Biologia (2023) 78:3609–3623
https://doi.org/10.1007/s11756-023-01512-5

REVIEW

Role and importance of lactic acid bacteria in different Indian fermented foods

Vishali Jhamb[1] · **Priya Swaminathan**[1]

Received: 22 February 2023 / Accepted: 16 August 2023 / Published online: 29 August 2023

Abstract

Various bacteria known as lactic acid bacteria (LAB) are crucial for food fermentation and producing probiotic products. Most of the lactic acid produced by the LAB, a genus of Gram-positive, non-spore-forming cocci or rods, is responsible for the fermentation of carbohydrates. In anaerobic fermentation, yeast and bacteria break food components into other products. Fermented foods and beverages are described as having carefully controlled microbial development. Some nutrients include proteins, soluble fibre, minerals, vitamins, essential fatty acids, and some essential amino acids found in fermented foods and beverages. There are many different types of fermented foods, so it's essential to describe each one's role in terms of its nature. The bacteria employed in fermentation are typically probiotic, meaning they are good for human health. These bacteria may help us to enhance the nutrient content of food, gastrointestinal infection prevention, improve lactose digestion and cancer prevention, and lower serum cholesterol levels. Indian fermented foods are classified according to the raw materials they contain, like cereal-based, meat-based, pulse-based, vegetable and fruit-based, sweets and snacks-based fermented foods widely used in the Indian Scenario. This review article brings a complete view of traditional fermented foods of different raw materials that are significant and naturally beneficial for human health, with special mention of significant LABs in various fermented foods from India.

Keywords LAB · Fermentation · Beverages · Indian fermented foods · Probiotics

Abbreviations
LAB Lactic acid bacteria

Introduction

Since ancient times, the human diet has included fermented foods as a protein source. It can be made using relatively straightforward methods and techniques at home or in a small business. During low demand, fermentation was developed to protect food from spoiling. It is one of the earliest and most affordable processes for growing and storing food (Kumar et al. 2013). Fermentation is a low-cost method of food preservation that also increases the nutritional value and sensory qualities of food, and it has long been a significant part of Indian diets (Sathe and Mandal 2016). Food's digestibility, flavor, and aroma are enhanced by biologically enriching protein-rich dietary sources, essential amino acids, vitamins, and important fatty acids during fermentation while also having health-promoting effects. The most prevalent organisms are lactic acid bacteria (LAB), which are necessary for creating and storing fermented foods high in nutrients. Additionally, fermentation increases the food's overall quality, taste, and aroma and increases the food's digestion, breaks down complex carbs into simpler ones, and increases the bioavailability of necessary amino acids, vitamins, and minerals. Fermented foods are nutraceutical agents that positively impact health (Rawat et al. 2018). A variety of LABs are generally used to ferment traditional Indian foods, including *Lactobacillus spp., Lactobacillus plantarum, L. pentosus, L. brevis, L. fermentum, L. casei, Leuconostoc mesenteroides, L. kimchi,*

✉ Priya Swaminathan
priyas@srmist.edu.in

[1] Department of Biotechnology, School of Bioengineering, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu 603 203, India

L. fallax, Weissella confusa, W. koreenis, W. cibaria, and Pediococcus, and many more which are regarded as probiotic sources. The probiotic nature of the microorganisms utilized in fermentation means that they will improve the consumers' health and are an integral component of the gut microflora. Most lactic acid bacteria are cocci or rods and are very resistant to low pH. Although more than 60 genera of lactic acid bacteria are involved in food fermentation from the genera *Lactobacillus, Lactococcus, Leuconostoc, Pediococcus, Streptococcus, Enterococcus, Weissella*, and others (Wang et al. 2021). lactic acid bacteria (LAB) are a type of bacteria that are extensively distributed in nature in habitats of dairy (processed), meat, and vegetable origin. They can be found in the gastrointestinal and urogenital systems of people and animals, soil, and water. These microorganisms are well known for their capacity to generate lactic acid as the primary byproduct of their anaerobic metabolism, in addition to a large variety of metabolites that have a favorable influence on the technical, sensory, and nutritious aspects of fermented food products. (Rodríguez et al., 2019). Because of their superior capacity for spontaneous adaptation throughout the fermentation process, LAB is the best choice for boosting fermentation in terms of product safety. Recently, the role of bacteria in maintaining the health of humans and animals has begun to take shape, especially regarding the digestive system and disease prevention. Lactic acid bacteria (LAB), which can be found in fermented foods and enhance digestive health, are known as probiotics. Probiotics are recognized as an important functional food group and are frequently used as dietary supplements that include microbes. Therefore, ingesting probiotics is beneficial for shielding the body from dangerous bacteria in the gut microbiota. Maintaining the gut microbiota's normal balance is beneficial for promoting immune and digestive health (Milanda et al. 2021). The word "probiotic" comes from Greek and means "for life." Still, through time, it has come to mean more and more things as people have become more interested in using supplements that include live bacteria and as our understanding of how those bacteria work has improved. The term was first applied to substances made by one microorganism that encouraged the growth of other microorganisms. Later, it was also applied to tissue extracts that promoted microbial growth and to supplements added to an animal feed that positively impacted animals by promoting a balance in their intestinal flora (Kechagia et al. 2013). At the level of the intestinal tract, some of the most important effects of probiotics include the following: regulating and restoring the microbiota of the gut, providing protection against pathogens, modulating the immune system, and maintaining the integrity of the intestinal barrier. Dietary supplements, food, medical device formulations, and infant formulas are some of the most common places where probiotics can be found. They have demonstrated significant results as potential treatments for various gastrointestinal illnesses (Dwivedi 2018). There are still many unanswered questions, such as safety concerns about using live microorganisms, especially in vulnerable groups, the lack of precise clinical recommendations in each specific clinical situation, the scarcity of results, particularly from clinical trials for some indications, the restricted control of probiotics, or the general paucity of conducted to evaluate the survivability of microorganisms when they are present in the intestine and the primary distinction between prebiotics and probiotics (Piqué et al. 2019). As more and more research is published that suggests potential health benefits for consumers, there is an increase in the demand for probiotic-containing foods on a global scale. Probiotics have been linked to several significant health advantages, including improvements in lactose metabolism, immune system stimulation, cancer prevention, serum cholesterol decrease, and therapy of irritable bowel syndrome-related diarrhoea (Lye et al. 2016). Consuming probiotics is, therefore, helpful for maintaining the gut microbiota's natural balance and aids in promoting immune and digestive health by protecting the body from microbial pathogens in the gut microbiota (Milanda et al. 2021). The four genera *Lactobacillus, Leuconostoc, Pediococcus, and Streptococcus* constitute the core group. Their significance is mainly related to their safe metabolism during growth, which produces organic acids and other metabolites using available sugars. The three main metabolic processes that contribute to the formation and synthesis of flavor in fermented food products are glycolysis (fermentation of sugars), lipolysis (degradation of fat), and proteolysis (degradation of proteins). A portion of the intermediate pyruvate can also be converted to diacetyl, acetoin, acetaldehyde, or acetic acid; however, lactate is the major product produced by the metabolism of carbohydrates. Proteolysis is the main metabolic process for flavor generation in fermented foods, while lipolysis is largely unaffected by LAB. Additional degradation of these molecules can produce different acids, esters, acids, alcohols, and aldehydes compounds to form particular flavors in fermented food products (Bintsis 2018). Probiotics work through many different processes, though the specifics of how they do so still need to be fully understood. The creation of short-chain fatty acids and bacteriocin, lowering of gut pH, healthy competition, activation of mucosal barrier function, and immunomodulation are a few of the processes. Numerous studies have focused on immunomodulation in particular, and there is strong evidence that probiotics have an impact on many immune system functions, including phagocytosis and IgA secretion, T-cell responses that are altered, Th1 responses that are enhanced, and Th2 responses that are diminished (Kechagia et al. 2013).

This review gives the readers an overview of the different traditional fermented foods widely used in Indian homes. The collation of these Indian fermented foods is a starting point for characterizing "**Food as a therapeutic cure for illnesses**".

Probiotics and their uses

Probiotics have a wide range of suggested positive health effects; (Parvez et al. 2006)

Nutrient synthesis and bioavailability

The amount, availability, and digestibility of various dietary nutrients have been proven to be enhanced by the action of microorganisms when preparing cultured foods or in the digestive tract. Folic acid levels in yoghurt, Bifidus milk, and kefir are increased during Lactic acid bacteria-assisted food fermentation. It is well known that Lactic acid bacteria release different enzymes and vitamins into the intestinal lumen. By reducing intestinal malabsorption symptoms and producing lactic acid, which lowers the pH of the intestinal contents and prevents the growth of invasive pathogens like *Salmonella spp*. or strains of *E. coli*, these have synergistic effects on digestion.

Effects of probiotics in the prevention and treatment of diarrhoea in human health

The prevention and treatment of acute viral and bacterial diarrhoea and the management of diarrhoea brought on by antibiotics are two areas of substantial potential value for probiotics, which are well-known for their usage in these areas. Several particular strains, including *Lactobacillus GG, Lactobacillus reuteri, Saccharomyces boulardii, Bifidobacteria spp.*, and others have been demonstrated to have considerable benefits for diarrhoea. Probiotics' impact on the immune system can help prevent or treat diarrhoea. Additionally, because pathogenic viruses and bacteria compete with probiotics for binding sites on epithelial cells, it may prevent infection.

