Chapter 2
Sources and Selection Criteria of Probiotics

Sukhminderjit Kaur, Rajinder Kaur, Nitu Rani, Swati Sharma, and Mahavir Joshi

Abstract Probiotics are the living microbial consortia that confer the health benefits to humans when incorporated in diet in adequate amount. These bacteria, referred to as "good bacteria," are present in human gut through various dietary sources and exhibit anti-inflammatory, anti-cancerous, immunity enhancing benefits. With enhancing knowledge about the field of probiotics, its potential sources are also been scrutinized so that cheap and easy availability of the probiotic product is produced. Traditionally fermented dairy products, fermented vegetables, fermented soy products are available throughout the world with different names. These traditional fermented products are conferring many health benefits owing to the presence of probiotic bacteria present in it. Presently, dairy companies are active producers of the probiotic rich yogurts, buttermilks, and tofu. These products are artificially supplemented with probiotics and are easy available options for the consumers. Also, many pharmaceutical companies are providing active probiotic supplements in the form of capsules and sachets which are recommended to patients with diarrhea, various infections, and allergies. However, with the fast emergence of the probiotic industry, it is imperative that the guidelines for bacteria to be termed as probiotic should be well defined so that the users can get a product with claimed benefits. These characteristics will ensure that the consumer is getting a standardized product with ensured efficiency.

Keywords Probiotics · Good bacteria · Health benefits · Sources · Probiotic supplements

S. Kaur (✉) · R. Kaur · S. Sharma · M. Joshi
University Institute of Biotechnology, Chandigarh University Mohali, Mohali, Punjab, India
e-mail: sukhminderjit.uibt@cumail.in

N. Rani
University Institute of Agricultural Sciences, Chandigarh University, Mohali, Punjab, India

G. Goel, A. Kumar (eds.), *Advances in Probiotics for Sustainable Food and Medicine*, Microorganisms for Sustainability 21,
https://doi.org/10.1007/978-981-15-6795-7_2

2.1 Introduction

Living microorganisms that can be incorporated into foods, dietary supplements, functional foods, and drugs in adequate amount for conferring health benefits to the host are called as probiotics. These live microorganisms provide health benefits to the host animal beyond their inherent nutrition. Earliest idea of the beneficial effects of bacteria to human health was provided by Nobel Laureate Metchnikoff, who tried to find out the possible effects of microbes on human health. He reported that the auto-intoxification caused by the intestinal microbes can be prevented by the intake of lactic acid producing bacteria present in yogurt. In his book, "The prolongation of life; optimistic studies," he suggested that the growth of proteolytic microbes can be prevented by intake of dairy products because they lower the colon pH by breaking lactose. He supported his hypothesis by providing the fact that villagers in Bulgaria who consumed fermented sour milk had longer life expectancy compared to general population. A pediatrician, Henry Tissier, from the Pasteur Institute reported the discovery of *Bifidobacterium* spp. in the gut of breast-fed infant. He reported that the gastroenteritis could be prevented by *Bifidobacterium* spp. Stamen Grigorov in 1905 identified Lactobacilli spp. in the starter culture of fermented Bulgarian diary product. Years later, in 1917, a German professor, Alfred Nissle, isolated non-pathogenic *E. coli* from the feces of two soldiers not affected by the epidemic of shigellosis. He reported that presence of non-pathogenic *E. coli* in these soldiers prevented the adherence of pathogenic bacteria by the secretion of bacteriocins (Sonnenborn and Schulze 2009).

Earlier the term probiotics was limited to the Lactobacillus and Bifidobacterium spp. With identification of new bacteria and increase in research in probiotics, bacterial spp. belonging to genera *Streptococcus, Leuconostoc, Pediococcus, Propionibacterium,* and *Enterococcus* are being used as probiotics. Yeast and molds like *Aspergillus niger, A. oryzae, Candida pintolopesii*, *Saccharomyces boulardii,* and *S. cerevisiae* are also regarded as probiotics.

Human gut is inhibited by both good (probiotics) and bad bacteria. Good bacteria confirm various health benefits to humans. They improve food digestion by fermenting the carbohydrates into simpler structures, producing vitamin-K, and compensating various deficiencies in the body. Probiotics play an important role in proliferation of epithelial cells, development of immune system (Cammarota et al. 2009). Bad bacteria, usually present, but are apparently non-existing, because they are under the pressure of good bacteria. Good bacteria are able to compete with these bad bacteria and prevent their colonization. In the conditions of stress, high alcohol consumption, high fats, genetic disorders, high chlorine and fluoride concentration in diet can cause decrease in the number of good bacteria and bad bacteria will take their position and produce toxins deteriorating human health. In that case, probiotics need to be administrated in higher dosage (Amara 2012).

