Indian Journal of Natural Products and Resources
Vol. 17(3), September 2026, pp. 381-396
DOI: 10.56042/ijnpr.v17i3.18112

Pediococcus species: A lactic acid bacteria with promising therapeutic applications

Mona Kumari[1], Saurabh N. Singh[2] and Ena Gupta[1]*
[1]Department of Family and Community Sciences, University of Allahabad, Prayagraj 211002, Uttar Pradesh, India
[2]Centre for Microbiology, Department of Botany, Ewing Christian College, Prayagraj 211003, Uttar Pradesh, India

Received 21 March 2025; revised received 01 August 2026; accepted 04 August 2026

Pediococcus species, prominent Gram-positive lactic acid bacteria, exhibit significant biotechnological properties. A comprehensive literature search and review were conducted using several authentic electronic databases for the publication of recent studies to analyse relevant studies on *Pediococcus* species, antimicrobial metabolites, and their application in food preservatives that evidence the therapeutic efficacy of the species. The bacteriocin produced by these species provides antimicrobial activity that also enhances food quality by improving the flavour, texture, shelf-life, and nutritional quality of developed food products. Several researchers reported that among all species, *P. acidilactici* and *P. pentosaceus* are well-versed in enhancing functional and therapeutic properties. It produces antibacterial peptides, bacteriocins called pediocin, which are highly involved in food preservation. Additionally, *P. acidilactici* produces bioactive compounds that increase the levels of antioxidants, phenolics, flavonoids, and L-alanine to enhance nutritional quality. *Pediococcus* species possess probiotic properties as they can tolerate low gastric pH and bile salt, are non-hemolytic, and show antibacterial activities. *P. acidilactici* and *P. pentosaceus* demonstrateanti-proliferative and anticancer effects on cancer cells. *P. parvulus* also exhibits anti-inflammatory and anti-pathogenic properties, making it a suitable probiotic strain. *P. damnosus* demonstrated only a bacteriostatic effect on the pathogens; on the other hand, *P. acidilactici* and *P. Pentosaceus* show both bacteriostatic and bactericidal effects on pathogens. Additionally, some *Pediococcus* species are also involved in lowering glucose and cholesterol levels. However, *Pediococcus* species are generally regarded as safe (GRAS) and can be effectively utilised in the food industry. Various fermented foods, including dairy products, meat, fruits, and vegetables, and also in beer and wine making, are produced using *Pediococcus* as a starter culture. *Pediococcus* species are also efficient for the formulation of functional food asthey are potent for improving gut health and immune function. However, using *Pediococcus* species in food production is subject to regulation and safety considerations.

Keywords: Bacteriocin, Fermentation, Lactic acid bacteria, *Pediococcus*, Preservation, Therapeutic

IPC code; Int. cl. (2021.01)− A61K 35/00, A61K 35/74, A61K 35/744

Introduction

Recently, there has been a growing use of microorganisms in the food sector, health sciences, and biotechnology. Some microbes are notorious for their harmful effects, while others play proficient functions in human health and have important applications in food production and quality improvement. Additionally, a huge number of bacteria are found in the human gastrointestinal tract and are highly involved in competition as well as coordination for limited surroundings and resources. These arrangements and interplay are potentially associated with human health conditions[1]. A recent study demonstrated that gut microbiome dysbiosis can contribute to inflammatory and immune responses associated with rheumatoid arthritis[2]. This increases concern about opting for an alternative solution to treat such human health issues. Moreover, the burden of digestive diseases and Inflammatory Bowel Disease (IBD) in developing countries is rising continuously, which leads to significant economic and social impact[3,4]. However, Diet plays an essential role in overall human health, working as a frontline defence against these diseases[5]. In this context, probiotics become a prominent choice to get a safer solution. The term "probiotics" is derived from two Latin words: *pro*, meaning for, and *bios*, meaning life. The World Health Organisation (WHO) defined probiotics as live microorganisms that, when consumed in adequate amounts, show beneficial health impacts. These help to maintain the equilibrium in gut microbiota by restricting the growth of harmful bacteria. Currently, it has become a potent alternative and complementary medicine in medical therapies as it possesses immunomodulatory potential and a safety profile. Commonly, *Lactobacillus* and *Bifidobacterium*

*Correspondent author
Email: enagupta67@gmail.com

species have hypoglycaemic, antioxidant, and anti-inflammatory effects against many immunological disorders. Furthermore, probiotics are also crucial in combating obesity, appetite, metabolic disease, improving digestive health, the immune system function, and even mental wellness[6-9]. In this way, Lactic acid bacteria (LAB) are effective probiotics being used traditionally; they are a heterogeneous, Gram-positive, non-spore-forming, non-motile, rod-shaped or spherical-shaped microorganisms that are either aerotolerant anaerobes or microaerophiles and whose major end product of carbohydrate fermentation is lactic acid. The genera "lactic acid bacteria" belongs to the order *Lactobacillales*, which includes the species of *Lactobacillus*, *Lactococcus*, *Streptococcus*, *Leuconostoc*, *Pediococcus*, *Enterococcus*, *Carnobacterium*, *Tetragenococcus*, *Vagococcus*, and *Weissella*[10]. LAB are notable microorganisms with significant biochemical and pharmacological capabilities. These bacteria are essentially important to the food industry because of their role as starter cultures, probiotics, and functional food ingredients, as well as their contributions to texture, flavour, and aroma enhancement, and as a significant biopreservation agent. LAB exhibited various nutritional properties associated with improved adhesive adaptive characteristics that enhanced the survivability of bacteria in distinct surroundings, such as in dairy food products, fermented foods, vegetables, and gut microflora[11]. Specifically, *Pediococcus* species, a genus of lactic acid bacterium that belongs to the *Lactobacillaceae* family, has a promising future in the food sector due to its positive health qualities and physiological features. Recently, *Pediococcus* species have gained increased research interest in the food industry due to their beneficial technological properties, which are key to ensuring high-quality final food products[12]. Thus, a comprehensive literature review was conducted, and recent published studies were searched by using authentic electronic databases to identify relevant studies and evidence on *Pediococcus* species, which produce bacteriocins and antimicrobial metabolites, and their application in food preservatives for therapeutic applications.

Morphological and structural characteristics

Pediococcus are Gram-positive, non-motile, coccus-shaped, and oxidase-negative, as shown in Fig. 1. Because of their unique manner of cell division, they typically form pairs or tetrads. These organisms can thrive in low-oxygen settings and were formerly best known for their capacity to ferment carbohydrates into lactic acid. They are chemo-organotrophs and nutritionally fastidious microorganisms[13], as amino acids and Vitamin B are vital nutrients that account for the growth of *Pediococcus* species in agar media[14]. They are the only acidophilic, homo-fermentative. This is extremely significant in preserving and flavouring fermented foods[15]. *Pediococcus* is generally catalase-negative, but certain strains can exhibit pseudo-catalase activity when cultured in a low-carbohydrate medium[16].

Taxonomy

The genus *Pediococcus* belongs to the group of LAB, phylum Firmicutes, class Bacilli, order *Lactobacillales*, and family *Lactobacillaceae*[17]. *Pediococcus* has gone through numerous naming schemes over the years. The term *Pediococcus* was initially created by Balcke. Later, Balcke recognised *Pediococcus* as a genus in 1949 and designated the *Pediococcus* species "*Pediococcus cerevisiae*"[18]. According to Bergey's manual, eight species of *Pediococcus* are present[19], but on the other hand, ten species of the genus *Pediococcus* were documented by Pfannebecker and Frohlich[20]. The International Committee on Systematic Bacteriology identified seven species of *Pediococcus*: *Pediococcus pentosaceus*, *Pediococcus acidilactici*, *Pediococcus damnosus*, *Pediococcus halophiles*, *Pediococcus parvulus*, *Pediococcusurinaee-equi*, and the last, untitled as Gunther and white group III[19]. The genus *Pediococcus* species includes several species, such as *Pediococcus acidilactici, Pediococcus pentosaceus, Pediococcus inopinatus*, *Pediococcus dextrinicus*, *Pediococcus clausseni, Pediococcus cellicola,*

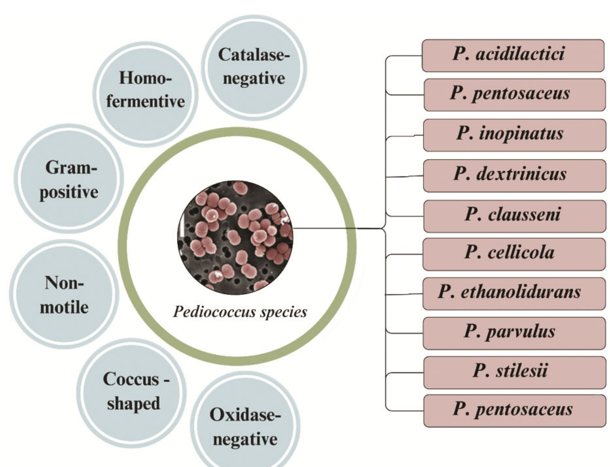

Fig. 1 — Morphology and several species of *Pediococcus*.

Pediococcus ethanolidurans, Pediococcus parvulus, and *Pediococcus stilesii*. Among all, *P. pentosaceus* is commonly found in various foods like cheese, drinks, pickles, wine, dairy products, and meat[21]. Table 1 illustrates the different varieties of *Pediococcus* species, their characteristics, and isolation sources, as these are commonly isolated from diverse sources such as fermented plants, fruits, vegetables, and environments like breweries, distilleries, and wineries. In particular, *P. parvulus* is frequently associated with the wine making process. Such a species might influence flavour and quality due to malolactic fermentation and the production of exopolysaccharides, tending to affect texture and mouth feel. *P. parvulus* can cause spoilage due to its unwanted growth, which usually develops undesirable flavours, although it has many benefits[22]. The cultural growth of *Pediococcus* species requires nutrient-rich media and also has distinct biochemical and physiological characteristics[15,19,23,24]. *Pediococcus* strains exhibit different levels of tolerance to oxygen, pH, temperature, and NaCl[15,19,23]. The taxonomy of *Pediococcus* species was based on their biochemical, functional, morphological, and biomolecular properties, which were proposed by Bergey's Manual of Systematics of Archaea and Bacteria1[5,25]. Various biomolecular and genetic approaches have been adopted during the past decades for studying the genomic diversity of *Pediococcus* species. Other methods applied include specific DNA target probes, which are nucleotide sequences that are short and specific enough to attach to a sample's complementary DNA[26-28]. DNA target probes have been used to assess genetic diversity by targeting specific areas of DNA and this method allows for the accurate identification and comparison of strains, providing valuable information on the genetic makeup and relatedness of the species[29].