Effect of probiotics for lactose intolerance alleviation in human health

Yogurt's lactic acid helps lactose-intolerant people by reducing their lactose intolerance symptoms. The positive impact seems to result from the lactic acid bacteria in fermented milk enhancing lactase activity in the small intestine.

Effect of probiotics against HIV and immune function in human health

Children with HIV infections commonly experience malabsorption due to potential bacterial overgrowth and have episodes of diarrhoea. Immunocompromised hosts can safely receive *L. plantarum* 299v administration, which can enhance immunological response and growth and development.

Probiotics may improve both specific and nonspecific immune responses, according to the vast majority of data from in vitro systems, animal models, and human subjects. These effects are thought to be mediated by activating macrophages, boosting cytokine levels, enhancing the activity of natural killer cells, and/or increasing immunoglobulin levels.

Effect of probiotics against allergies/eczema to ease food allergy in human health

Especially in Western nations, allergy illnesses have become more common over the past 35 to 40 years. Probiotics may have a positive impact by enhancing mucosal barrier function and immune system microbial activation, despite the lack of sufficient data on how they might affect allergic reactions. Additionally, probiotics may be useful in easing some of the symptoms of food allergies, such as those brought on by milk protein. The hydrolyzed whey formula that was given to infants reduced the symptoms of atopic dermatitis, perhaps by breaking down these proteins into smaller peptides and amino acids. It is generally accepted that native microbial communities have advantageous traits for the host and are host- and location-specific, and extremely complex in composition. Probiotics have several significant health advantages. Their potential processes are illustrated in Table 1. (Nagpal et al. 2012)

The bio-constituents of probiotics

The probiotic organisms are known to produce bioactive compounds like bacteriocins, amino acids, peptides, vitamins, short-chain fatty acids and exopolysaccharides (Chugh & Kamal, 2020).

Each of these molecules renders a health benefit to the host and allows greater synergism benefits both for the host and the organism.

The direct implications of the bioactives produced by different LAB organisms are listed in Table 2 (Chugh & Kamal, 2020) and provide the reader with a summary of the benefits incurred by probiotics bio constituents on human health.

Table 1 Probiotic bacteria's health advantages for the host and the underlying mechanisms (Nagpal et al. 2012)

Health benefits	Mechanisms involved
Facilitate lactose digestion	In the small intestine, bacterial lactase digests lactose.
Immune system modulation	Protection against infection and malignancies is strengthened on a non-specific and antigen-specific level.
Allergy	Preventing the transfer of antigen into the bloodstream.
Enhanced nutrient value	Vitamin and cofactor production
Resistance against enteric pathogens	Activity of antagonism Increased adjuvant effect Production of antibody
Gastroenteritis caused by rotavirus	IgA reaction to the virus is increased
Type I diabetes and inflammatory bowel disorders	Enhanced mucosal barrier performance
Blood lipids, heart disease	Bacterial cells assimilating cholesterol Changes in the activity of the BSH enzyme antioxidant effect
Dietary carcinogens have neutralized	The formation of butyric acid counteracts the effects of dietary carcinogens.
The proliferation of bacteria in the small intestine	The flora activity in overgrowth is influenced by lactobacilli, which reduces the formation of harmful metabolites.
Hepatic encephalopathy	Inhibition or competitive exclusion of intestinal flora that produces urease

Traditional fermented foods and beverages

Around 3500 different types of fermented meals and beverages made from milk, vegetables, or fruits are thought to be created globally. Depending on the substrate used to produce them, traditional fermented foods and drinks are a substantial source of nutrients. Protein, soluble fibre, essential fatty acids (linoleic and linolenic), minerals including iron and zinc, vitamin K, vitamin B9, vitamin B1, and vitamin B6 are all found in fermented foods made from soybean and cabbage, such as Chungkookjang, Doenjang, Meju, Gochujang, Natto, Sauerkraut, and Tempeh. Similarly, several milk-based fermented foods like Yoghurt, Kefir, and Dahi primarily comprise high-biological value proteins, calcium, and vitamins B2, B12, and B9 (Fig. 1) (Kerry et al. 2018). The essential amino acids threonine, valine, isoleucine, and leucine, as well as insoluble fiber, are present in fermented foods prepared from cereals (pozol, red yeast rice) (Fig. 2) (De Paula et al. 2015).

Cereal-based (with/without pulses) fermented foods

The main ingredients used in the preparation are Red, green, and black gramme dals which are examples of pulses. Other common foods include rice (*Oryza sativa*), ragi flour (*Eleusine coracana*), wheat flour (*Triticum spp.*), barley flour (*Hordeum vulgare*), and a variety of grains used to make flour. These grains and legumes can be employed as a source of indigestible carbohydrates to support the growth of *Lactobacilli* and *Bifidobacteria*, making them suitable substrates for creating probiotic-incorporated functional foods. They contain water-soluble fibers, such as b-glucan, arabinoxylan, galacto- and fructo-oligosaccharides, which certain LAB groups may degrade. In the large intestine, several bacterial species break down grains and legumes to produce a range of fermentation products, most notably short-chain fatty acids (SCFAs). The resulting SCFA is well known for creating an alkaline environment that promotes the development of lactic bacteria. When preparing fermented meals like Idli, Dosa, Adai dosa, Kallappam, Ambali, and Dhokla, the batter is prepared from the basic ingredients and kept overnight at room temperature for fermentation. The development of yeast and LAB can sometimes be facilitated by adding sodium bicarbonate. Idli is a naturally fermented food, and the components typically introduce both bacteria and yeasts. The most prevalent bacterium is *Leuconostoc*

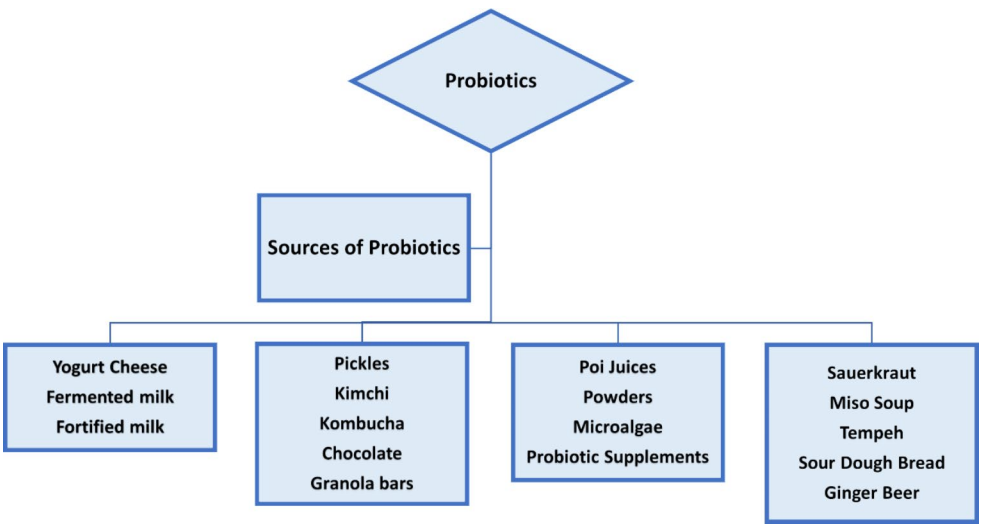

Fig. 1 Benefactions of probiotics for human health (Kerry et al. 2018)

Table 2 Bioactives produced by Probiotics

S.No.	Bioconstituents	Functions	Examples of bio constituents	References
1	Bacteriocidins	Exert their antimicrobial effects by acting as pore-forming agents or membrane perturbers or by inhibiting cellular division processes	Nisin, Lactocin, Mersacidin, Pediocin PA1, Sakicin A,	Porubsky et al. 2018
2	Amino acids and peptides	Immunomodulatory effect leading to reduction of allergic reactions	Amino acids, Phenols, Lactones, and Indoles	Seddik et al. 2017
3	Short-chain fatty acids	Make conditions unfavorable for pathogenic bacteria	Isobutyric, Isovaleric, and 2-Methyl butyric acids	Nagpal et al. 2018
4	Vitamins	growth and establishment of useful bacteria	Vitamin K	Gu et al., 2016
5	Antioxidants	Scavenging of free radicals, chelation of transition metal ions, down-regulation of pro-oxidant enzymes such as cyclooxygenase and certain cytochrome P450 isozyme	Glutathione S-transferase, Glutathione reductase, Glutathione peroxidase, Superoxide dismutase	Kim et al. 2020
6	Exopolysaccharides	production of quorum sensing molecules and growth of useful bacteria in the gut	Heteropolysaccharides containing different pentoses (D-arabinose, D-ribose, D-xylose), Hexoses (D-glucose, D-galactose, D-mannose)	Angelin et al., 2020

mesenteroides (Kumar et al. 2013). After liver transplants and in individuals who have had other high-risk procedures, the use of this strain has been shown to lower bacterial infection rates (Paula et al. 2015). By customers' rising health concerns, cereal-based fermented goods have experienced