2.2 Sources of Probiotics

Since ages humans are taking probiotics in diet through fermented food products such as beverages, yogurt, and cheese (Amara 2012). Intake of fermented foods or the dietary supplements are the two ways in which we can take probiotics. Fermented foods are regarded well over dietary supplements because their use is advocated to treat certain diseases and are not recommended for daily use. Fermented dairy products are one of the best sources of probiotics (Liong 2011). Kefir, sauerkraut, pickles, tempeh, miso, kimchi, sourdough bread, and some cheese are important fermented products which are rich sources of probiotics.

1. *Yogurt*—The "Yogurt" is the Turkish word which means to get thick. Turks are believed to be the earliest users of yogurt to treat gastrointestinal diseases (Atalay 2006). Yogurt, "the milk of eternal life" prepared from milk of goat was used to treat severe gastrointestinal diseases in France (Ozen and Dinleyici 2015). Yogurt is the fermented milk by the fermentation of milk by bacteria called as "Yogurt cultures." Yogurt culture is the combination of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. *S. thermophile* is responsible for the lactic acid fermentation and consequent cuddling of the milk to give it a gel like consistency. *L. bulgaricus,* on the other hand imparts flavor, hydrolyses the casein proteins into smaller peptides. Yogurt is considered as the best carrier food that can be used to deliver *L. acidophilus* and *Bifidobacterium bifidum* to human gut, the most common probiotics present in the dairy products. Many other probiotic bacteria are also present in the yogurt. These include *B. animalis, B. lactis, B. longum, Enterococcus faecium*, *Lactobacillus casei, L. delbrueckii*, *L. johnsonii*, *L. gasseri*, *L. plantarum*, *L. rhamnosus*, and *S. boulardii.* Probiotics bacteria present in yogurt are associated with the prevention of acute diarrhea, allergies, inflammation, genitourinary infections, cardiovascular diseases, vaginitis. The yogurt has attracted the interest of scientific communities due to its antimicrobial, antihypersensitivity, immunomodulatory, lipid-lowering properties, anti-inflammatory properties (Ebringer et al. 2008; Zemel et al. 2005; Ricci-Cabello et al. 2012). Clinical trials have shown the lower risk of antibiotic induced diarrhea with the consumption of yogurt (Beniwal et al. 2003). Lactoferrin, the peptide formed by the digestion of proteins by the probiotic bacteria, present in the yogurt is associated with eradication of *Helicobacter pylori* infections (Sachdeva et al. 2014).
2. *Kefir*—It is a fermented milk product similar to yogurt. There has been an increased interest in the commercial use of kefir as a health promoting beverage due to the probiotics present in it. Kefir has a long history of being recommended for health benefits in Soviet nations. The health benefits of kefir are linked both to the consortia of probiotics in it and also due to the presence of organic acids. In addition to being a rich resource of probiotics, it can also be effectively used as a matrix for the delivery of beneficiary microorganisms to the human body (Oliveira et al. 2013; Medrano et al. 2008). Lactose fermenting yeast, non-lactose fermenting yeast, heterofermentative and homofermentative lactic

acid bacteria, lactic acid bacteria such as *L. kefiri, L. kefiranofaciens, L. paracasei, L. acidophilus, L. parabuchneri*, *L. delbrueckii, L. bulgaricus, L. plantarum, Acetobacter aceti, A. lovaniensis, A. rasens, A. syzygii, Leuconostoc mesenteroides, Lactococcus lactis, Enterococcus durans, the fungus such as Geotrichum candidum, S. cerevisiae, S. unisporus, Candida kefyr, and Kluyveromyces marxianus* (Zanirati et al. 2015; Witthuhn et al. 2004) are present in the kefir. The probiotic population in Kefir varies according to the kefir origin (Gao et al. 2012). Benefits of kefir like hypocholesterolemic effects, antiallergenic properties, food preservative properties, antitumor, and reduction in blood pressure are related to the biological properties of the probiotics present in Kefir (Liu et al. 2002; Chen et al. 2008; Yanping et al. 2009). Antibacterial compounds and antibiotics produced by probiotics present in kefir, inhibit the growth of pathogenic bacteria such as *Helicobacter, Shigella sonnei, Staphylococcus, Salmonella, Helicobacter, Escherichia coli, Enterobacter aerogenes, Micrococcus luteus, Listeria monocytogenes, Streptococcus pyogenes, Streptococcus faecalis* and fungus like *Candida albicans*, *Fusarium graminearum, Clostridium difficile* (Lopitz et al. 2006; Ismaiel et al. 2011).