Ribotyping, which involves digesting bacterial DNA with restriction enzymes, followed by hybridisation of rRNA gene fragments to investigate. These patterns or ribotypes have aided in distinguishing between species and strains of bacteria. Ribotyping has been employed to determine genetic diversity and relationships among *Pediococcus* species strains by comparing their ribosomal DNA profiles[30-32].

DNA-DNA hybridisation involves the denaturation and bonding of DNA strands from different organisms, thus comparing genetic similarities. The level of hybridisation would determine genetic association, where the higher the degree of hybridisation, the closer the genetic relation[23]. In research on *Pediococcus*, for example, DNA-DNA hybridisation is used to differentiate between strains or closely related species[29].

16S rRNA gene sequencing has become a standard technique in identifying and classifying bacteria. The method targets the investigation of the highly conserved 16S ribosomal RNA gene[30,33]. Variable regions down the gene are used in distinguishing the species[29].

Other molecular fingerprinting techniques include Rep-PCR involves the amplification of repetitive DNA to identify strains, while RAPD-PCR uses random primers in generating distinctive DNA banding patterns. On the other hand, PFGE separates large DNA fragments to develop detailed genetic profiles. These are essential in effectively distinguishing and comparing bacterial strains[34-37].

Table 1 — Different varieties of *Pediococcus* species, their characteristics, and isolation sources

Species	Characteristics	Isolation sources	References
P. acidilactici	Tolerant to low pH and high salt	Fermented foods (meat, dairy), silage, gastrointestinal tract of animals	38,39
P. pentosaceus	Produces lactic acid, grows well in acidic conditions	Fermented plant products (sauerkraut, pickles), dairy, human gut, aquatic products, raw animal	40
P. damnosus	Produces lactic acid, associated with spoilage	Wine, beer, cider (often associated with spoilage)	41
P. claussenii	Resistant to hops, capable of beer spoilage, β-Glucan production	Beer (especially in breweries, often involved in spoilage)	42
P. ethanolidurans	Tolerant to high ethanol and low sugar concentrations	Commercial Cucumber Fermentation, Dongcheng pickle, Daqu(Chinese liquor)	43, 44
P. inopinatus	More sensitive to ethanol	Kimchi	45
P. parvulus	Produces exopolysaccharides	Wine and cheese	46
P. dextrinicus	Dextrin fermenter, heterofermentative	Meat	47
P. siamensis	Produces lactic acid, moderate temperature tolerance	Thai fermented tea leaves, Miang	48, 49
P. stilesii	Produces lactic acid, tolerates high salt	Korean fermented foods and maize grains	50, 51

Functional properties

Flavour and texture development

Lactic acid bacteria, particularly *Pediococcus* species, are an excellent choice to maintain the flavour of food. Among them, *P. pentosaceus*, a notable *Pediococcus* strain, is well-known for significantly improving cheese flavour, whether it is innate or formulated into the product. Previous studies have convincingly demonstrated the crucial role of LAB in enhancing the quality, acceptability, and flavour attributes of wine, particularly in secondary fermentation[52]. The use of recombinant *Pediococcus acidilactici* BD16 (*fcs* + /*ech*+) in the secondary fermentation of wine boosts the production of flavour compounds like vanillin and cinnamic acid derivatives, enhancing the wine's aroma, colour, and flavour. Vanillin adds a creamy mouthfeel, while therapeutic phenolics like laricitrin and quercetin are abundantly boosted. This method is also characterised by constant flavour and confirms *P. acidilactici* BD16 as an excellent starter for malolactic fermentation[53]. Similarly, *P. pentosaceus* strain also influenced the flavour development in Manura cheese, although it was not dominant in terms of quantity[54]. According to Kaur *et al.,*[55] *P. pentosaceus* incorporated into sausage fermentation is responsible for the desirable volatile compounds formation, a reduction in microbial diversity, and a dominance of beneficial anaerobic bacteria resulting in a higher quality of sausage products with enhanced flavour and reduced risk of contamination. In another study, the use of *Lactobacillus plantarum* and *P. pentosaceus* as starters in *Suancai* fermentation was found to improve the product's quality. Co-inoculating both strains led to higher bacterial diversity and a flavour profile more similar to spontaneously fermented *Suancai*. These starter cultures positively influenced the production of flavour compounds[56,57]. Further investigated the effects of two *Pediococcus* strains, PE1 (*P. acidilactici*) and PE2 (*P. pentosaceus*) strains, and compared them to a commercial starter culture (COS) named *Starter kulturen Almi Rohschinken* on the sensory characteristics of dry fermented sausage during fermentation and ripening. The research showed *P. acidilactici* and *P. Pentosaceus* effectively decreased the pH level of fermented sausage and increased its acidity during fermentation. The best quality fermented sausages resulted from *P. Acidilactici* strains because of the highest efficiency in improving the quality by enhancing colour appearance while reducing off-flavour and improving overall acceptability. The metabolism of *P. enthanolidurans* shows a direct association with the characteristics of volatile compounds that indicate *P. Enthanolidurans* strain plays a vital function in developing distinctive flavours during the fermentation of peppers.

Preservation and shelf-life extension

The application of *Pediococcus* species as biopreservatives existed in the food industry before the establishment of modern microbiology. These species have a wide application in dairy products as well as various fermented foods. *P. acidilactici* and *P. pentosaceus* are strains that show productive involvement in the fermentation of a wide range of food products, including silage, dairy products, meat, dough, and fruit juices[58,59]. Bacteriocins are antibacterial peptides produced by *Pediococcus* species known as pediocins that have broad applications in both the food and health industries. The biopreservation properties of these bacteriocins, which effectively prevent and control the contamination of gram-positive pathogenic bacteria, especially *Listeria monocytogenes* have been highlighted by several researchers. Most pediocins produced by diverse *Pediococcus* species belong to the IIa subclass, although pediocin N5p is classified as a member of Class IV. Unique codes are often used to differentiate specific variants or isomers of pediocins, usually correlated with the producing strain or distinctive bacteriocin modifications. Illustrative examples include pediocin AcH, pediocin SJ, pediocin JD, and pediocin PA-1[60]. Both nisin and pediocin PA-1 are particularly noted for their effective use in bio-preservation[61]. Several findings of researchers showed the preservation potential of pediocin produced from *Pediococcus* species, as demonstrated in Table 2. For instance, Pato *et al.,*[62] studied the antibacterial and biopreservation application of bacteriocin produced by *P. pentosaceus* and stated that the use of bacteriocins in fish balls, particularly 0.60% of concentration improved their quality during storage, especially at low temperature. The *Pediococcus* species, *P. pentosaceus* 1101 and *P. acidilactici* LAB 001, have strong antibacterial and antifungal properties. Thus, they are valuable biopreservative cultures and could potentially be used as starter cultures in various food processes to extend the shelf life of food products[63,64].

Nutritional enrichment

The European Food Safety Authority (EFSA) shows that *Pediococcus* species bacteria contribute to

Table 2 — Application of pediocin in food preservation

Bacteriocin	Food products	Target microorganisms	Mode of action	Preservation effect	References
pediocin PA-1/AcH	Meat products	L. monocytogenes	Cell wall destruction and membrane integrity	Inhibition of pathogenic bacterial growth, extends shelf life	65
Pediocin NV 5	Sausages	*Staphylococcus* strains	Cell wall inhibition	inhibited the growth of the pathogenic bacteria	66
Pediocin 05-10	pork ham	L. monocytogenes 54002	bactericidal	Extended shelf life	67
Pediocin PA-1	Dairy products	L. monocytogenes *S. aureus*	Antimicrobial spectrum	Increased the shelf life	68,69
pediocin ST18	*Boza* (Beverages)	L. innocua	Cell lysis	complete growth inhibition	70

both nutritional supply as well as the maintenance of physiological function and offer significant nutritional benefits. The synthesis of necessary vitamins and amino acids by these bacteria leads to increased nutritional quality of foods. Their supplementation in traditional and industrial foods not only improves the taste but also boosts nutrition and food safety[40]. LAB produces essential metabolites like organic acids, aromatic compounds, exopolysaccharides, bacteriocins, and vitamins during food fermentation. These substances, released into the food, enhance its nutritional value and contribute to the overall quality of fermented products. Some studies have identified that the genes of the *Pediococcus* species are responsible for vitamin synthesis and have investigated their ability to produce vitamin B12[71]. Hence, there is an urgent need to resolve both safe bacterial strains and effective amino acid production since these biomolecules serve as essential building blocks for the biological development and maintenance of living organisms. LAB, particularly *Pediococcus* species, is capable of hydrolysing extracellular protein into free amino acid components, making them a good source of functional amino acids[72]. Research has shown that certain *Pediococcus* strains have strong amino acid production capabilities. According to Toe *et al.,*[73] among the eight strains, *P. pentosaceus* UL-6 showed a strong ability to produce proline whereas *P. pentosaceus* UP-2 demonstrated the capacity to produce a variety of amino acids at the highest concentration**.** *P. pentosaceus* CFR R123 was utilized for MFSC (malted finger millet seed coat) and soy milk due to the ability of this bacteria to degrade phytate along with a reduction in phytate levels that increases the bioavailability of minerals such as calcium and magnesium when the strains were isolated from fermented grains[74].

Bioactive compound production

Pediococcus species are extensively acknowledged for their ability to ferment food while simultaneously producing organic acids along with bacteriocins, exopolysaccharides, and various phenolic compounds, that improve the nutritional, functional, and sensory aspects of various fermented products. Researchers used recombinant *P. acidilactici* BD16 (alaD+) strains as a starter culture to produce L-alanine in situ for the development of sweet and nutritious fermented buttermilk and soy milk. Studies have shown that the strain improves the functional along with the nutritional, and bioactive properties of the drinks because it increases their level of antioxidants, phenolics, flavonoids, and L-alanine, boosting their quality and health-promoting attributes[52]. Among its many uses *P. acidilactici* has notable functional properties and bioactive compounds. The bacterial culture produces L-Lactic acid (85.19%), Methyltartronic acid (7.47%), Pyrrolo [1,2a] pyrazine1,4dione, hexahydro (5.89%), and Phenol, 2,4bis (1,1dimethylethyl) (8.32%), all of which show strong antibacterial activity. n-Hexadecanoic acid (6.61%) exhibits anti-inflammatory, while Geranyl-isovalerate (0.33%), Benzaldehyde, 2,4 dimethyl (1.23%), and Hexadecane, 2,6,11,15 tetramethyl (0.71%) enhance flavour and are used as food additives. Hexadecane (2.00%), Pyrrolo [1,2a] pyrazine1,4 dione, hexahydro3 (2methylpropyl) (0.72%), Hexadecane (1.70%), Tetradecane (2.11%), and Dodecane (1.73%) offer significant antioxidant properties[75].