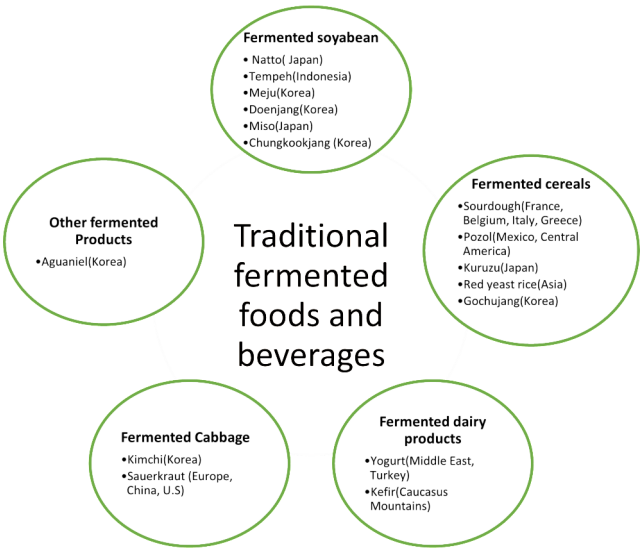

Fig. 2 Classification of conventionally fermented beverages and foods according to their foundation and nutritional content (de Paula et al. 2015)

a surge in popularity. Cereals are crucial sources of proteins, carbs, fibre, minerals, and vitamins (Tsafrakidou et al. 2020). However, compared to milk and milk products, cereals' sensory qualities and nutritional value are often low in quality or inadequate. Several factors have a role in this, including a lower protein content, a deficiency in some crucial amino acids (lysine), poor carbohydrate availability, the presence of particular antinutrients (phytic acid, tannins, and polyphenols), and the coarse texture of the grains (Tsafrakidou et al. 2020). Oats, barley, and buckwheat are a few cereal species that are frequently employed in the food business because of their beneficial chemical components. Cereal-based drinks can be found in a variety of tastes, with or without additional sweets, and they can be low-fat, vitamin- and mineral-fortified, as well as environmentally friendly. In a variety of regional fermented foods and beverages made from legumes, fruits, and vegetables (such soy sauce, pickles, or silage) or employing lactic acid bacteria (LAB), yeast, and/or fungus, cereals and pseudocereals are employed (such as beer, boza, or sake). Cereals or pseudo cereals are the base for a lot of traditional beverages. For instance, the fermentation of rice, oats, millet, rye, barley, oats, or rye results in boza. Grains or seeds without a cover are used to create cereal- and pseudo-cereal-based beverages. A similar theory underlies the manufacture of all plant-based beverages. In simple terms, the production process involves crushing the plant material, removing solid components, and then thermally treating the fluid that is produced (Fig. 3) (Ignat et al. 2020).

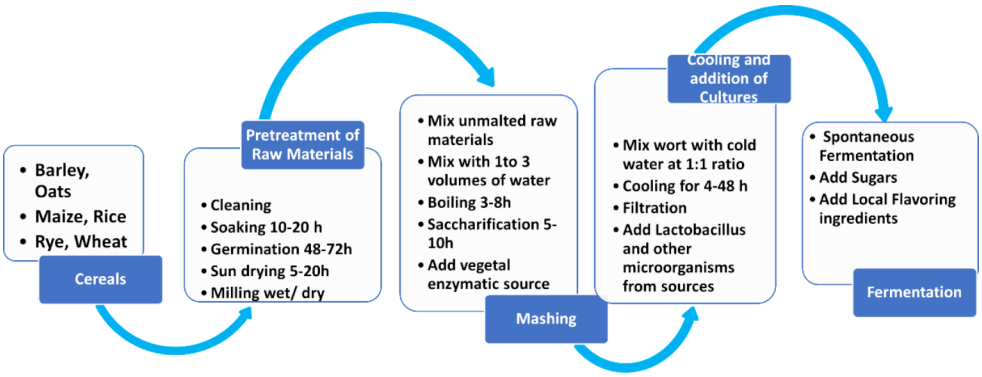

Fig. 3 Production process of cereal beverages (Ignat et al. 2020)

Cereal/pulses and buttermilk-based fermented foods

In this category of fermented foods, buttermilk provides an essential source of LAB. Even though there are few dishes in this category listed, most of India consumes these foods frequently (Kumar et al. 2013). Due to its distinctive composition and the release of highly valuable biological components from the milk fat globules that are destroyed during the churning of butter, buttermilk is of particular scientific interest. Buttermilk contains high concentrations of neutral lipids like monoglycerides, diglycerides, triglycerides, cholesterol, and esters, as well as polar lipids like phospholipids and sphingolipids, all of which are present in considerably lower amounts. Casein and whey proteins, glucose, vitamins, and minerals are all present in buttermilk in the same amounts as in skim milk, but its phospholipid content is nearly nine times higher (Liutkevičius et al. 2016). Buttermilk is a by-product of the churning process used to make butter from fermented milk or cream (Fig. 4) (Ali 2019). Additionally, buttermilk may be a by-product of churning sugar (unfermented) cream. It contains lactose and water-soluble milk salts, vitamins, proteins, and residual fat. Both conventional/traditional buttermilk and cultured buttermilk can be used to describe it. Traditional buttermilk is the liquid that remains after fermented milk or cream has been grown by lactic acid bacteria produced organically. However, cultured buttermilk is made commercially by fermenting pasteurized skim milk through the action of a mixed strain starter culture made up of *Leuconostoc mesenteroides spp. cremoris* and *Lactococcus lactis* subsp. *cremoris* and *lactis* (Gebreselassie et al. 2016). Fermented dairy products have been linked to a lower risk of metabolic diseases, immune-related illnesses, and obesity. By giving the consumer simple nutrients to metabolize and healthy bacteria, fermented meals may result in these health advantages. In addition to having fatty acids, nutrients, and mineral deposits, these products also have bioactive substances and living microbes that have the potential to modify immune responses and influence the gut microbiota's composition and function (González et al. 2019). LAB plays a part in the fermentation of milk to produce acid, which is crucial for serving as a preservative and imparting flavor to the finished goods. Additionally, they create exopolysaccharides, which are crucial for texture creation (Widyastuti et al., 2014). Indian North-Western semi-arid regions are known for their love of the local natural cereal-based beverage known as "Rabadi." Rabadi is traditionally made by combining grain flour with sour buttermilk. The mixture is given a second fermentation by being exposed to sunlight for 3–4 h before being cooked. Either the product is taken straight away or is diluted with buttermilk or milk. The technology for making rabadi is still a domestic craft, which leads to considerable variety and short shelf life (Modha and Pal 2011). It is a milk product made using pearl millet and lactic acid fermentation. Comparing pearl millet to other grains, which have a lower glycemic index, helps to control non-insulin-dependent diabetes mellitus, which is primarily brought on by a breakdown in glucose metabolism (Sathe and Mandal 2016). Milk from several indigenous types of cattle, including Churu, sheep, goats, and buffalo, (a combination of cow and yak) is used to make traditional milk-based products in Himachal Pradesh (Sathe and Mandal 2016). Most of the state's regions make Kadi/Kadu or Kheeru, which is an extremely popular cuisine. Buttermilk or chaas, spices, and a small amount of gram flour are cooked together to make it (besan). The main food, such as rice or chapati, is carried this way. To make kadi, chaach (buttermilk), besan (gram flour), and spices are simmered together (Savitri & Bhalla 2013).To make the soup known as Churpa or churpe, firstly buttermilk is cooked, after which the water is removed, and the solids are then thoroughly dried. The major bacteria are *Lactobacillus plantarum, L. curvatus, L. fermentum, L. paracasei subsp. pseudoplantarum, and Leuconostoc mesenteroides (*Sathe and Mandal 2016*)*. Wheat flour is cooked in milk with some salt to make "Nudu", a ceremonial dish eaten with ghee (Savitri & Bhalla 2013).