3. *Sauerkraut*—It is one of the oldest fermented foods prepared from the cabbage and has a long history of human nutrition. It is regarded as a wonder food due to the presence of probiotics in it. Sauerkraut does not need any culture to ferment as the cabbage growing in a healthy soil has all the bacteria needed to start fermentation. The fermented end product is rich is Lactic acid bacteria (LAB). Predominant species of LAB found in it are identified as *L. brevis, L. plantarum, Leuconostoc mesenteroides, Leuconostoc fallax, Pediococcus pentosaceus, L. curvatus, L. sakei, Lactococcus lactis* (Björkroth et al. 2002; Murcia-Martinez and Collins 1990; Vogel et al. 1991).These bacteria have established therapeutic role in the treatment of constipation, diarrhea, irritable bowel syndrome, urinary tract infections, and certain cancers. Presence of LAB in sauerkraut has an established role to enhance immunity, prevent certain diseases, and promote lactose tolerance in human body (Orgeron II et al. 2016).
4. *Fermented Vegetables*—Fermentation is the oldest and the widest used biotechnological method to preserve the perishable vegetable products (Fleming et al. 1995). It is regarded as the natural method of enhancing the nutritional quality and organoleptic properties of the vegetables. Species of LAB such as *Lactobacillus, Lactococcus, Pediococcus, and Leuconostoc* are naturally present in the vegetables that carry out natural fermentation. Different fermented vegetables have different types of probiotic bacteria (Table 2.1). Probiotic LAB spp. isolated from vegetables are resistant to natural bile and gastric juices tolerating gut stress, therefore vegetables are considered as another important source of probiotics. These probiotic bacteria have found to have antimicrobial activity against Salmonella spp., against gram-positive and gram-negative pathogens (Wang et al. 2010).
5. *Kombucha*—Kombucha is a fermented black tea which is slightly carbonated and sweet in taste. The fermented tea was very popular in China, Germany, and Russia for preventing metabolic diseases, arthritis, hemorrhoids, and rheumatism,

Table 2.1 Different probiotics present in fermented vegetable products

Fermented product	Region	Source	Probiotic organisms	Reference
Gundruk	Nepal	Leafy vegetables	Pediococcus and Lactobacillus spp., *L. cellobiosus* *L. plantarum*	Karki et al. (1983)
Sinki	India, Nepal, Bhutan	Radish taproot	*L. fermentum* *L. brevis* *L. plantarum*	Tamang (2009)
Khalpi	Nepal	Cucumber	*L. plantarum* *L. brevis* *Leuconostoc fallax* *P. pentosaceus*	Tamang (2009), Dahal et al. (2005)
Inziangsang	North east India	Mustard leaves	*L. plantarum* *L. brevis* *Pediococcus*	Tamang (2009); Yan et al. (2008)
Soidon	Manipur	Bamboo shoots	*Lactobacillus brevis* *Leuconostoc fallax* *Lactococcus lactis*	Tamang (2009)
Goyang	Sikkim and Nepal	Magane saag (Brassicaceae)	*Lactobacillus plantarum* *Lactobacillus brevis* *Lactobacillus lactis* *Enterococcus faecium* *Pediococcus pentosus* *Yeast like candida spp.*	Tamang and Tamang (2007)
Mesu	Sikkim	Bamboo shoot, shoots of choya bans (Dendrocalamus hamiltonii), Karati bans (Bambusa tulda) and Bhalu bans (Dendrocalamus sikkimensis)	*Lactobacillus plantarum* *Lactobacillus brevis* *Lactobacillus curvatus* *Leuconostoc citreum* *Pediococcus pentosaceus*	Tamang and Sarkar (1993)
Soibum	Manipur	Bamboo shoots of Dendrocalamus hamiltonii, D. sikkimensis and D. giganteus, Bambusa tulda and B. balcona.	*L. plantarum,* *L. brevis,* *L. coryniformis,* *L. delburkii,* *Leuconostoc fallax* *Lactococcus lactis* *L. mesenteroides* *Enterococcus durans* *Streptococcus lactis* *Bacillus subtilis* *B. licheniformis* *B. coagulans* *Yeast like Candida* *Saccharomyces and Torulopsis*	Giri and Janmejay (1987) and Sarangthem and Singh (2003)