Therapeutic properties

Probiotic properties

The Food and Agriculture Organisation of the United Nations and the World Health Organisation define probiotics as "Live microorganisms which when administered in adequate amounts confer a health benefit on the host"[76]. LAB have been historically used as probiotics to produce fermented foods because they are generally regarded as safe (GRAS). LAB, such as *Lactobacillus, Bifidobacterium, Streptococcus*, and *Pediococcus,* have recently been used in probiotic production as they can tolerate extremely low gastric pH and the detergent effects of bile salt. Table 3 illustrates the fundamental probiotic properties of certain *Pediococcus* strains. *Pediococcus* species, in particular, have been extensively studied for their roles in the food industry and favourable impact on human and animal health. Certain *Pediococcus* strains have been suggested to be used as probiotics[77]. According to a study, only two out of 20 *Pediococcus* species can be fruitfully utilised as probiotic microorganisms[78]. These probiotic bacteria are incorporated into substrates that serve as a matrix for the growth and viability of the starter culture through the "probiotication" process. This is to address the needs of the lactose-intolerant populace and vegetarians[79]. In a study conducted by Plaza-Díaz *et al.,*[80], probioticated mango juice was developed using *Pediococcus* strains such as *P. acidilactici* and *P. pentosaceus*, in which *P. acidilactici* was shown to be a suitable probiotic strain for the production of nutraceutical mango juice, whereas *P. pentosaceus* surpassed in all tests. The popularity of *Pediococcus* species has risen in the fermented sausage industry because they are functionally effective and excellent probiotic strains[81]. *Pediococcus* species helps improve the digestive system and contributes to overall wellness. Specifically, *P. pentosaceus* can be used as a probiotic as well as a bioprotective culture in fermented food because it can reach the gut intact and fight against harmful bacteria[40,63]. According to Wanna *et al.,*[82] *P. pentosaceus* MR001 proved to be advantageous as a probiotic for white shrimp. The study found that adding *P. pentosaceus* MR001 (at 10^9 CFU/g) when incorporated into shrimp feed promotes faster growth and improves digestion while providing disease resistance to the shrimp. Thus, the researchers recommended using this strain as a dietary supplement for white shrimp. *Pediococcus* species isolated from local dairy products show exceptional probiotic characteristics because they can tolerate gastrointestinal conditions, are resistant to antibiotics, and show antimicrobial activity[83]. Other studies showed that *Pediococcus* species isolated from non-dairy sources also contain probiotic properties. *P. acidilactici* TMAB26 strain, isolated from a traditional South Indian tomato pickle made with tamarind and spices such as chilli, fenugreek, mustard, and turmeric, was found to be an outstanding probiotic, along with the capability to survive strong acid and bile tolerance. These strains have antibacterial, anti-proliferative, and anticancer properties and arenon-hemolytic[84].

Anti-inflammatory effects

Probiotic consumption contributes to the fight against gut infections by boosting immunity through improved anti-inflammatory response[87,88]. The anti-inflammatory and pro-inflammatory cytokines respond to different strains of probiotic LAB, which help reduce intestinal inflammation[87]. *Pediococcus acidilactici* NCD 252 demonstrated strong anti-inflammatory effects by stabilising cell membranes and preventing hemolysis[89]. Inflammation leads to the production of joint swelling together with stiffness, while protein denaturation causes the development of autoantigens. Furthermore, *P. acidilactici* R037 can potentially treat multiple sclerosis by inhibiting inflammatory cytokines. The combination of Lactobacillus fermentum with *P. acidilactici* supports gut health development through their ability to decrease inflammation and support beneficial bacteria growth in the body. The postbiotics, which are exopolysaccharides derived from Lactic acid bacteria (EPS), produce various health benefits. The EPS

Table 3 — Fundamental probiotic properties of certain *Pediococcus* strains

Probiotic conditions	*Pediococcus acidilactici* M76	*P. pentosaceus* 1101	*P. parvulus* 2.6
Isolation source	Korean traditional rice wine, *makgeolli*	Fermented meat products (Spanish-type chorizo)	Obtained from the UPV culture collection, Universidad de Pais Vasco (San Sebastian, Spain)
Gastric pH tolerance	71.7% survival (pH 2.5)	86.8% (pH 2.0); 93.9% (pH 3.0)	High survival (pH 2.5); Reduced at pH1.5; oat milk improves survival by 2000x at pH 1.5
Bile salt stress	100% survival (0.3-3.0%)	99.1% survival (0.5%)	10% survival (20% bile); able to grow under extreme bile conditions.
Pathogen inhibition	Broad spectrum inhibition	Sensitive to key antibiotics; inhibits pathogens	Inhibits gram-positive bacteria, including *B. cereus*; no activity against *L. monocytogenes*.
References	85	63	86

extracted from *P. pentosaceus* 4412 has the potential to modulate inflammatory responses, reduce oxidative stress, and protect organs. EPS 4412 can be a natural food additive and anti-inflammatory agent in both the food and pharmaceutical industries[90]. Barigela and Bhukya,[84] reported that *P. acidilactici* TMAB26, isolated from tomato pickle under reference MTCC 13014, exhibits important functions for treating inflammatory conditions in the digestive system. Studies have proven that *P. parvulus* 2.6 contains anti-inflammatory and anti-pathogenic potential for development as a probiotic in fish feed production[91].

Antimicrobial activity

Lactic Acid Bacteria (LAB) play a significant role in preventing microbial spoilage and contamination in fermented foods by producing substances that include lactic acid, hydrogen peroxide, diacetyl, and especially bacteriocins. These antibacterial properties also contribute to the taste and texture of fermented food[92]. The advantage of *Pediococcus* species is related to their bacteriocins secretion capacity, which shows exceptional antimicrobial effects against major foodborne pathogenic agents such as *Listeria monocytogenes*. The traits of *Pediococcus* species establish them as beneficial agents to enhance food safety. Research investigations show that *Pediococcus* species possess anti-listeria capacities to minimise *L. monocytogenes* proliferation in meat products and milk[93-96]. The antimicrobial effects of *P. acidilactici* PFC69 worked on all tested indicator strains through agar spot assays, effectively inhibiting all vancomycin-resistant *Enterococcus faecium* (VRE) and five strains of methicillin-resistant *Staphylococcus aureus* (MRSA). During the good diffusion test, the antimicrobial properties were seen in *P. acidilactici* PFC69 supernatants; however, they were not effective against Gram-negative rods or MRSA[97]. In another study, *P. pentosaceus* shows a bacteriostatic inhibition against *Listeria monocytogenes* while a bactericidal effect against *Listeria innocua* and *Listeria ivanovii*. Whereas, *P. acidilactici* showed a strong bactericidal effect against all three *Listeria* strains, which are common contaminants in animal-derived food products. On the other hand, *P. damnosus* demonstrated only a bacteriostatic effect on the tested pathogens[98]. *P. Pentosaceus* and *P. acidilactici* serve as starter cultures for the food industry to extend shelf life and enhance safety and quality of many food products by destroying harmful microorganisms.

Anticancer potential

Microorganisms demonstrate potential as anticancer agents with less harmful side effects than traditional chemotherapy and synthetic drugs because they don't harm healthy human cells and tissues during therapeutic use[99]. Several studies have shown that Lactic acid bacteria with probiotic potential produce potent results in the prevention and treatment of cancer[100]. Particularly, *Pediococcus* species are strongly effective in alternative cancer therapies and functional food supplements because they have probiotic efficacy[83]. For example, *P. acidilactici* TMAB26, isolated from tomato pickles, known as MTCC 13014 strains, demonstrates significant potential in targeting cancer cells, which may enable its application in colorectal cancer research[84]. Similarly, *P. pentosaceus* OBK05 was evaluated for anticancer effects through *in vivo* and *in vitro* experiments. The cell-free supernatant (CFS) of OBK05 was experimented on mice models, which alleviated intestinal abnormalities in mice injected with HT-29 cells along with strong anticancer activity[101]. The combination of living *P. acidilactici* cells together with their cell-free supernatant (CFS) reduced viability in MDA-MB 231 breast cancer cells during a 24-hour exposure[102].

Immune modulation

The immune system functions as the essential component that determines both wellness and the conditions of illness. The gut immune system might undergo influence through the application of probiotic lactic acid bacteria (LAB). The growing scientific interest in immunobiotic LAB happens because these bacteria affect the gastrointestinal tract immune response at different levels of stimulation[103-105]. For example, the *P. pentosaceus* OZF strain survives digestion inside mice to eventually activate the immune system. The interaction between immune cells and bacteria shows evidence that it stimulates an immune response[106]. According to Singla *et al.*[107], the livestock industry identified *P. acidilactici* SRCM102607 as an effective probiotic because it significantly improves the immune system, which stimulates high levels of TNF-α production, a cytokine crucial for immune responses. The use of *P. acidilactici* strains provides benefits of healthier livestock with better productivity and reduced antibiotic use, resulting in improved resistance to disease alongside sustainable farming practices, which makes it an important tool for contemporary livestock farming operations.

Antioxidant properties

The antioxidant properties of LAB (Lactic Acid Bacteria) strains enable them to capture and neutralise reactive oxygen species (ROS). This ability helps to delay and prevent the oxidation of fermented food[108-109]. The researchers observed that increasing concentrations of H_2O_2 triggered oxidative stress, which produced complete homeostasis breakdown and cell mortality while reducing ATP levels within the cells. The oxidative stress caused both morphological changes and membrane stability deterioration of *P. pentosaceus* R1. This microbe exhibited a strong defence capability through enhanced H_2O_2 tolerance along with increased antioxidant enzyme functions. The antioxidant defence system of *P. pentosaceus* R1 became more active after exposure to both 1 and 2 mM H_2O_2 concentrations. This increase enhanced the overall antioxidant capabilities of the bacterial cells[110]. In addition, *P. acidilactici* proved to show both antioxidant and antihyperglycemic activities in cell-free supernatants, indicating the presence of pharmacological metabolites and soluble factors in them. Thus, the *P. acidilactici* strain can be used as an alternative to synthetic drugs[89].