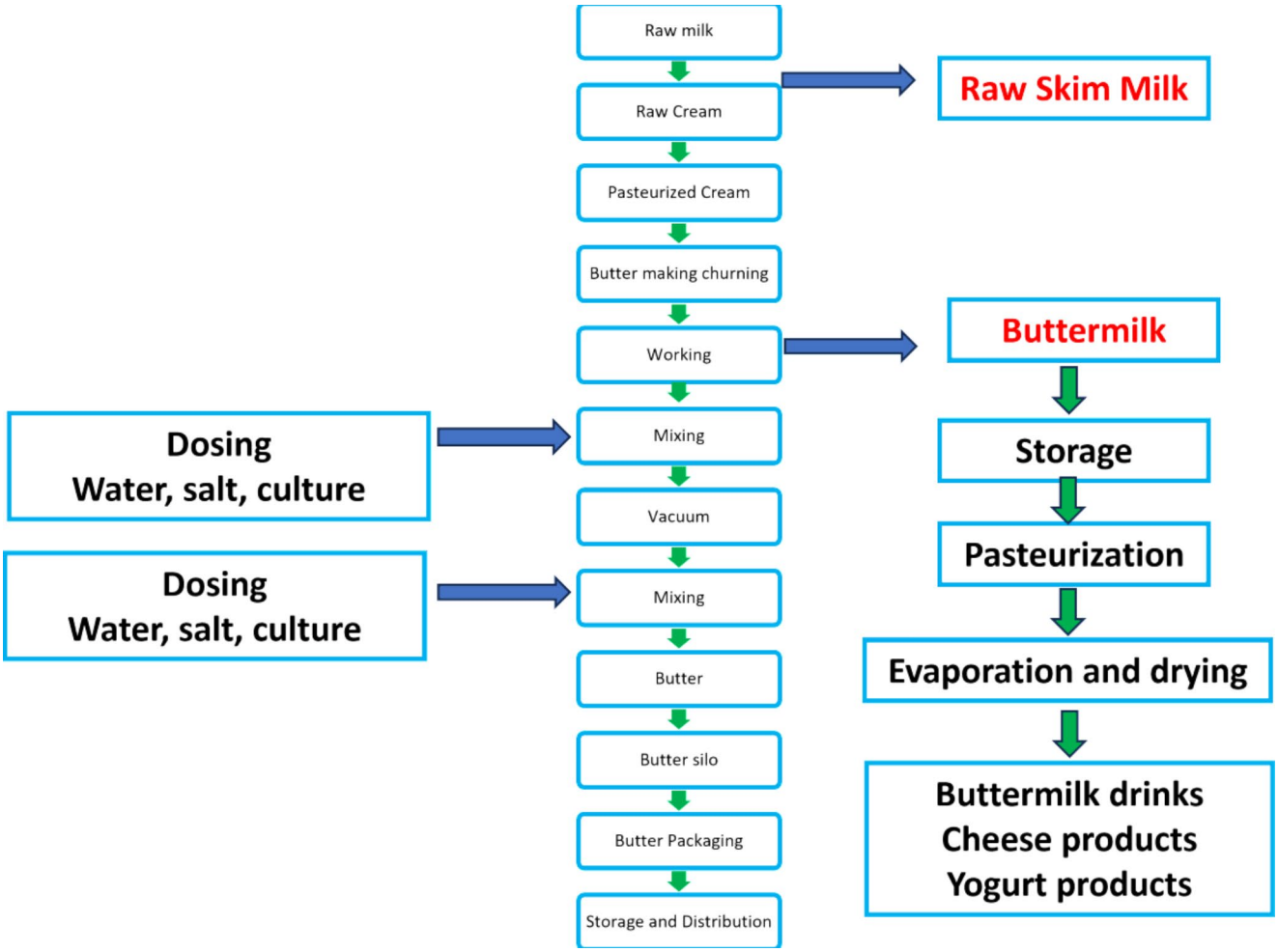

Fig. 4 Production process of buttermilk beverages (Ali 2019)

Cereal-based fermented sweets and snacks

During festivals and other important events, people typically eat these meals. Cereals most commonly used are those with wheat, rice, and barley flour. The fermented foods must include an addition of salt or sugar (Kumar et al. 2013). Rot, a sweet snack popular in Una, Hamirpur, and Bilaspur, is formed with dough made with wheat flour and jaggery. It is employed for religious or puja purposes. While fermented flour slurry is used to create oval-shaped balls known as Gulgulae (sweet fritters) in the Mandi and Kangra areas (Arya et al. 2023; Sharma 2022.) Maida (refined grain bread), dahi, and water make this sweetened fermented food. After being deep-fried in simple sugar syrup for a short while, the fermented mixture is shaped into spirals and placed in hot oil. The fermented batter contains the bacteria *Lactobacillus fermentum, L. buchneri, Streptococcus lactis, S. faecalis, and Saccharomyces cerevisiae*. The pH drops from 4.4 to 3.3, and the batter's volume increases by 9%. Fermentation causes a decrease in both free sugar and amino nitrogen (Dimidi et al. 2019). Fermented cereal sweet and snack products can be consumed by those who are lactose intolerant, allergic to milk, or who follow a low-fat or vegan diet because they are plant-based matrices. Additionally, they are thought of as innovative probiotic delivery systems and possible functional meals (Tsafrakidou et al. 2020). Several different kinds of traditional wheat-based fermented snack foods created indigenously in India, including Bhatura, Kulcha, and Nan are products manufactured from white wheat flour (wheat flour product). *Saccharomyces cerevisiae*, particularly, is used as the primary fermentation agent for those products (Gupta and Tiwari 2014).

Meat-based fermented foods

Biological deterioration of meat is very likely to occur. Among the essential phases in the conventional meat processing are drying, smoking, and fermentation (Oki et al. 2011). For longer-term storage, people in India's northeastern area ferment yak, goat, pig, fish, and crab meat.

Kargyong is a fermented, sausage-like ethnic food from yak, cattle, and pork. Three different types of Kargyong are produced and eaten: yak kargyong (made from yak meat), lang kargyong (made from beef), and faak kargyong (prepared from pork). In the Himalayas, Sikkim, Ladakh, Tibet, Arunachal Pradesh, and Bhutan are popular places for yak kargyong, a fermented sausage (Rai et al. 2010). In South-East Asia, which lacks adequate protein, fermented fish items play a significant role in the diet. It's been a long-standing practice to preserve fish using salt. Because of its accessibility and low processing cost, this preservation technique is still widely used in many impoverished nations. There is typically some degree of fermentation occurring when fatty fish are salted. Microorganisms and Autocatalytic enzymes from fish cause fish to ferment in high salt concentrations (Kumar et al. 2013).

Hentak

In Manipur, hentak is a thick paste in the shape of a ball that is made by fermenting a combination of powdered sun-dried fish (*Esomus danricus*) which are crushed to powder and aroid plant petioles (*Alocasi macrorhiza*) which are cut into pieces, washed with water and exposed to sunlight. The sliced pieces are then crushed in equal weights with fish powder to create a paste. An earthen pot develops the mixture for 7–9 days. Only after two weeks of complete fermentation, which gives the food the right texture and flavor, is it ready to be eaten (Fig. 5) (Thapa et al. 2004). *Bacillus cereus, B. subtilis, Staphylococcus aureus, Enterococcus faecium, and Candida sp*. are among the microorganisms found in Hentek.

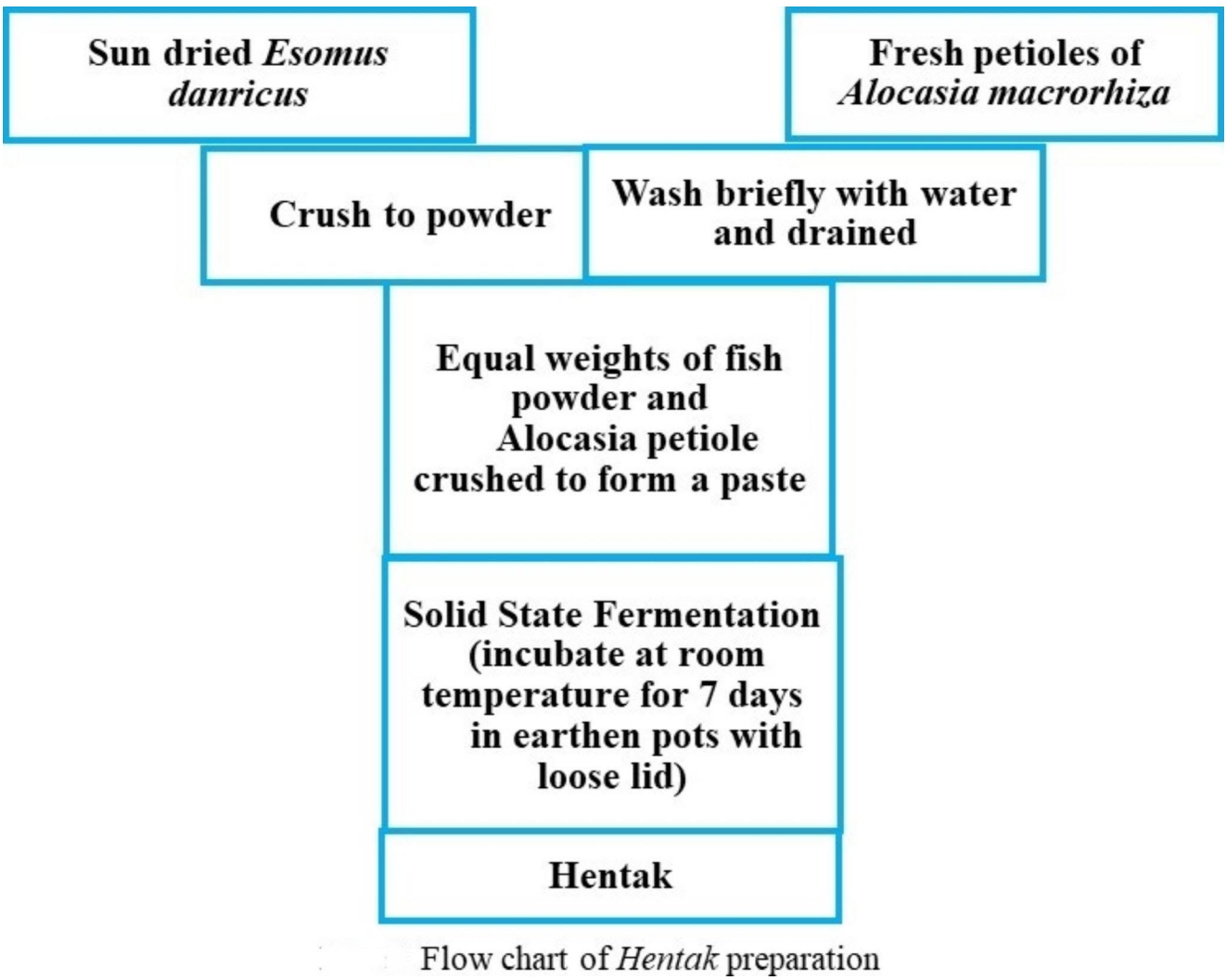

Fig. 5 Flow chart of *Hentak* preparation

Ngari

People in Manipur consume ngari, a fermented fish product, as a fundamental component of their diet in the Eastern region of India.(Devi et al. 2019). The Puntius sophore fish species' phoubu, a sun-dried, unsalted dry form, is used to make the ngari dish (Narzary et al. 2021). It is processed by being sun-dried, quickly wetted, and then removing the water for 24 h. It is then spread out, wrapped in gunny sacks, and compressed hard with the legs before being placed into an earthen pot with a 45–50 kg capacity that has been reinforced with a steel lining (internally coated with mustard oil and covered with mud). At room temperature, solid-state fermentation occurs for 4 to 12 months, with *Lactococcus plantarum, Lactobacillus plantarum, Bacillus subtilis, B.pumilus, Micrococcus sp., and Enterococcus faecium* making up the majority of the microflora (Fig. 6) (Thapa et al. 2004).

