathogenesis, 128, 171–177. https://doi.org/10.1016/j.micpath.2019.01.002
19. *lactic-acid-bacteria-v1*. (n.d.).
20. Li, Z. , Xie, S., Sun, B., Zhang, Y., Liu, K. , Liu. L. (2022). Effect of KCl replacement of NaCl on fermentation kinetics, organic acids and sensory quality of sauerkraut from Northeast China. Journal of Food Processing and Preservation, *46*(9).
21. Liang, H., He, Z., Wang, X., Song, G., Chen, H., Lin, X., Ji, C., Li, S. (2020). Effects of salt concentration on microbial diversity and volatile compounds during suancai fermentation. Food Microbiology, 91. https://doi.org/10.1016/j.fm.2020.103537
22. Ljungh, Å., & Wadström, T. (n.d.). *Lactic Acid Bacteria as Probiotics*. www.caister.com/bacteria-plant
23. Martín, R., Langella, P. (2019). Emerging health concepts in the probiotics field: Streamlining the definitions. Frontiers in Microbiology, 10. https://doi.org/10.3389/fmicb.2019.01047
24. Miszczak, I., Tańska, M., Rejmer, W., Konopka, I., Zielińska, M. (2024). Spontaneous Fermentation of Beetroot – Effect of Fermentation Time and Temperature and Slice Thickness on Leaven Quality. Polish Journal of Food and Nutrition Sciences, 255–267. https://doi.org/10.31883/pjfns/192122

25. Moore, J. F., DuVivier, R., Johanningsmeier, S. D. (2022). Changes in the free amino acid profile of pickling cucumber during lactic acid fermentation. Journal of Food Science, *87*(2), 599–611. https://doi.org/10.1111/1750-3841.15990
26. Mozzi, F., Raya, R. R., Vignolo, G. M., Cagno, R. Di, Filannino, P., Gobbetti, M. (2016). Biotechnology of lactic acid bacteria: Novel Applications, Second Edition. Edited Vegetable and Fruit Fermentation by Lactic Acid Bacteria.
27. Özer, C., Kalkan Yıldırım, H. (2019). Some Special Properties of Fermented Products with Cabbage Origin: Pickled Cabbage, Sauerkraut and Kimchi. Turkish Journal of Agriculture - Food Science and Technology, *7*(3), 490–497. https://doi.org/10.24925/turjaf.v7i3.490-497.2350
28. Panagou, E. Z., Hondrodimou, O., Mallouchos, A., Nychas, G. J. E. (2011). A study on the implications of NaCl reduction in the fermentation profile of Conservolea natural black olives. Food Microbiology, *28*(7), 1301–1307. https://doi.org/10.1016/j.fm.2011.05.008
29. Pires-Cabral, P., Pires-Cabral, P., Mira, H., & Quintas, C. (2025). The Effect of Calcium in the Fermentation of White Cabbage with Salicornia. Fermentation, 11(2). https://doi.org/10.3390/fermentation11020091
30. Replacement of Sodium Chloride by Potassium Chloride in Armenian Cucumber "Cucumis melo Var. Flexuosu" Pickles: Sensory and Microbiological Evaluation. (2020). Middle East Journal of Applied Sciences. https://doi.org/10.36632/mejas/2020.10.4.66
31. Sevindik, O., Guclu, G., Agirman, B., Selli, S., Kadiroglu, P., Bordiga, M., Capanoglu, E., Kelebek, H. (2022). Impacts of selected lactic acid bacteria strains on the aroma and bioactive compositions of fermented gilaburu (Viburnum opulus) juices. Food Chemistry, *378*. https://doi.org/10.1016/j.foodchem.2022.132079
32. Shah, N. N., Singhal, R. S. (2017). Fermented Fruits and Vegetables. Current Developments in Biotechnology and Bioengineering: Food and Beverages Industry, 45–89. https://doi.org/10.1016/B978-0-444-63666-9.00003-0
33. Sharma, R., Garg, P., Kumar, P., Bhatia, S. K., Kulshrestha, S. (2020). Microbial fermentation and its role in quality improvement of fermented foods. Fermentation, 6(4). https://doi.org/10.3390/fermentation6040106
34. Skowron, K., Budzyńska, A., Grudlewska-Buda, K., Wiktorczyk-Kapischke, N., Andrzejewska, M., Wałecka-Zacharska, E., Gospodarek-Komkowska, E. (2022). Two Faces of Fermented Foods—The Benefits and Threats of Its Consumption. Frontiers in Microbiology, 13. https://doi.org/10.3389/fmicb.2022.845166
35. Sun, R., Vermeulen, A., Devlieghere, F. (2021). Modeling the combined effect of temperature, pH, acetic and lactic acid concentrations on the growth/no growth interface of acid-tolerant

Bacillus spores. International Journal of Food Microbiology, *360*. https://doi.org/10.1016/j.ijfoodmicro.2021.109419

36. Swain, M. R., Anandharaj, M., Ray, R. C., Parveen Rani, R. (2014). Fermented Fruits and Vegetables of Asia: A Potential Source of Probiotics. Biotechnology Research International, 1–19. https://doi.org/10.1155/2014/250424
37. Tan, X., Cui, F., Wang, D., Lv, X., Li, X., Li, J. (2024a). Fermented Vegetables: Health Benefits, Defects, and Current Technological Solutions. Foods, 13 (1). https://doi.org/10.3390/foods13010038
38. Tan, X., Cui, F., Wang, D., Lv, X., Li, X., Li, J. (2024b). Fermented Vegetables: Health Benefits, Defects, and Current Technological Solutions. Foods, 13 (1). https://doi.org/10.3390/foods13010038
39. Tufail, T., Fatima, S., Bader Ul Ain, H., Ikram, A., Noreen, S., Rebezov, M., AL-Farga, A., Saleh, R., Shariati, M. A. (2025). Role of Phytonutrients in the Prevention and Treatment of Chronic Diseases: A Concrete Review. ACS Omega. American Chemical Society. https://doi.org/10.1021/acsomega.4c02927
40. Viridiana, C.-R., Lidia, D.-A., Audry, P.-L., Humberto, H.-S. (2018). Lactic acid bacteria isolated from vegetable fermentations: probiotic characteristics. Reference Module in Food Science. https://doi.org/10.1016/b978-0-08-100596-5.22601-2
41. Wang, Y., Wu, J., Lv, M., Shao, Z., Hungwe, M., Wang, J., Bai, X., Xie, J., Wang, Y., Geng, W. (2021). Metabolism characteristics of lactic acid bacteria and the expanding applications in food industry. Frontiers in Bioengineering and Biotechnology, 9. https://doi.org/10.3389/fbioe.2021.612285
42. Wei, L., Beeck, W. Van, Hanlon, M., Dicaprio, E., Marco, M. L. (2025). Lacto-fermented fruits and vegetables: bioactive components and effects on human health. *45*, 53. https://doi.org/10.1146/annurev-food-052924
43. Yuan, X., Wang, T., Sun, L., Qiao, Z., Pan, H., Zhong, Y., Zhuang, Y. (2024). Recent advances of fermented fruits: A review on strains, fermentation strategies, and functional activities. Food Chemistry: X, 22. https://doi.org/10.1016/j.fochx.2024.101482
44. Yuan, Y., Yang, Y., Xiao, L., Qu, L., Zhang, X., Wei, Y. (2023). Advancing Insights into Probiotics during Vegetable Fermentation. Foods, 12(20). https://doi.org/10.3390/foods12203789