Other properties

Chronic metabolic disorders like diabetes and high cholesterol are significant challenges to worldwide health. Studies indicate that using probiotics may demonstrate promise as a method to control these health conditions. Researchers investigated *P. pentosaceus* OBK05 for its potential antidiabetic and cholesterol-lowering properties through both *in vitro* and *in vivo* experiments. The cell-free supernatant (CFS) of OBK05 showed strong antidiabetic effects by inhibiting α-amylase (72%) and α-glucosidase (61%), close to the performance of the standard drug acarbose (86%). In cholesterol-fed mice, OBK05 significantly lowered lipid levels and reduced liver lipid droplet accumulation[101]. The *in vivo* trial performed on diabetic mice confirmed that all *P. acidilactici* demonstrated an important ability to reduce blood glucose and low-density lipoprotein concentrations in the mice. Notably, two of the four strains were significantly more effective ($p<0.0001$) than metformin at reducing blood glucose. This implies that *P. acidilactici* functions as a probiotic to prevent hyperglycemia, hypercholesterolemia, and gastrointestinal infections[111]. According to Song *et al.*[112], two strains, namely, *P. acidilactici* SK and *P. acidilactici* OLS3-1, show effectiveness in slowing the onset of insulin resistance, which typically appears in the early stages of obesity when investigated through a diet-induced obesity mouse model. The illustration in Fig. 2 represents the functional and therapeutic characteristics of Pediococcus species together with their major attributes.

Applications of *Pediococcus* species in the food industry

Dairy product fermentation and preservation

Lactic acid bacteria (LAB) conduct milk fermentation to produce fermented dairy products, which include cheese, yoghurts, and kefir. The bacterial species *Pediococcus* now attracts the dairy food fermentation industry due to its beneficial health properties. Research has highlighted the use of *P. acidilactici* and *P. pentosaceus* during the manufacturing process of different fermented food items. Consumers enjoy fermented dairy products because they have many nutritional elements along

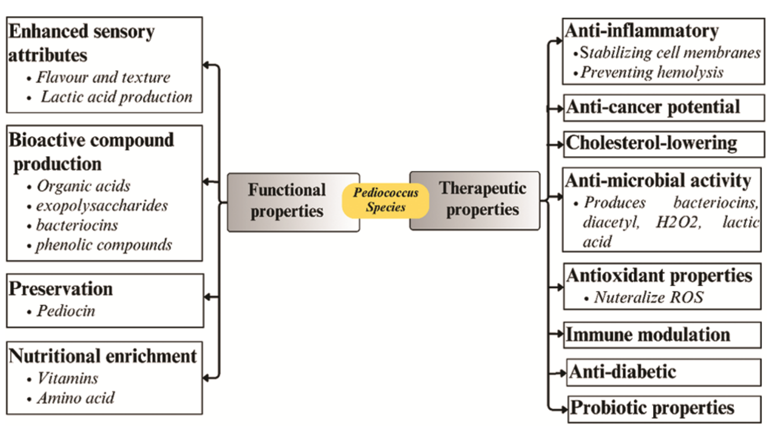

Fig. 2 — Functional and therapeutic properties of *Pediococcus* species and their attributes.

with simple storage methods, high digestibility, and enough flavour content. *P. pentosaceus* serves as a highly valuable fermenter because it is naturally present in or added to cheese, enhances flavour, and accelerates the ripening of cheese[72]. Safety concerns over aflatoxins (Afs) contamination in dairy food products, particularly for young children. Martínez *et al.*[113] highlighted *P. pentosaceus* for its role in binding and degrading AFM1, reducing toxin levels, and improving dairy safety. *P. acidilactici* Kp10 demonstrated strong peptidase (leucine-arylamidase) and esterase-lipase (C4 and C8) activities involved in the development of fruity flavours and improved the quality of fermented dairy and meat products such as cheese, bacon, and fermented sausages[114].

Meat product fermentation

The bio-fermentation technique for fermented meat products depends on using particular microorganisms to ferment raw meat, so it produces acids or alcohol, which lowers the pH. The preservation of the meat products occurs through this method, which inhibits the growth of spoilage and pathogenic bacteria and extends shelf-life. Additionally, microbial fermentation reduces unpleasant odours, making the product more appealing to consumers[72]. The application of *Pediococcus* species in meat products was examined by several researchers. Organic acid produced by LAB suppresses the growth of bacterial cells. Pediocin produced by *P. acidilactici* proved to inhibit the growth of *L. monocytogenes* in fermented sausages by routine preservation in a refrigerator at a lower temperature[115]. *P. pentosaceus* SWU73571 improved the quality and safety of sour meat products when inoculated with *Lactobacillus curvatus* LAB26 as a double-starter culture[116]. A multi-omics approach revealed that *P. pentosaceus* controls both the sensory characteristics and chemical breakdown products in fermented sausage production. Headspace SPME/GC-MS detected a total of 27 volatile metabolites with 17 distinct compositions between treatments and strong *P. pantosaceus* treatment effects, as well as combined *P. pantosaceus* and *S. carnosus* treatments. A UHPLC-MS analysis identified lipids (42.03%) as the leading non-volatile category, while organic acid (25%) came in second place among the detected metabolites, and both showed a strong correlation with 20 flavour compounds that differentiated samples[117]. The effects of different *Pediococcus* species on food products, inoculum counts, and processing parameters appear in Table 4.

Bakery products fermentation

P. pentosaceus SP2 has commercial potential as a dry, lightweight, and self-stable immobilized starter for industrial applications. *P. pentosaceus* SP2 strains prove to be an effective sourdough starter because producing bread using this bacterium results in improved acidity, higher organic acid content, and greater spoilage resistance compared to sourdough

Table 4 — Influence of various *Pediococcus* species on food products, inoculum count, and processing conditions

Food products	Pediococcus species	Inoculum Count	Processing condition	Influence on food product quality indicator	References
Fermented sausages	*P. pentosaceus* (KCTC-13100 strain) *P. acidiliactici* (PE1)	7 Log CFU/g, 6 Log CFU/g	Fermentation(1st 7 days): 23ºC, Ripening(next 21 days): 15ºC, anaerobic	Improved colour and overall sensory acceptance	57, 123
Yogurt	*P. acidilactici* BK01 *P. pentosaceus* TOKAI 759	9.106 -10.376 log CFU/mL, 0.5 × 10^9 CFU/mL	refrigerator temperature 4ºC.	Enhanced taste, aroma, and texture; modulate microbiota & prevent inflammation.	124, 125
Sourdough bread	*P.pentosaceus* LD7, *P.pentosaceus* SA8	108 CFU cells /g	electric oven at 180 ºC for 40 min	Extend shelf life, enhanced texture, aroma and taste, low pH inhibit spoilage	126
Cucumber Pickle	*P. parvulus* HL14	9 log CFU/mL	Fermentation 20-25 ºC / 15days Storage 4 ºC /9weeks	Probiotic viability and stability	127
Probioticated Mango juice	*P. pentosaceus, P. acidilactici*	1.5 × 10 8 CFU/mL	incubated at 37ºCfor 72 h, stored at 4 and 25 ºCfor four weeks	increased acidity and nutritional composition, enhanced Probiotic viability, possessed antimicrobial properties	80
Suancai	*P.pentosaceus* CGMCC	107 CFU/mL	6% salt, Preservation at 15 ◦C for 30 days	Increased acidity, reduced nitrite, and enhanced flavour	85

made with traditional wild microbiota. Freeze-drying and wheat bran immobilization by this starter proved most effective for maintaining its sourdough viability[118]. The combination of *P. acidilactici* (L19) and *P. pentosaceus* (J28) with wheat bran incorporated in black bean flour sourdough proved effective for enhancing bread baking quality and extending shelf-life together with staling properties[119].

Beverages applications

The microorganism *P. inopinatus* chooses to utilise lees substances that make its growth cycle and biogenic amine formation more intense. When compared to other *Pediococcus* species, *P. inopinatus* produces both positive and negative outcomes that affect wine quality. The bacterium produces lactic acid that affects wine flavour but exposes the possibility of generating histamine under special scenarios. When chemicals exist in wine, people who have sensitivities face health issues along with off-flavours that develop in the beverage. Through proper nutrient management and effectiveness tracking, wine producers can preserve targeted flavours and defend their products from damaging transformations leading to bad tastes[120]. Biosuspension starter culture *P. acidilactici* HW01 was applied in malting operations to enhance microbiological stability and reduce filtration times while raising viscosity levels. Several acid and antimicrobial substances contribute to preventing malt from the beer spoilage bacteria of the genus Pseudomonas[121]. *Pediococcus* species, while often linked to spoilage in winemaking, show promise for producing pediocins as a sulphite-free method for controlling malolactic fermentation and enhancing stability, particularly in high-pH wines. Scientific studies need to investigate both beneficial *Pediococcus* strains while examining deterioration conditions and determining the relationship between vineyard practices and *Pediococcus* proliferation[22]. During the process of fermenting pasteurised broccoli juice, researchers used *P. pentosaceus* JBCC 106 as an inoculum strain. The number of broccoli juice cells reached their highest level at 12 hours of fermentation time, but subsequently declined while the juice acidity decreased along with increased antioxidant levels and elevated sulforaphane concentration[122]. Fig. 3 depicts different food production fields where *Pediococcus* species operate as well as their specific strain applications in each sector.