The Khasi people of Meghalaya are the original inhabitants of this. It is produced at the home and village levels and is mostly sold at the monthly markets around the area (Agrahar-Murugkar and Subbulakshmi 2006). Lactobacillus has been found among the microorganisms in Tungtap and *Lactobacillus coriniformis, L. lactis, L. fructosus, Bacillus cereus, B. subtilis, Candida sp., and Saccharomycopsis sp* are the microbes identified (Thapa et al. 2004). In an earthen pot, the fish is combined with salt and allowed to ferment for four to seven days. It is eaten as a pickle (Thapa et al. 2004). Protein, amino acids, and minerals are all abundant in Ngari. Probiotic, antioxidant, and antihypertensive qualities may be present in the product. However, if the product is not processed hygienically, there is a risk of cross-contamination, which could result in foodborne illness.

Pulse-based fermented foods

An annual legume crop known as a pulse produces 1 to 12 seeds in a pod that can vary in size, shape, and color. For this kind of fermented food, the most widely consumed pulses are black gram, soybean, Bengal gram, red gram, and green gram. In North-East India, soybean is a summer leguminous crop that is cultivated in upland terraces under rain-fed circumstances as a solitary crop or in combination with wheat and rice up to a height of 1500 m; due to the presence of Mongolians, eating of various soybean recipes is popular. Food scientists have identified several Indian fermented foods made from soybeans (Tamang 2015). In comparison to animal and dairy products, fermented soybean foods is a more affordable component of plant protein that is readily available to the North Eastern region's rural poor.

Kinema

Kinema is a fermented food from whole soybean seeds in the Eastern Himalayas region. It has a sticky texture, a grey-tan color, and a flavorful flavor. It is made by the naturally occurring fermentation of certain types of bacteria namely *Bacillus subtilis* and *Enterococccus faecium.* Additionally, fungal species have been isolated from commercially available kinema namely *Candida parapsilosis and Geotrichum candidum* (Kharnaior and Tamang 2022). Kinema is a functional food since it includes several properties that are good for your health, such as antioxidants, digestible protein,

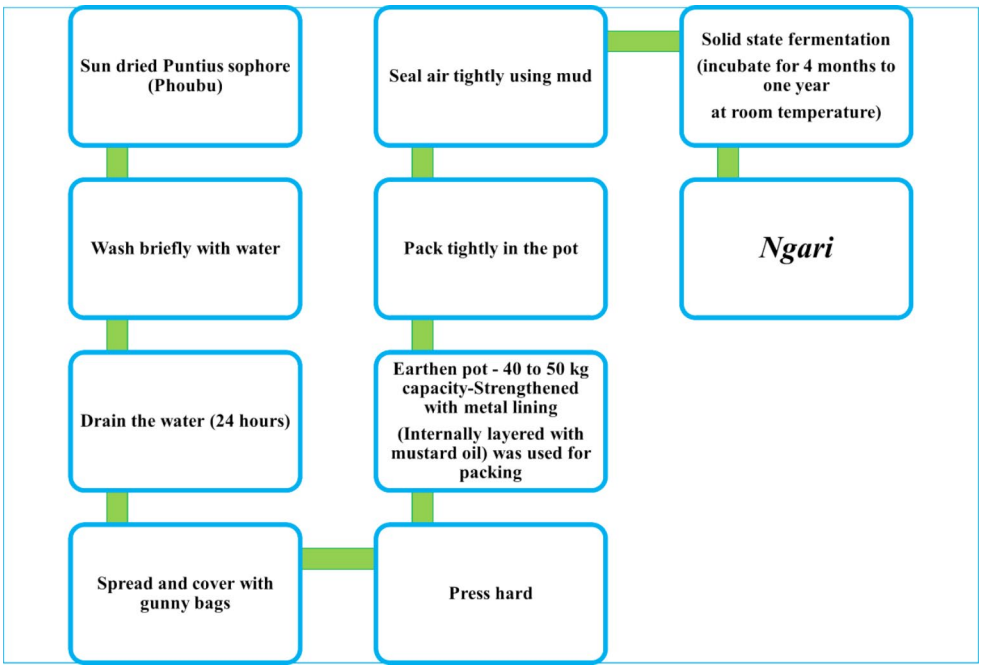

Fig. 6 Flow chart of *Ngari* preparation

vital amino acids, vitamin B complex, and reduced cholesterol levels (Tamang 2015).

Soybeans are boiled to make them softer as part of the kinema preparation process. Once the excess water has been drained, the cotyledons are gently ground open in a wooden mortar and pestle. To promote rapid fermentation, the surface area is increased. A small amount of firewood ash—about 1%—is added to maintain the pH level. Then, soybean grits are placed in a bamboo basket lined with fresh fern. After that, a jute bag is placed over the basket, and it is allowed to spontaneously ferment at room temperature (which in Sikkim is between 20 and 350°C). The entire thing is placed over an earthen boiler and left to sit for one to two days (Fig. 7) (Tamang 2015). When the fermentation is finished, a white viscous mass appears on the soybeans as well as an ammonia-like odor is released. It must be stored for 5–7 days in the winter and 2–3 days in the summer. (Tamang 2015).

Hawaijar

In the Western region of India, it is a daily source of protein that is made from alkaline-fermented soybeans. Between 26% and 27% of its composition are soluble proteins. It lacks salt and has a distinctive taste and stickiness (Ray and Didier 2014). The primary microbe behind the manufacturing of this product is *Bacillus spp.* (Gopikrishna et al. 2021). The native food frequently includes Hawaijar as a low-cost source of high-protein food. Numerous studies have noted its numerous health advantages; their anti-cancer, anti-osteoporosis, and hypocholesterolemic properties are well established (Keishing 2013). For preparation, soybean seeds are steeped in water for an entire night, then thoroughly rinsed with water before being cooked to soften the seeds. After thoroughly cleaning, they are placed in a small lidded bamboo basket called a "Lubak" and packed tightly. Banana plant (*Musa sp.)* or fig plant (*Ficus hispida*) leaves are piled at the base of the basket. After that, a jute cloth is placed over the basket, left in the sunlight, adjacent to a stove, or submerged in a paddy. This aids in sustaining the ideal temperature (over 40°C) needed for the fermentation. After 3–5 days, the fermented product is suitable for consumption. The finished product has a brown color, a sticky texture, and an ammonia-like odor. After that, banana leaves are used to wrap the fermented product for storage (Fig. 8) (Das et al. 2016; Keishing 2013).

Vegetable and fruit based fermented foods

Since it can lengthen the fermented product's shelf life and improve the microbiological quality, palatability, acceptance, nutritional value, and palatability. A crucial technology is the fermentation of vegetable lactic acid, which utilizes preservation techniques while creating finished and semi-finished goods. (Kingston et al. 2010). In India's eastern Himalayan areas, various fermenting vegetable products are made to bioprocess perishable vegetables for preservation and future use (Dallal et al. 2017). The leading LAB involved in ethnic fermented vegetables includes *Lactobacillus brevis, L. plantarum, Pediococcus pentosaceus, P. acidilactici, and Leuconostoc fallax*. Some LAB strains may also possess beneficial and protective traits that make them intriguing candidates to be used as starter culture(s) for controlled and optimum fermentation of vegetable products