Safety and regulation

According to the Food and Drug Administration, *Pediococcus* species are recognized as safe (GRAS) and demonstrate therapeutic uses. Numerous bacterial strains show medical advantages when applied to human health. It is essential to consider any potential adverse effects from a consumer safety standpoint. Evaluating the overall safety of lactic acid bacteria-based food products requires examining their origin and nature, potential pathogenicity, method of administration, presence or absence of antibiotic resistance genes, exposure level, the health condition of the consumer, and the intended purpose of the product [128]. However, the use of *Pediococcus* species in food production raises additional security risks since infections can affect immunocompromised people and antibiotic-resistance genes can spread, leading to harmful byproducts such as biogenic amines and D-lactate. In addition, many

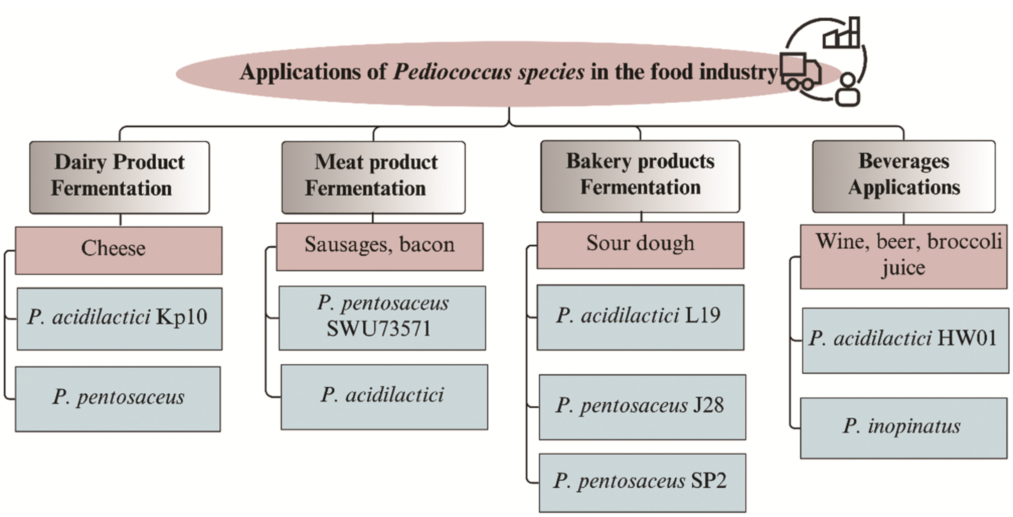

Fig. 3 — Applications of *Pediococcus* species in various branches of the food industry, along with strains used for production.

countries aim for safety and regulatory frameworks to protect consumers from misleading claims about food products. Different nations implement distinct regulatory rules in the commercial market depending on the intended use of *Pediococcus* species, demographic factors, and market dynamics[129]. The pharmacological functions of *Pediococcus* species present challenges, particularly as probiotics transition from food to medicinal use. These obstacles include strain stability concerns, maintaining quality control, and clearing complicated regulatory steps. For establishing *Pediococcus* species application with a wellness perspective, perform strain-specific research while implementing global standards for monitoring products after they reach the market safely.

Future perspective for the study

The taxonomic characteristics of *Pediococcus* species and their capacity to act as starter cultures,biopreservatives, and potential probiotic features have been discussed in the current study. Moreover, Specific research in the future should focus on identifying improved health-benefiting strains while implementing genetic optimisation to enhance novel functionalities. Studies that investigate particular *Pediococcus* strains for practical uses in defined medical and industrial applications will better reveal their industrial and therapeutic worth.

Conclusion

The reviewed studies focused both on *Pediococcus* species taxonomy and morphology while demonstrating different pharmacological applications related to probiotics, food preservation, and biopreservation functions. The food industry requires *Pediococcus* species to function as starter cultures as well as natural preservatives because of their unique ability to produce acids and demonstrate antimicrobial behaviour. The health advantages *Pediococcus* strains offer to gut health and immune system regulation make them promising substances for therapeutic use. Thus, it can be concluded that *P. pentosaceus* species functions as an effective probiotic bacterium and *P. acidilactici* exhibits superior properties for enhancing food product sensory performance. Various researchers established the industrial effectiveness of *Pediococcus* species through their studies.

Conflicts of interest

The authors declare that they have no conflict of interest.

AI use disclosure

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely as an AI-assisted language tool to enhance grammar, sentence structure, clarity, and overall readability. The tool was not used for the experimental design, generation or analysis of data, interpretation of results, preparation of figures, or development of scientific conclusions. All AI-assisted content was carefully reviewed, verified, and revised by the authors. The authors assume full responsibility for the originality, accuracy, integrity, and scientific content of the manuscript.

References

1 Ying W, Zhu W, Zheng Q, Xie J and Sheng G, The therapeutic potential of Pediococcus pentosaceus in systemic diseases: current evidence and future prospects, *Front Microbiol*, 2026, **17**, 1820634, doi: 10.3389/fmicb.2026.1820634
2 Huang H J, Liu C, Sun X W, Wei R Q, Liu L W, *et al.*, The rheumatoid arthritis gut microbial biobank reveals core microbial species that associate and effect on host inflammation and autoimmune responses, *iMeta*, 2024, **3**(5), e242, doi: 10.1002/imt2.242.
3 Chen X, Xiang X, Xia W, Li X, Wang S, *et al.*, Evolving trends and burden of inflammatory bowel disease in Asia, 1990–2019: A comprehensive analysis based on the global burden of disease study, *J Epidemiol Glob Health*, 2023, **13**(4), 725-739, doi: 10.1007/s44197-023-00145-w.
4 Wang R, Li Z, Liu S and Zhang D, Global, regional, and national burden of 10 digestive diseases in 204 countries and territories from 1990 to 2019, *Front Public Health*, 2023, **11**, 1061453, doi: 10.3389/fpubh.2023.1061453.
5 Abdul Hakim B N, Xuan N J and Oslan S N H, A comprehensive review of bioactive compounds from lactic acid bacteria: potential functions as functional food in dietetics and the food industry, *Foods*, 2023, **12**(15), 2850, doi: 10.3390/foods12152850.
6 Akmaliyah R, Mustopa A Z, Budiarti S, Mubarik N R, Mamangkey J, *et al.*, *Pediococcus acidilactici* WSP-AZM23: Genomic Insights, *In vitro* probiotic potential, and computational analysis for biotherapeutic applications, *Biochem Genetics*, 2026, 1-39, doi: 10.1007/s10528-026-11361-x.
7 Gupta M K and Srivastava R, Gut microbiome interventions: from dysbiosis to next-generation probiotics (NGPs) for disease management, *Probiotics Antimicrob Prot*, 2025, **17**(4), 2629-2652, doi: 10.1007/s12602-025-10582-7.
8 Tercanli E, Ka T K, Karaarslan T and Atasever M, Therapeutic effects of probiotic *Pediococcus acidilactici* CNCM MA 18/5 (Bactocell PA) via modulation of oxidative stress and inflammatory pathways in streptozotosin induced diabetic rats, *Food Sci Nutr*, 2026, **14**(5), e71902-e71902, doi: 10.1002/fsn3.71902.
9 Zulfiqar T, Tipu M K, Khan M T, Abouzied A S, Al Kazman B S, *et al.*, Safety assessment and therapeutic

potential of *Pediococcus acidilactici* NMCC-B in attenuating arthritis progression, *Plos One*, 2025, **20**(5), e0324060, doi: 10.1371/journal.pone.0324060.

10 Stabnikov V, Kovshar I and Stabnikova O, Recent advances in the study of the properties and applications of lactic acid bacteria, *World J Microbiol Biotechnol*, 2025, **41**(8), 287, doi: 10.1007/s11274-025-04499-0.

11 Ayivi R D, Gyawali R, Krastanov A, Aljaloud S O, Worku M, *et al.*, Lactic acid bacteria: Food safety and human health applications, *Dairy*, 2020, **1**(3), 202-232, doi: 10.3390/dairy1030015.

12 Adesulu-Dahunsi A T, Sanni A I and Jeyaram K, Diversity and technological characterization of *Pediococcus pentosaceus* strains isolated from Nigerian traditional fermented foods, *LWT*, 2021, **140**, 110697, doi: 10.1016/j.lwt.2020.110697.

13 Simpson W J and Taguchi H, The genus *Pediococcus*, with notes on the genera *Tetratogenococcus* and *Aerococcus*, In *The genera of lactic acid bacteria*, edited by B J B Wood and W H Holzapfel, (Springer, US), 1995, doi: 10.1007/978-1-4615-5817-0_5.

14 Atlas R M, *Handbook of microbiological media*, (CRC Press. Boca Raton FL, USA), 2004, doi: 10.1201/ 9781420039726.

15 Holzapfel W H, Franz C M, Ludwig W, Back W and Dicks L M, The genera *pediococcus* and *tetragenococcus*, *Prokaryotes*, 2006, **4**(1), 229-266, doi: 10.1007/0-387-30744-3_8.

16 Singla V, Mandal S, Anand S and Tomar S K, Techno-functional attributes of *Pediococcus* spp.: a review, *Ind J Dairy Sci*, 2017, **70**(4), 381-390.

17 Zheng J, Wittouck S, Salvetti E, Franz C M, Harris H, *et al.*, A taxonomic note on the genus *Lactobacillus*: Description of 23 novel genera, emended description of the genus *Lactobacillus* Beijerinck 1901, and union of *Lactobacillaceae* and *Leuconostocaceae*, *Int J Syst Evol Microbiol*, 2020, **70**, 2782–2858, doi: 10.1099/ijsem. 0.004107.

18 Pederson C S, The genus *Pediococcus*, *Bacteriol Rev*, 1949, **13**, 225-232.

19 Garvie E I, Genus *Pediococcus*, In *Bergey's Manual of Systematic Bacteriology*, edited by P H A Sneath, N S Mair, M E Sharp, J G Holt, (The Williams & Wilkins Co, Baltimore), 1986, **2**, 1075-1079.

20 Pfannebecker J and Frohlich J, Use of a species-specific multiplex PCR for the identification of *pediococci*, *Int J Food Microbiol*, 2008, **128**, 288-296, doi: 10.1016/j.ijfoodmicro.2008.08.019.

21 Zommiti M, Bouffartigues E, Maillot O, Barreau M, Szunerits S, *et al.*, *In vitro* assessment of the probiotic properties and bacteriocinogenic potential of *Pediococcus pentosaceus* MZF16 isolated from artisanal Tunisian meat "dried ossban", *Front Microbiol*, 2018, **9**, 2607, doi: 10.3389/fmicb.2018.02607.

22 Wade M E, Strickland M T, Osborne J P and Edwards C G, Role of *Pediococcus* in winemaking, *Aust J Grape Wine Res*, 2019, **25**(1), 7-24, doi: 10.1111/ajgw.12366.

23 Dallaglio F, Trovatelli L D and Sarra P G, DNA-DNA homology among representative strains of the genus *Pediococcus*, *Zentbl Bakteriol Mikrobiol Hyg*, 1981, **2**, 140–150, doi: 10.1016/S0721-9571(81)80036-1.

24 Ray B, *Pediococcus* in fermented foods, in *Food Biotechnology: Microorganisms*, edited by Y H Hui, G Khachatourians, (Wiley-VCH USA), 1995, 745–747.

25 Gasson M J and DeVos W M, *Genetics and biotechnology of lactic acid bacteria*, (Blackie Academic & Professional, Glasgow, UK), 1994.

26 Mora D, Fortina M G, Parini C, Daffonchio D and Manachini P L, Genomic sub-populations within the species *Pediococcus acidilactici* detected multilocus typing analysis: relationships between pediocin AcH/PA-1 producing and non-producing strains, *Microbiol*, 2000, **146**(8), 2027–2038, doi: 10.1099/00221287-146-8-2027.

27 Mora D, Fortina M G, Parini C and Manachini P L, Identification of *Pediococcus acidilactici* and *Pediococcus pentosaceus* based on 16S rRNA and ldhD-targeted multiplex PCR analysis, *FEMS Microbiol Lett*, 1997, **151**(2), 231–236, doi: 10.1111/j.1574-6968.1997.tb 12575.x.

28 Mora D, Parini C, Fortina M G and Manachini P L, Discrimination among pediocin AcH/PA-1 producer strains by comparison of ped B and pedD amplified genes and multiplex PCR assay, *Syst Appl Microbiol*, 1998, **21**(3), 454–460, doi: 10.1016/S0723-2020(98)80056-8.

29 Olive D M and Bean P, Principles and applications of methods for DNA-based typing of microbial organisms, *J Clin Microbiol*, 1999, **37**(6), 1661-1669, doi: 10.1128/jcm.37.6.1661-1669.1999.

30 Barney M, Volgyi A, Navarro A and Ryder D, Riboprinting and 16S rRNA gene sequencing for identification of brewery *Pediococcus* isolates, *Appl Environ Microbiol*, 2002, **67**(2), 553–56, doi: 10.1128/AEM.67.2.553-560.2001.

31 Jager K and Harlander S, Characterization of a bacteriocin from *Pediococcus acidilactici* PC and comparison of bacteriocin-producing strains using molecular typing procedures, *Appl Microbiol Biotechnol*, 1992, **37**, 631–637, doi: 10.1007/BF00240739.

32 Satokari R, Mattila-Sandholm T and Suihko M L, Identification of *pediococci* by ribotyping, *J Appl Microbiol*, 2000, **88**, 260–265, doi: 10.1046/j.1365-2672.2000.00956.x.

33 Omar N B, Ampe F, Raimbault M, Guyot J P and Tailliez P, Molecular diversity of lactic acid bacteria from cassava sour starch, *(Colombia) Syst Appl Microbiol*, 2000, **23**(2), 285–291, doi: 10.1016/S0723-2020(00)80016-8.

34 Albano H, Todorov S D, van Reenen C A, Hogg T, Dicks L M T, *et al.*, Characterization of a bacteriocin produced by *Pediococcus acidilactici* isolated from "Alheira", a fermented sausage traditionally produced in Portugal, *Int J Food Microbiol*, 2007, **116**(2), 239–247, doi: 10.1016/j.ijfoodmicro.2007.01.011.

35 Cavicchioli V Q, Camargo A C, Todorov S D and Nero L A, Potential control of *Listeria monocytogenes* by Bacteriocinogenic *Enterococcus hirae* ST57ACC and *Pediococcus pentosaceus* ST65ACC strains isolated from artisanal cheese, *Probiotics Antimicrob Prot*, 2019, **11**, 696–704, doi: 10.1007/s12602-018-9449-0.

36 Gutierrez-Cortes C, Suarez H, Butirago G, Nero L A and Todorov S D, Characterization of bacteriocins produced by strains of *Pediococcus pentosaceus* isolated from Minas cheese, *Ann Microbiol*, 2018, **68**, 383–398, doi: 10.1007/s13213-018-1345-z.

37 Simpson P J, Stanton C, Fitzerald G F and Ross R P, Genomic diversity within the genus *Pediococcus* as revealed by randomly amplified polymorphic DNA PCR and pulsed-field gel electrophoresis, *Appl Environ Microbiol*, 2002, **68**(2), 765–771, doi: 10.1128/AEM.68.2.765-771.2002.

38 Fugaban J I I, Bucheli J E V, Park Y J, Suh D H, Jung E S, *et al.*, Antimicrobial properties of *Pediococcus acidilactici* and *Pediococcus pentosaceus* isolated from silage, *J Appl Microbiol*, 2022, **132**(1), 311–330, doi: 10.1111/jam.15205.

39 Elkalla W S, Ragab Y M, Ramadan M A and Mansour N M, The complete genome sequences of the two novel probiotics were isolated from the human gut microbiota: *Pediococcus acidilactici* WNYM01 and *Pediococcus acidilactici* WNYM02, vitamin B9, and B2-producers, *Egypt Pharm J*, 2024, **23**(4), 702-709.

40 Jiang S, Cai L, Lv L and Li L, *Pediococcus pentosaceus*, a future additive or probiotic candidate, *Microb Cell Fact*, 2021, **20**, 45, doi: 10.1186/s12934-021-01537-y.

41 Xu Z, Wang K, Liu Z, Soteyome T, Deng Y, *et al.*, A novel procedure in combination of genomic sequencing, flow cytometry and routine culturing for confirmation of beer spoilage caused by *Pediococcus damnosus* in viable but nonculturable state, *LWT*, 2022, **154**, 112623, doi: 10.1016/j.lwt.2021.112623.

42 Bockwoldt J A, Bacterial β-glucan-Applicability for in situ enriched sourdoughs and molecular background of the biosynthesis and degradation, (Doctoral dissertation, Technische Universität München), 2022.

43 Li Y, Luo X, Long F, Wu Y, Zhong K, *et al.*, H Quality improvement of fermented chili pepper by inoculation of *Pediococcus ethanolidurans* M1117: Insight into relevance of bacterial community succession and metabolic profile, *LWT*, 2023, **179**, 114655, doi: 10.1016/j.lwt.2023.114655.

44 Guan T, Long L, Liu Y, Tian L, Peng Z, *et al.*, Complete genome sequencing and bacteriocin functional characterization of *Pediococcus ethanolidurans* CP201 from Daqu, *Appl Biochem Biotechnol*, 2023, **195**, 4728–4743, doi: 10.1007/s12010-023-04575-x.

45 Yi E J and Kim A J, Antimicrobial and antibiofilm effect of bacteriocin-producing *Pediococcus inopinatus* K35 isolated from kimchi against multidrug-resistant *Pseudomonas aeruginosa*, *Antibiotics*, 2023, **12**(4), 676, doi: 10.3390/antibiotics12040676.

46 Monroy I, Olmeda I, Ferrer S and Pardo I, Biochemical characterization of three heterologous lactic acid bacteria laccases from *Pediococcus*, *Lactobacillus,* and *Lactococcus* genus and their potential to degrade biogenic amines using ABTS and epicatechin as mediators, *Fermentation*, 2023, **10**(1), 32, doi: 10.3390/fermentation10010032.

47 Adnan M, Siddiqui A J, Hamadou W S, Ashraf S A, Hassan M I, *et al.*, Functional and structural characterization of *Pediococcus pentosaceus*-derived biosurfactant and its biomedical potential against bacterial adhesion, quorum sensing, and biofilm formation, *Antibiotics*, 2021, **10**(11), 1371, doi: 10.3390/antibiotics10111371.

48 Phuengjayaem S, Nuhwa R, Phongsopitanun W and Tanasupawat S, *Secundilactobacillus folii* sp. nov., isolated from fermented tea leaves in Thailand, *Int J Syst Evol Microbiol*, 2021, **71**(2), 004635, doi: 10.1099/ijsem.0.004635.

49 Sivamaruthi B S, Alagarsamy K, Suganthy N, Thangaleela S, Kesika P, *et al.*, The role and significance of *bacillus* and *lactobacillus* species in Thai fermented foods, *Fermentation*, 2022, **8**(11), 635, doi: 10.3390/fermentation 8110635.

50 Park S K, Jo D M, Yu D, Khan F, Lee Y B, *et al.*, Reduction of trimethylamine off-odor by lactic acid bacteria isolated from korean traditional fermented food and their in situ application, *J Microbiol Biotechnol*, 2020, **30**(10), 1510-1515, doi: 10.4014/jmb.2005.05007.

51 Shangpliang H N J and Tamang J P, Metagenomics and metagenome-assembled genomes mining of health benefits in jalebi batter, a naturally fermented cereal-based food of India, *Food Res Int*, 2023, **172**, 113130, doi: 10.1016/j.foodres.2023.113130.

52 Sharma A, Noda M, Sugiyama M, Kumar B, and Kaur B, Application of *Pediococcus acidilactici* BD16 (alaD+) expressing L-alanine dehydrogenase enzyme as a starter culture candidate for secondary wine fermentation, *Biotechnol Biotechnol Equip*, 2021, **35**(1), 1643-1661, doi: 10.1080/13102818.2021.1995496.

53 Kaur B, Kumar B, Kaur G, Chakraborty D and Kaur K, Application of recombinant *Pediococcus acidilactici* BD16 (*fcs* $^{+}$/*ech* $^{+}$*)* in malolactic fermentation, *Appl Microbiol Biotechnol*, 2015, **99**, 3015–3028, doi: 10.1007/s00253-015-6413-8.

54 Gerasi E, Litopoulo-Tzanetaki E and Tzanetakis N, Microbiological study of Manura, a hard cheese made from raw ovine milk in the Greek island Sifnos, *Int J Dairy Technol*, 2010, **56**, 117–122, doi: 10.1046/j.1471-0307.2003.00085.

55 Li C, Zhao Y, Wang Y, Li L, Huang J, *et al.*, Contribution of microbial community to flavor formation in tilapia sausage during fermentation with *Pediococcus pentosaceus*, *LWT*, 2022, **154**, 112628, doi: 10.1016/j.lwt.2021.112628.

56 Song G, He Z, Wang X, Zhao M, Cao X, *et al.*, Improving the quality of Suancai by inoculating with *Lactobacillus plantarum* and *Pediococcus pentosaceus*, *Food Res Int*, 2021, **148**, 110581, doi: 10.1016/j.foodres.2021.110581.

57 Seleshe S, Ameer A and Kang S N, Incorporation of selected strains of *Pediococcus* spp. on quality characteristics of dry fermented sausage during fermentation and ripening, *Food Sci Anim Resour*, 2021, **41**, 1078–1094, doi: 10.5851/kosfa.2021.e60.

58 Fugaban J I I, Vazquez Bucheli J E, Park Y J, Suh D H, Jung E S, *et al.*, Antimicrobial properties of *Pediococcus acidilactici* and *Pediococcus pentosaceus* isolated from silage, *J Appl Microbiol*, 2022, **132**(1), 311-330, doi: 10.1111/jam.15205.

59 Papagianni M and Anastasiadou S, Pediocins: The bacteriocins of *Pediococci*. Sources, production, properties and applications, *Microb Cell Fact*, 2009, **8**, 3, doi: 10.1186/1475-2859-8-3.