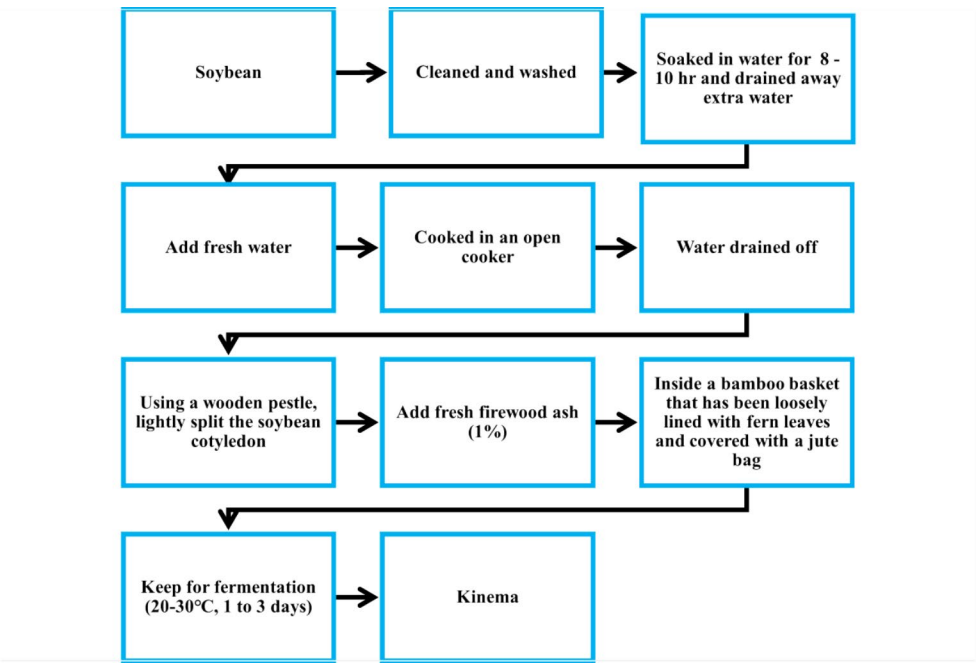

Fig. 7 Flow chart of Kinema preparation

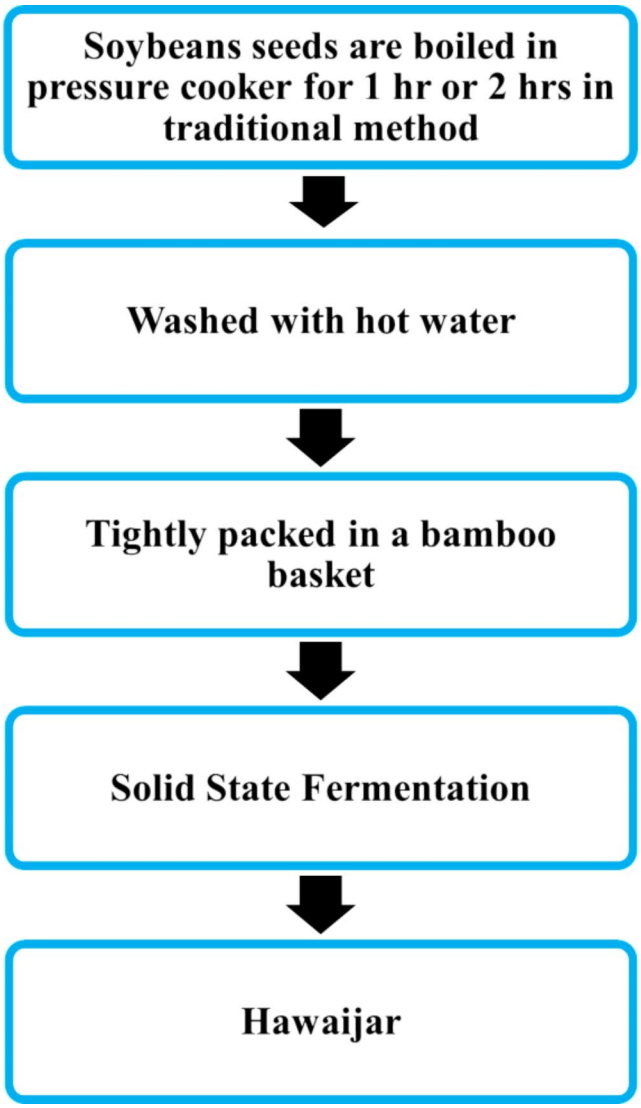

Fig. 8 Flow chart of Hawaijar preparation

(Szutowska 2020). Due to their high levels of lactic acids, ascorbic acid, carotene, and dietary fiber, the fermented leafy vegetable product Gundruk and the fermented radish tap-root (Sinki) both possess anti-carcinogenic properties.

Importance of bioactive compounds from vegetables and fruits in the diet of human health

Bioactive compounds which are present in vegetables and fruits are flavonoids, anthocyanins, tannins, carotenoids, plant sterols, betalains and glucosinolates. These compounds have antioxidant, anti-inflammatory and anti-carcinogenic properties; and are helpful against various diseases and metabolic disorders. These effects make them an ideal for the development of new functional food with potential properties.

Flavonoids are rich in fruits and vegetables, and major sources include berries, grapefruit, carrot, apple, onion, broccoli, cabbage, tomato, lemon, buckwheat and legumes (Rees et al. 2018).

Effect of bioactive compounds on chronic diseases

The easiest way to prevent and control cancer risk is to consume enough fruits and vegetables because they are high in biological activity. The study proved the relation between consumption of carotenoid-rich fruits and vegetables and decreased risk of cancer, mainly lung cancer, prostate cancer, breast cancer, and head and neck cancers. Consumption of high fruits and vegetables in diet could reduce the risk of head and neck cancers by 50% (Foo et al. 2017).

Owing to their antioxidant, anti-inflammatory and immunoprotective properties, the bioactive compounds found in fruits and vegetables can defend against several diseases and metabolic disorders such as diabetes mellitus, cardiovascular diseases, and Cancer (van Dam et al. 2013).

Gundruk

The Nepali inhabitants of the Himalayan region are known for producing gundruk, a fermented vegetable product. Winter, from October through December, when perishable green vegetables are in abundance, is when it is most frequently made. The majority of these vegetables, which include radish (*R. sativus)*, rayo-saag *(B. rapa)*, cauliflower (*B. oleracea*), mustard (*B. juncea*), and a few other locally grown vegetables. (Tamang 2022). Fresh leaves of the chosen vegetables must first wilt and be sliced with a sickle or knife to begin the fermentation process. After lightly crushing them, these are then put into an earthen pot. The organic fermentation procedure is permitted for 7 to 10 days at room temperature once the container has been tightly sealed against ventilation. The leaves acquire a mildly acidic taste following the incubation period, signifying that fermentation has finished. After that, the Gundruk is removed and allowed to dry in the sun for three to four days, which aids in storage (Fig. 9) (Yan et al. 2008).

Sinki

A traditional food called Sinki is prepared from fermented radish tap roots, is typically made through pit fermentation, a special method of food biopreservation used in the Sikkim Himalayas of Western region. It is cooked in the winter when the air is the least humid and when there and is an abundant supply of this vegetable. *Lactobacillus plantarum, L. brevis, and L. fermentum* have been named as the bacteria responsible for their fermentation (Tamang et al. 2016). A