60 Todorov S D, Dioso C M, Liong M T, Nero L A, Khosravi-Darani K, *et al.*, Beneficial features of *pediococcus*: from starter cultures and inhibitory activities to probiotic benefits, *World J Microbiol Biotechnol*, 2023, **39**, 4, doi: 10.1007/s11274-022-03419-w.

61 Silva C, Silva S and Ribeiro S C, Application of bacteriocins and protective cultures in dairy food preservation, *Front Microbiol*, 2018, **9**, 594, doi: 10.3389/fmicb.2018.00594.

62 Pato U, Yusuf Y, Fitriani S, Fauzi D A, Ismadiah G, *et al.*, Antibacterial activity of bacteriocin from *Pediococcus pentosaceus* Strain 2397 and application as biopreservative for fishballs, *Philippine J Sci*, 2022, **15**(2).

63 Escobar-Sánchez M, Carrasco-Navarro U, Juárez-Castelán C, Lozano-Aguirre Beltrán L, Pérez-Chabela M L, *et al.*, Probiotic properties and proteomic analysis of *Pediococcus pentosaceus* 1101, *Foods*, 2022, **12**(1), 46, doi: 10.3390/foods12010046.

64 Das S, Mandal V and Mandal N C, Broad-spectrum antimicrobial efficacy of *Pediococcus acidilactici* LAB001 against food spoilage and toxigenic bacteria and fungi, *J Food Process Preserv*, 2021, **45**(1), e15066, doi: 10.1111/jfpp.15066.

65 Khorshidian N, Khanniri E, Mohammadi M, Mortazavian A M and Yousefi M, Antibacterial activity of pediocin and pediocin-producing bacteria against *Listeria monocytogenes* in meat products, *Front Microbiol*, 2021, **12**, 709959, doi: 10.3389/fmicb.2021.709959.

66 Mandal V, Sen S K and Mandal N C, Assessment of antibacterial activities of pediocin produced by *Pediococcus acidilactici LAB* 5, *J Food Saf*, 2010, **30**(3), 635-651, doi: 10.1111/j.1745-4565.2010.00230.x.

67 Huang Y, Luo Y, Zhai Z, Zhang H, Yang C, *et al.*, Characterization and application of an anti-Listeria bacteriocin produced by *Pediococcus pentosaceus* 05-10 isolated from Sichuan Pickle, a traditionally fermented vegetable product from China, *Food Control*, 2009, **20**(11), 1030-1035, doi: 10.1016/j.foodcont.2008.12.008.

68 Niamah A K, Structure, mode of action and application of pediocin natural antimicrobial food preservative: A review, *Basrah J Agric Sci*, 2018, **31**(1), 59-69, doi: 10.37077/25200860.2018.76.

69 Verma S K, Sood S K, Saini R K and Saini N, Pediocin PA-1 containing fermented cheese whey reduces total viable count of raw buffalo (*Bubalis bubalus*) milk, *LWT Food Sci Technol*, 2017, **83**, 193–200, doi: 10.1016/j.lwt.2017.02.031.

70 Todorov S D and Dicks L M, Pediocin ST18, an anti-listerial bacteriocin produced by *Pediococcus pentosaceus* ST18 isolated from boza, a traditional cereal beverage from Bulgaria, *Process Biochem*, 2005, **40**(1), 365-370, doi: 10.1016/j.procbio.2004.01.011.

71 Bansal P, Kumar R and Dhanda S, Characterization of starter cultures and nutritional properties of *Pediococcus acidilactici* NCDC 252: A potential probiotic of dairy origin, *J Food Process Preserv*, 2022, **46**(10), e16817, doi: 10.1111/jfpp.16817.

72 Qi Y, Huang L, Zeng Y, Li W, Zhou D, *et al.*, *Pediococcus pentosaceus*: screening and application as probiotics in food processing, *Front Microbiol*, 2021, **12**, 762467, doi: 10.3389/fmicb.2021.762467.

73 Toe C J, Foo H L, Loh T C, Mohamad R, Abdul Rahim R, *et al.*, Extracellular proteolytic activity and amino acid production by lactic acid bacteria isolated from Malaysian foods, *Int J Mol Sci*, 2019, **20**(7), 1777, doi: 10.3390/ijms20071777.

74 Raghavendra P, Ushakumari S R and Halami P M, Phytate-degrading *Pediococcus pentosaceus* CFR R123 for application in functional foods, *Benef Microbes*, 2011, **2**, 57–61, doi: 10.3920/BM2010.0031.

75 Gupta A and Sharma N, Characterization of potential probiotic lactic acid bacteria-*Pediococcus acidilactici* Ch-2 isolated from Chuli-A traditional apricot product of Himalayan region for the production of novel bioactive compounds with special therapeutic properties, *J Food Microbiol Saf Hyg*, 2017, **2**(1), 1-11.

76 FAO/WHO, Evaluation of health and nutritional properties of powder milk and live lactic acid bacteria, Rep from FAO/WHO Expert Consult, 2001, 1–4.

77 Bhagat D, Raina N, Kumar A, Katoch M, Khajuria Y, *et al.*, Probiotic properties of a phytase producing *Pediococcus acidilactici* strain SMVDUDB2 isolated from traditional fermented cheese product, Kalarei, *Sci Rep*, 2020, **10**, 1926, doi: 10.1038/s41598-020-58676-2.

78 Noohi N, Ebrahimipour G, Rohani M, Talebi M and Pourshafie M R, Evaluation of potential probiotic characteristics and antibacterial effects of strains of *Pediococcus species* isolated from broiler chickens, *Brit Poult Sci*, 2016, **57**(3), 317-323, doi: 10.1080/00071668.2016.1169247.

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

80 Adebayo-Tayo B C, Olomitutu F O and Adebami G E, Production and evaluation of probioticated mango juice using *Pediococcus pentosaceus* and *Pediococcus acidilactici* during storage at different temperature, *J Agric Food Res*, 2021, **6**, 100202, doi: 10.1016/j.jafr.2021.100202.

81 Diguță C F, Nițoi G D, Matei F, Luță G and Cornea C P, The biotechnological potential of Pediococcus spp. isolated from Kombucha microbial consortium, *Foods*, 2020, **9**, 1780, doi: 10.3390/foods9121780.

82 Wanna W, Surachat K, Kaitimonchai P and Phongdara A, Evaluation of probiotic characteristics and whole genome analysis of *Pediococcus pentosaceus* MR001 for use as probiotic bacteria in shrimp aquaculture, *Sci Rep*, 2021, **11**, 18334, doi: 10.1038/s41598-021-96780-z.

83 Jafari-Nasab T, Khaleghi M, Farsinejad A and Khorrami S, Probiotic potential and anticancer properties of *Pediococcus sp.* isolated from traditional dairy products, *Biotech Rep*, 2021, **29**, e00593, doi: 10.1016/j.btre.2021.e00593.

84 Barigela A and Bhukya B, Probiotic *Pediococcus acidilactici* strain from tomato pickle displays anticancer activity and alleviates gut inflammation *in-vitro*, *3 Biotech*, 2021, **11**(1), 23, doi: 10.1007/s13205-020-02570-1.

85 Song Y R, Lee C M, Lee S H and Baik S H, Evaluation of probiotic properties of *Pediococcus acidilactici* M76 producing functional exopolysaccharides and its lactic acid fermentation of black raspberry extract, *Microorganisms*, 2021, **9**(7), 1364, doi: 10.3390/microorganisms9071364.

86 Immerstrand T, Paul C J, Rosenquist A, Deraz S, Mårtensson O B, *et al.*, Characterization of the properties of *Pediococcus parvulus* for probiotic or protective culture use, *J Food Prot*, 2010, **73**(5), 960-966, doi: 10.4315/0362-028x-73.5.960.

87 Plaza-Díaz J, Ruiz-Ojeda F J, Vilchez-Padial L M and Gil A, Evidence of the anti-inflammatory effects of probiotics and synbiotics in intestinal chronic diseases, *Nutrients*, 2017, **9**(6), 555, doi: 10.3390/nu9060555.

88 Mousavi Z E, Mousavi S M, Razavi S H, Emam-Djomeh Z and Kiani H, Fermentation of pomegranate juice by probiotic lactic acid bacteria, *World J Microbiol Biotechnol*, 2011, **27**(1), 123–128, doi: 10.1007/s11274-010-0436-1.

89 Shweta D, Praveen K, Manjusha C and Suman D, *In vitro* studies on anti-inflammatory, antioxidant and antihyperglycemic activities of potential probiotic *Pediococcus acidilactici* NCDC 252, *Res J Biotech*, 2021, **16**(12), 12.

90 Angelin J and Kavitha M, Structural characterization and *in vivo* anti-inflammatory activity of EPS from *Pediococcus pentosaceus* 4412 in LPS-induced mice model, *Research Square (Preprint)*, 2023, doi: 10.21203/rs.3.rs-3498872/v1, (*Published in Int Immunopharmacol*, 2025, **150**, 114301, doi: 10.1016/j.intimp.2025.114301)

91 Pérez-Ramos A, Mohedano M L, Pardo M Á and López P, β-Glucan-producing *Pediococcus parvulus* 2.6: test of probiotic and immunomodulatory properties in zebrafish models, *Front Microbiol*, 2018, **9**, 1684, doi: 10.3389/fmicb.2018.01684.

92 Gálvez A, Abriouel H, López R L and Omar N B, Bacteriocin-based strategies for food biopreservation, *Int J Food Microbiol*, 2007, **120**(1-2), 51–70, doi: 10.1016/j.ijfoodmicro.2007.06.001.

93 Nieto-Lozano J C, Reguera-Useros J I, Peláez-Martínez M C, Sacristán Pérez-Minayo G, Gutiérrez-Fernández Á J, *et al.*, The effect of the pediocin PA-1 produced by *Pediococcus acidilactici* against Listeria monocytogenes and *Clostridium perfringens* in Spanish dry-fermented sausages and frankfurters, *Food Control*, 2010, **21**(5), 679-685, doi: 10.1016/j.foodcont.2009.10.007.

94 Kingcha Y, Tosukhowong A, Zendo T, Roytrakul S, Luxananil P, *et al.*, Anti-listeria activity of *Pediococcus pentosaceus* BCC 3772 and application as starter culture for Nham, a traditional fermented pork sausage, *Food Control*, 2012, **25**(1), 190-196, doi: 10.1016/j.foodcont.2011.10.005.

95 De Azevedo P O S, Mendonça C M N, Seibert L, Domínguez J M, Converti A, *et al.*, Bacteriocin-like inhibitory substance of *Pediococcus pentosaceus* as a biopreservative for Listeria sp. control in ready-to-eat pork ham, *Braz J Microbiol*, 2020, **51**(3), 949-956, doi: 10.1007/s42770-020-00245-w.

96 Somkuti G A and Steinberg D H, Pediocin production in milk by *Pediococcus acidilactici* in co-culture with *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, *J Ind Microbiol Biotechnol*, 2010, **37**(1), 65-69, doi: 10.1007/s10295-009-0648-2.

97 Kaya H I and Şimşek Ö, Characterization of *Pediococcus acidilactici* PFC69 and Lactococcus lactis PFC77 bacteriocins and their antimicrobial activities in tarhana fermentation, *Microorganisms*, 2020, **8**(7), 1083, doi: 10.3390/microorganisms8071083.

98 Tumbarski Y D, Pavlova T, Yanakieva V, Goranov B and Denkova-Kostova R, Antimicrobial activity of *Pediococcus* strains against some Listeria spp. during co-cultivation under static growth conditions, *J Microbiol Biotechnol Food Sci*, 2022, **12**(4), e9360, doi: 10.55251/jmbfs.9360.

99 Wang S M, Zhang L W, Fan R B, Han X, Yi H X, *et al.*, Induction of HT-29 cells apoptosis by lactobacilli isolated from fermented products, *Res Microbiol*, 2014, **165**(3), 202-214, doi: 10.1016/j.resmic.2014.02.004.

100 Kechagia M, Basoulis D, Konstantopoulou S, Dimitriadi D, Gyftopoulou K, *et al.*, Health benefits of probiotics: a review, *Int Sch Res Notices*, 2013, **2013**(1), 481651, doi: 10.5402/2013/481651.

101 Bhukya K K and Bhukya B, Exploration of antidiabetic, cholesterol-lowering, and anticancer upshot of probiotic bacterium *Pediococcus pentosaceus* OBK05 strain of buttermilk, *Probiotics Antimicrob Proteins*, 2023, **15**(6), 1484-1500, doi: 10.1007/s12602-022-10002-0.

102 Adumuah N N, Quarshie J T, Danwonno H, Aikins A R and Ametefe E N, Exploring anti-breast cancer effects of live pediococcus acidilactici and its cell-free supernatant isolated from human breast milk, *Int J Breast Cancer*, 2024, **2024**(1), 1841909, doi: 10.1155/2024/1841909.

103 Nagao F, Nakayama M, Muto T and Okumura K, Effects of a fermented milk drink containing *Lactobacillus casei* strain Shirota on the immune system in healthy human subjects, *Biosci Biotechnol Biochem*, 2000, **64**(12), 2706–2708, doi: 10.1271/bbb.64.2706.

104 Sheih Y H, Chiang B L, Wang L H, Liao C K and Gill H S, Systemic immunity-enhancing effects in healthy subjects following dietary consumption of the lactic acid bacterium Lactobacillus rhamnosus HN001, *J Am Coll Nutr*, 2001, **20**(2 Suppl), 149–156, doi: 10.1080/07315724.2001.10719027.

105 Lomax A R and Calder P C, Probiotics, immune function, infection and inflammation: a review of the evidence from studies conducted in humans, *Curr Pharm Des*, 2009, **15**(13), 1428–1518, doi: 10.2174/138161209788168155.

106 Osmanagaoglu O, Kiran F, Yagci F C and Gursel I, Immunomodulatory function and in vivo properties of *Pediococcus pentosaceus* OZF, a promising probiotic strain, *Ann Microbiol*, 2013, **63**, 1311-1318, doi: 10.1007/s13213-012-0590-9.

107 Shin S J, Ha G, Jeong S J, Ryu M S, Kim J, *et al.*, Probiotic properties and immunomodulator evaluation of the potential feed additive pediococcus acidilactici SRCM102607, *J Life Sci*, 2020, **30**(10), 896-904, doi: 10.5352/JLS.2020.30.10.896.

108 Chen Q, Kong B, Han Q, Xia X and Xu L, The role of bacterial fermentation in lipolysis and lipid oxidation in Harbin dry sausages and its flavor development, *LWT*, 2017, **77**, 389–396, doi: 10.1016/j.lwt.2016.11.075.

109 Neffeskocinska K, Jaworska D, Kolozynkrajewska D, Dolatowski Z J and Jachaczjowko L, The effect of lab as probiotic starter culture and green tea extract addition on dry fermented pork loins quality, *Biomed Res Int*, 2015, **2015**, 452757, doi: 10.1155/2015/452757.

110 Zhang H, Xu J, Chen Q, Wang H and Kong B, Physiological, morphological and antioxidant responses of *Pediococcus pentosaceus* R1 and *Lactobacillus fermentum* R6 isolated from harbin dry sausages to oxidative stress, *Foods*, 2021, **10**(6), 1203, doi: 10.3390/foods10061203.

111 Al-Emran H M, Moon J F, Miah M L, Meghla N S, Reuben R C, *et al.*, Genomic analysis and *in vivo* efficacy of

Pediococcus acidilactici as a potential probiotic to prevent hyperglycemia, hypercholesterolemia and gastrointestinal infections, *Sci Rep*, 2022, **12**(1), 20429, doi: 10.1038/s41598-022-24791-5.

112 Somalou P, Ieronymaki E, Feidaki K, Prapa I, Stylianopoulou E, *et al.*, Novel wild-type pediococcus and *Lactiplantibacillus* strains as probiotic candidates to manage obesity-associated insulin resistance, *Microorganisms*, 2024, **12**(2), 231, doi: 10.3390/ microorganisms12020231.

113 Martínez M P, Magnoli A P, González Pereyra M L and Cavaglieri L, Probiotic bacteria and yeasts adsorb aflatoxin M(1) in milk and degrade it to less toxic AFM(1)-metabolites, *Toxicon*, 2019, **172**, 1–7, doi: 10.1016/j.toxicon.2019.10.001.

114 Abbasiliasi S, Tan J S, Bashokouh F, Ibrahim T A T, Mustafa S, *et al.*, *In vitro* assessment of *Pediococcus acidilactici* Kp10 for its potential use in the food industry, *BMC Microbiol*, 2017, **17**, 121, doi: 10.1186/s12866-017-1000-z.

115 Cheun H I, Makino S I, Shirahata T and Mikami M, The practical application of pediocin produced by *Pediococcus acidilactici* in food, *Biosci Microflora*, 2000, **19**(1), 47-50.

116 Zhang Y, Hu P, Xie Y and Wang X, Co-fermentation with Lactobacillus curvatus LAB26 and *Pediococcus pentosaceus* SWU73571 for improving quality and safety of sour meat, *Meat Sci*, 2020, **170**, 108240, doi: 10.1016/j.meatsci.2020.108240.

117 Zhao Y, Zhou C, Ning J, Wang S, Nie Q, *et al.*, Effect of fermentation by *Pediococcus pentosaceus* and *Staphylococcus carnosus* on the metabolite profile of sausages, *Food Res Int*, 2022, **162**, 112096, doi: 10.1016/j.foodres.2022.112096.

118 Plessas S, Mantzourani I and Bekatorou A, Evaluation of *Pediococcus pentosaceus* SP2 as starter culture on sourdough bread making, *Foods*, 2020, **9**(1), 77, doi: 10.3390/foods9010077.

119 Huang J, Omedi J O, Huang C, Chen C, Liang L, *et al.*, Effect of black bean supplemented with wheat bran sourdough fermentation by *Pediococcus acidilactici* or *Pediococcus pentosaceus* on baking quality and staling characteristics of wheat composite bread, *Appl Food Res*, 2024, **4**(1), 100425, doi: 10.1016/j.afres.2024.100425.

120 Wanjohi E, *Impact of Pediococcus on the Sensory Properties and Biogenic Amine Content of Wine*, Master's Thesis, Oregon State University, 2024.

121 Kim D Y, Kim J, Kim J H and Kim W J, Malt and wort bio-acidification by *Pediococcus acidilactici* HW01 as starter culture, *Food Control*, 2021, **120**, 107560, doi: 10.1016/j.foodcont.2020.107560.

122 Park S K, Jin H, Song N E and Baik S H, Probiotic properties of *Pediococcus pentosaceus* JBCC 106 and its lactic acid fermentation on broccoli juice, *Microorganisms*, 2023, **11**(8), 1920, doi: 10.3390/microorganisms11081920.

123 Seleshe S and Kang S N, Effect of different *Pediococcus pentosaceus* and *Lactobacillus plantarum* strains on quality characteristics of dry fermented sausage after completion of ripening period, *Food Sci Anim Resour*, 2021, **41**(4), 636–649, doi: 10.5851/kosfa.2021.e21.

124 Juliyarsi I, Kurnia Y F, Pratama Y E and Pratama D R, The quality of fermented goat milk produced by *Pediococcus acidilactici* BK01 on refrigerator temperature, *Biodiversitas*, 2020, **21**(10), 4591–4596, doi: 10.13057/ biodiv/d211017.

125 Nakashima Y, Onuki K, Hibi T, Ohno R I, Sugawa H, *et al.*, Soymilk yogurt fermented using *Pediococcus pentosaceus* TOKAI 759 m improves mice gut microbiota and reduces pro-inflammatory cytokine production, *Biosci Biotechnol Biochem*, 2024, **88**(11), 1349-1361, doi: 10.1093/bbb/zbae112.

126 Olojede A O, Sanni A I, Banwo K and Michael T, Improvement of texture, nutritional qualities, and consumers' perceptions of sorghum-based sourdough bread made with *Pediococcus pentosaceus* and *Weissella confusa* strains, *Fermentation*, 2022, **8**(1), 32, doi: 10.3390/fermentation8010032.

127 Kirmizigul Peker A, Guney D and Sengun I, The use of both free and microencapsulated *Lactiplantibacillus plantarum* and *Pediococcus parvulus* in cucumber pickles, *Food Bioprocess Technol*, 2024, **17**(12), 4617–4631, doi: 10.1007/s11947-024-03400-5.

128 De Simone C, The unregulated probiotic market, *Clin Gastroenterol Hepatol*, 2019, **17**(5), 809-817, doi: 10.1016/j.cgh.2018.01.018.

129 Melchor S R, Skoblikov L, Schütte B, Urazbaeva A, Szajkowska A, *et al.*, The regulatory framework for the use of probiotics claims in food and food supplements around the world: a comparative analysis, *The Functional Field of Food Law: Reconciling the Market and Human Rights*, 2019, **11**, 155–169, doi: 10.3920/978-90-8686-885-8.