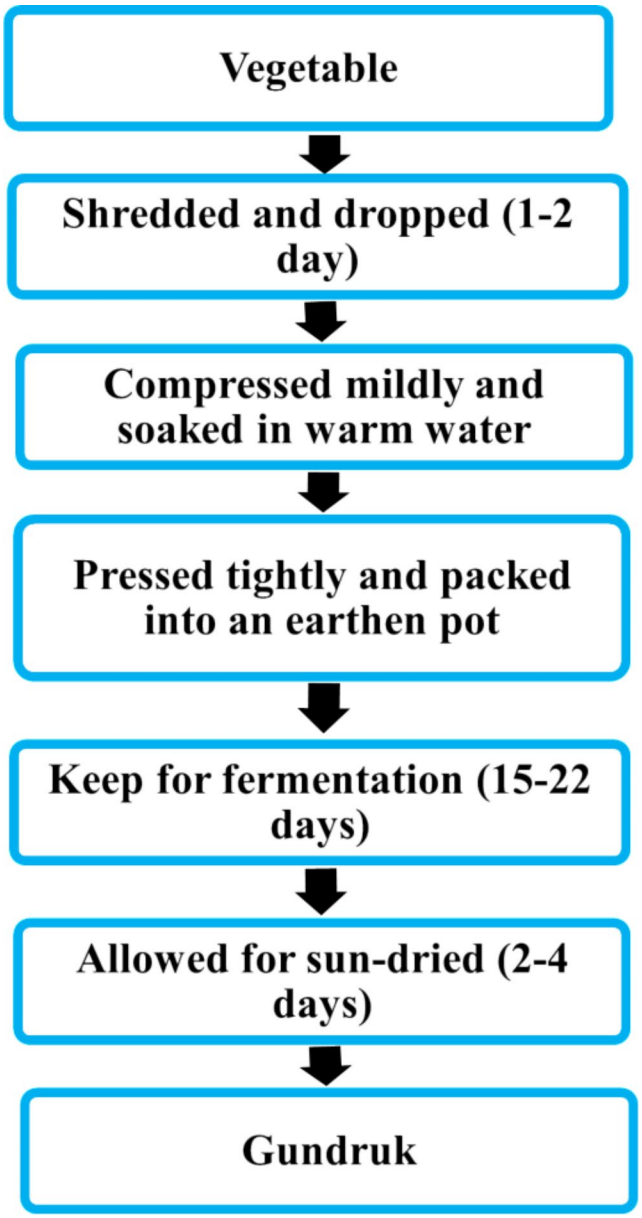

Fig. 9 Flow chart of Gundruk preparation

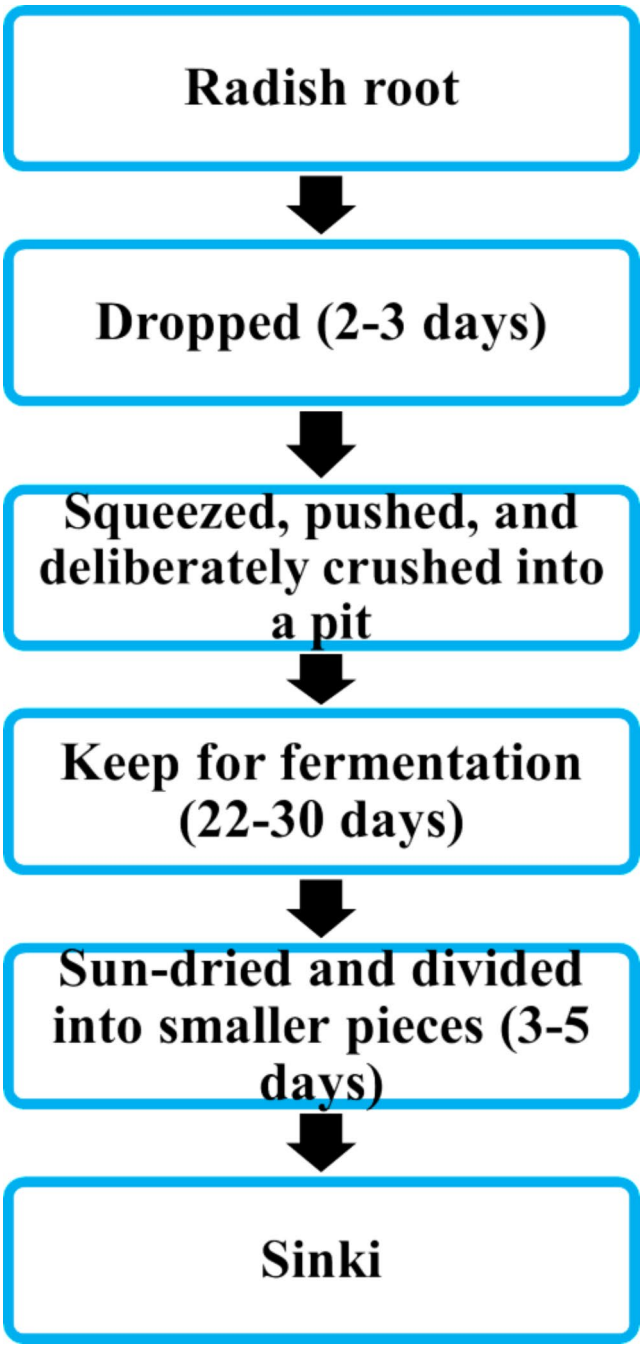

Fig. 10 Flow chart of Sinki preparation

well with a diameter of 2 to 3 feet was excavated in an arid area to produce sinki. The pit is cleansed, mud-plastered, and heated with fire. The pit is then lined with paddy straw and bamboo sheaths after the ashes have been removed. The radish's taproots are wilted for two to three days before being crushed, soaked in warm water, compacted, and then tightly packed into the pit. Then dried leaves are placed on top, and heavy objects like stones or planks are used to weigh them down. The mud is placed on top of the pit and allowed to ferment there for 22–30 days. Fresh sinki is withdrawn from the fermentation process, peeled into smaller parts, sun-dried for two to three days, and then preserved at room temperature for consumption later (Fig. 10) (Yan et al. 2008).

Both Gundruk, a fermented leafy vegetable product from the Himalayas, and Sinki, a fermented radish tap-root, contain significant levels of lactic acid, ascorbic acid, carotene, and dietary fiber, all of which have anti-carcinogenic properties. Sinki is claimed to assist in treating diarrhoea and stomach problems, according to the study, and gundruk is said to help women who are lactating produce more milk

since it is high in lactic acid. Gundruk is also said to be helpful for indigestion. Furthermore, lactic acid strengthens the immune system and relieves diarrhoea (Khadka and Lama 2020).

Conclusion

Indian traditional fermented foods are a wide variety because local health foods have changed over time in response to local climatic conditions, cultural traditions, and agricultural techniques. In the era where 'Food is considered as medicine', the lactic acid-producing bacteria found in these fermented foods have been shown to positively affect the host; in a different sense, they have probiotic qualities. These fermented foods have several processing, production, and health advantages. Additionally, some foods have gained popularity in specific areas based on the general health of the populace, such as lactose intolerance, which promotes the consumption of lactose-free dairy delights. Since some traditional fermented foods are not geographically widespread, research into these items is necessary to create them with specific microflora while preserving their nutritional value. Indian fermented foods can elevate the ability to make food tasty, relieve diarrhoea, constipation, stomach pain, and gas, as well as prevent plaque, infection, cancer and neurological diseases. This paperwork is one of a kind - to be a one-stop data for different historically beneficial probiotic foods of India. This paper wishes to trigger more research into these traditional foods. Consequently, there is a need to isolate more probiotic bacteria from these rich foods and conduct in-depth research on their probiotic qualities.

The science of fermentation is evolving quickly as the -omics technology advances. Thus this has enabled microbiome assessments and metabolomic analysis in micro-ecosystems. These technologies will allow customized products with proper labelling and contraindications that will help the consumer benefit in health and alleviate disease.

Acknowledgements We, the authors, thank the Biotechnology Department of SRMIST for all its support and encouragement to do this work.

Declarations

The authors declare that the article has not been submitted elsewhere or not under any other considerations.

Conflict of interest The authors declare that they have no conflict of interest.

References

Agrahar-Murugkar D, Subbulakshmi G (2006) Preparation Techniques and Nutritive Value of Fermented Foods from the Khasi Tribes of Meghalaya. Ecol Food Nutr 45(1):27–38. https://doi.org/10.1080/03670240500408336

Ali AH (2019) Current knowledge of buttermilk: composition, applications in the food industry, nutritional and beneficial health characteristics. Int J Dairy Technol 72(2):169–182. https://doi.org/10.1111/1471-0307.12572

Angelin J, Kavitha M (2020) Exopolysaccharides from probiotic bacteria and their health potential. Int J Biol Macromol 162:853–865. https://doi.org/10.1016/j.ijbiomac.2020.06.190

Arya A, Kumar S, Paul R, Suryavanshi A, Kain D, Sahoo RN (2023) Ethnopharmacological survey of indigenous medicinal plants of Palampur, Himachal Pradesh in north-western Himalaya, India. Adv Tradit 23:169–212. https://doi.org/10.1007/s13596-021-00607-1

Bhalla STC (2013) Characterization of bhatooru, a traditional fermented food of Himachal Pradesh: microbiological and biochemical aspects. 3 Biotech 3(3):247–254. https://doi.org/10.1007/s13205-012-0092-2

Bintsis T (2018) Lactic acid bacteria: their applications in foods. J Bacteriol Mycol 5(2):1065. https://doi.org/10.15406/jbmoa.2018.06.00182

Chugh B, Kamal-Eldin A (2020) Bioactive compounds produced by probiotics in food products. Curr Opin Food Sci 32:76–82. https://doi.org/10.1016/j.cofs.2020.02.003

Dallal SMM, Zamaniahari S, Davoodabadi A, Hosseini M, Rajabi Z (2017) Identification and characterization of probiotic lactic acid bacteria isolated from traditional persian pickled vegetables. GMS HIC 12:Doc15. https://doi.org/10.3205/dgkh000300

Das G, Patra JK, Singdevsachan SK, Gouda S, Shin HS (2016) Diversity of traditional and fermented foods of the seven sister states of India and their nutritional and nutraceutical potential: a review. Front Life Sci 9(4):292–312. https://doi.org/10.1080/21553769.2016.1249032

de Paula AT, Jeronymo-Ceneviva AB, Silva LF, Todorov SD, Mello Franco BD, Penna ALB (2015) Leuconostoc mesenteroides SJRP55: a potential probiotic strain isolated from brazilian water buffalo mozzarella cheese. Ann Microbiol 65(2):899–910. https://doi.org/10.1007/s13213-014-0933-9

Devi HS, Sharma D, Sangita Senapati S (2019) A study on indigenous fermented foods of Manipur, India. Int J Curr Microbiol Appl Sci 8(05):754–757. https://doi.org/10.20546/ijcmas.2019.805.088

Dimidi E, Cox SR, Rossi M, Whelan K (2019) Fermented Foods: definitions and characteristics, impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease. Nutr J 11(8). https://doi.org/10.3390/nu11081806

Dwivedi M (2018) Role of probiotics in immune regulation. Acta Sci Microbiol 1:29–30. https://doi.org/10.31080/ASMI.2018.01.0007

Foo YZ, Rhodes G, Simmons LW (2017) The carotenoid beta-carotene enhances facial color, attractiveness and perceived health, but not actual health, in humans. Behav Ecol 28(2):570–578. https://doi.org/10.1093/beheco/arw188

Gebreselassie N, Abrahamsen RK, Beyene F, Abay F, Narvhus JA (2016) Chemical composition of naturally fermented buttermilk. Int J Dairy Technol 69(2):200–208. https://doi.org/10.1111/1471-0307.12236

González S, Fernández-Navarro T, Arboleya S, de Los Reyes-Gavilán CG, Salazar N, Gueimonde M (2019) Fermented dairy Foods: impact on intestinal microbiota and health-linked biomarkers. Front Microbiol 10:1046. https://doi.org/10.3389/fmicb.2019.01046

Gopikrishna T, Suresh Kumar HK, Perumal K, Elangovan E (2021) Impact of *Bacillus* in fermented soybean foods on human health. Ann Microbiol 71(1):30. https://doi.org/10.1186/s13213-021-01641-9

Gu Q, Li P (2016) Biosynthesis of vitamins by probiotic bacteria. In: Rao V, Rao L. Probiotics and prebiotics in human nutrition and health, 135–148. https://doi.org/10.5772/63117

Gupta A, Tiwari SK (2014) Probiotic potential of Lactobacillus plantarum LD1 isolated from batter of Dosa, a south indian fermented food. Probiotics Antimicrob Proteins 6(2):73–81. https://doi.org/10.1007/s12602-014-9158-2

Ignat MV, Salanță LC, Pop OL, Pop CR, Tofană M, Mudura E, Coldea TE, Borșa A, Pasqualone A (2020) Current functionality and potential improvements of non-alcoholic fermented cereal beverages. Foods 9(8):1031. https://doi.org/10.3390/foods9081031

Kechagia M, Basoulis D, Konstantopoulou S, Dimitriadi D, Gyftopoulou K, Skarmoutsou N, Fakiri EM (2013) Health benefits of Probiotics: a review. ISRN Nutr 2013:1–7. https://doi.org/10.5402/2013/481651

Keishing SK (2013) Hawaijar –A Fermented Soya of Manipur, India. Rev IOSR-JESTFT 4(2):29–33. https://doi.org/10.9790/2402-0422933

Kerry RG, Patra JK, Gouda S, Park Y, Shin HS, Das G (2018) Benefaction of probiotics for human health: a review. J Food Drug Anal 26,(3):927–939. https://doi.org/10.1016/j.jfda.2018.01.002

Khadka DB, Lama JP (2020) Traditional fermented food of Nepal and their nutritional and nutraceutical potential. Nutritional and Health Aspects of Food in South Asian Countries. Academic Press, pp 165–194. https://doi.org/10.1016/B978-0-12-820011-7.00022-8

Kharnaior P, Tamang JP (2022) Metagenomic-metabolomic mining of a naturally fermented soybean food of the Eastern Himalayas. Front Microbiol 13:868383. https://doi.org/10.3389/fmicb.2022.868383

Kim H, Kim JS, Kim Y, Jeong Y, Kim JE, Paek NS, Kang CH (2020) Antioxidant and probiotic properties of Lactobacilli and Bifidobacteria of human origins. Biotechnol Bioproc E 25:421–430. https://doi.org/10.1007/s12257-020-0147-x

Kingston JJ, Radhika M, Roshini PT, Raksha MA, Murali HS, Batra HV (2010) Molecular characterization of lactic acid bacteria recovered from natural fermentation of beetroot and carrot Kanji. Indian J Microbiol 50(3):292–298. https://doi.org/10.1007/s12088-010-0022-0

Kumar RS, Kanmani P, Yuvaraj N, Paari KA, Pattukumar V, Arul V (2013) Traditional indian fermented foods: a rich source of lactic acid bacteria. Int J Food Sci Nutr 644:415–428. https://doi.org/10.3109/09637486.2012.746288

Liutkevičius A, Speičienė V, Alenčikienė G, Mieželienė AL, Narkevičius R, Kaminskas A, Abaravičius JA, Vitkus D, Jablonskienė V, Sekmokienė D (2016) Fermented buttermilk-based beverage: impact on young volunteers' health parameters. Czech J Food Sci 34(2):143–148. https://doi.org/10.17221/344/2015-CJFS

Lye HS, Barat B, Kampar Balakrishnan K, Thiagarajah K, Ismail NIM, Ooi SY (2016) Beneficial Properties of Probiotics. Trop Life Sci Res 27(2):73–90. https://doi.org/10.21315/tlsr2016.27.2.6

Milanda T, Soemarie Y, Barliana M (2021) Fermented foods as probiotics: a review. J Adv Pharm Technol Res 12(4):335. https://doi.org/10.4103/japtr.japtr_116_21

Modha H, Pal D (2011) Optimization of Rabadi-like fermented milk beverage using pearl millet. J Food Sci Technol 48(2):190–196. https://doi.org/10.1007/s13197-010-0146-6

Nagpal R, Kumar A, Kumar M, Behare PV, Jain S, Yadav H (2012) Probiotics, their health benefits and applications for developing healthier foods: a review. FEMS Microbiol Lett 334(1):1–15. https://doi.org/10.1111/j.1574-6968.2012.02593.x

Nagpal R, Wang S, Ahmadi S, Hayes J, Gagliano J, Subashchandrabose S, Yadav H (2018) Human-origin probiotic cocktail increases short-chain fatty acid production via modulation of miceand human gut microbiome. Sci Rep 8:12649. https://doi.org/10.1038/s41598-018-30114-4

Narzary Y, Das S, Goyal AK, Lam SS, Sarma H, Sharma D (2021) Fermented fish products in South and Southeast Asian cuisine: indigenous technology processes, nutrient composition, and cultural significance. J Ethn Foods 8(1). https://doi.org/10.1186/s42779-021-00109-0

Oki K, Rai AK, Sato S, Watanabe K, Tamang JP (2011) Lactic acid bacteria isolated from ethnic preserved meat products of the western Himalayas. Food Microbio 28(7):1308–1315. https://doi.org/10.1016/j.fm.2011.06.001

Parvez S, Malik KA, Ah Kang S, Kim HY (2006) Probiotics and their fermented food products are beneficial for health. J Appl Microbiol 100(6):1171–1185. https://doi.org/10.1111/j.1365-2672.2006.02963.x

Piqué N, Berlanga M, Miñana-Galbis D (2019) Health benefits of heat-killed (Tyndallized) Probiotics: an overview. Int J Mol Sci 20(10):2534. https://doi.org/10.3390/ijms20102534

Porubsky CF, Glass AB, Comeau V, Buckley C, Goodman MB, Kober MM (2018) The role of Probiotics in Acne and Rosacea. In: Enany S Probiotics: Current Knowledge and Future Prospects Intechopen. https://doi.org/10.5772/INTECHOPEN.79044

Rai AK, Tamang JP, Palni U (2010) Microbiological studies of ethnic meat products of the Eastern Himalayas. Meat Sci 85(3):560–567. https://doi.org/10.1016/j.meatsci.2010.03.006

Rawat K, Kumari A, Kumar S, Kumar R, Gehlot R (2018) Traditional fermented products of India. Int J Curr Microbiol Appl Sci 7(4):1873–1883. https://doi.org/10.20546/ijcmas.2018.704.214

Ray RC, Didier M (2014) Microorganisms and fermentation of Traditional Foods. CRC Press, Boca Raton. https://doi.org/10.1201/b17307

Rees A, Dodd GF, Spencer JPE (2018) The Effects of Flavonoids on Cardiovascular Health: a review of human intervention trials and implications for cerebrovascular function. Nutr 10(12):1852. https://doi.org/10.3390/nu10121852

Ruiz Rodríguez LG, Mohamed F, Bleckwedel J, Medina R, De Vuyst L, Hebert EM, Mozzi F (2019) Diversity and functional Properties of lactic acid Bacteria isolated from wild fruits flowers Present in Northern Argentina. Front Microbiol 10:1091. https://doi.org/10.3389/fmicb.2019.01091

Sathe GB, Mandal S (2016) Fermented products of India and its implication: a review. J dairy 35(1). https://doi.org/10.18805/ajdfr.v35i1.9244

Seddik HA, Bendali F, Gancel F, Fliss I, Spano G, Drider D (2017) Lactobacillus plantarum and its probiotic and food potentialities. Probiotics Antimicrob Proteins 9:111–122. https://doi.org/10.1007/s12602-017-9264-z

Sharma R (2022) Legume Based Traditional foods of Palampur region of Himachal Pradesh and their nutritional composition. Preprint Res square https://doi. https://doi.org/10.21203/rs.3.rs-1733612/v1

Szutowska J (2020) Functional properties of lactic acid bacteria in fermented fruit and vegetable juices: a systematic literature review. Eur Food Res Technol 246(3):357–372. https://doi.org/10.1007/s00217-019-03425-7

Tamang JP (2015) Naturally fermented ethnic soybean foods of India. J Ethn Foods 2(1):8–17. https://doi.org/10.1016/j.jef.2015.02.003

Tamang JP (2022) Ethno-microbiology of ethnic indian fermented foods and alcoholic beverages. J Appl Microbiol 133(1):145–161. https://doi.org/10.1111/jam.15382

Tamang JP, Watanabe K, Holzapfel WH (2016) Review: diversity of Microorganisms in Global Fermented Foods and Beverages. Front Microbiol 7:377. https://doi.org/10.3389/fmicb.2016.00377

Thapa N, Pal J, Tamang JP (2004) Microbial Diversity in Ngari, Hentak and Tungtap, fermented Fish Products of North-East

India. World J Microbiol Biotechnol 20(6):599–607. https://doi.org/10.1023/b:wibi.0000043171.91027.7e

Tsafrakidou P, Michaelidou AM, Biliaderis CG (2020) Fermented cereal-based Products: nutritional aspects, possible impact on Gut Microbiota and Health Implications. Foods 9(6):734. https://doi.org/10.3390/foods9060734

van Dam RM, Naidoo N, Landberg R (2013) Dietary flavonoids and the development of type 2 diabetes and cardiovascular diseases: review of recent findings. Curr Opin Lipidol 24(1):25–33. https://doi.org/10.1097/MOL.0b013e32835bcdff

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 the Food Industry. Front Bioeng Biotechnol 9:612285. https://doi.org/10.3389/fbioe.2021.612285

Widyastuti Y, Rohmatussolihat Febrisiantosa A (2014) The role of lactic acid bacteria in milk fermentation. Food Sci Nutr 5(04):435–442. https://doi.org/10.4236/fns.2014.54051

Yan PM, Xue WT, Tan SS, Zhang H, Chang XH (2008) Effect of inoculating lactic acid bacteria starter cultures on the nitrite concentration of fermenting chinese paocai. Food Control 19(1):50–55. https://doi.org/10.1016/j.foodcont.2007.02.008