(continued)

Table 2.1 (continued)

Fermented product	Region	Source	Probiotic organisms	Reference
Yan-dong-gua	Taiwan	Wax gourd	*W. cibaria* *W. paramesenteroides*	Lan et al. (2009)
Yan-jiang	Taiwan	Ginger	*L. sakei* *Lactococcus lactis* *W. cibaria* *L. plantarum*	Chang et al. (2011)
Burong mustala	Philippines	Mustard Leaf	*L. brevis* *Pediococcus cerevisiae*	Karovicova et al. (2002)
Ca muoi	Vietnam	Eggplant	*L. fermentum* *L. pentosus* *L. brevis*	Nguyen et al. (2013) and Sesena et al. (2001)
Dhamuoi	Vietnam	Cabbage and leafy vegetables	*Leuconostoc mesenteroides* *L. plantarum*	Steinkraus (1997)
Kimchi	Korea	Cabbage, raddish, vegetables	*Leuconostoc mesenteroides* *L. brevis* *L. plantarum* *L. sakei*	Lee et al. (2005)
Olive	Spain and Italy	Olive	*L. plantarum* *L. brevis* *L. pentosus* *P. cerevisiae* *L. mesenteroides*	Argyri et al. (2013) and Nychas et al. (2002).

reducing blood pressure, increasing immune response, and curing cancer (Greenwalt et al. 2000). The health benefits of Kombucha are attributed to the presence of vitamins, polyphenols, organic acids produced during the process of fermentation and presence of various lactic acid, gluconic acid, and acetic acid producing bacteria with probiotic attributes (Greenwalt et al. 2000; Malbasa et al. 2008). The *Acetobacter xylinum, A. aceti, A. xylinoides, A. pasteurianus,* and Gluconobacter are the predominant bacteria present in Kombucha, while yeasts species includes Brettanomyces, Saccharomyces, Pichia, Zygosaccharomyces, and Candida species (Malbasa et al. 2008; Malbasa et al. 2011). However, the yeast population is found to be variable in the Kombucha from different regions (Table 2.2).

6. *Tempeh*—Tempeh is a fermented soy product, popularly found in Indonesia and is rich in fibers. Tempeh consumption enhances the human gut health by enhancing the number of *A. muciniphila* and *Bifidobacterium* significantly (Stephanie et al. 2019). Indonesian tempeh is rich in probiotic microbial consortia consisting of *Acetobacter indonesiensis, Flavobacterium sp., Bacillus subtilis, L. agilis,*

Table 2.2 Variable yeast species present in Kombucha

Place of origin	Yeast species found	Reference
German	Brettanomyces, Zygosaccharomyces, and Saccharomyces	Mayser and Fromme (1995)
Switzerland	Pichia and Zygosaccharomyces (NRRL Y-4810 and Y-4882)	Hesseltine (1965)
Taiwan	*Saccharomyces cerevisiae, Zygosaccharomyces bailii,* and *Brettanomyces bruxellensis*	Liu et al. (1996)
Mexico	*Brettanomyces intermedius, Candida famata, Pichia membranaefaciens, S. cerevisiae, S. cerevisiae*, *Torulaspora delbrueckii*, *Z. bailii*, and *Z. rouxii*	Herrera and Calderon-Villagomez (1989)
Yugoslavia	Saccharomyces, Torulopsis, Mycotorula, Schizosaccharomyces, Saccharomyces, Pichia, Torula, Mycoderma, and Candida	Jankovic and Stojanovic (1994)
North America	Zygosaccharomyces, and *S. cerevisiae*	Roussin (1996)

L. fermentum, and Enterobacter cecorum, Brevundimonas sp., Pseudomonas putida, and Acinetobacter spp. (Barus et al. 2008; Radita et al. 2017).

7. *Probiotic supplements*—WHO documented that most of the today's diseases are life style related diseases and advocated to switching over to the use of probiotics for treating these diseases. With enhancing health concerns and inclination towards the benefits of probiotics, the demand for "probiotic functional foods" and the probiotic drug supplements is increasing, especially among the younger generation. Probiotic-infused juices, yogurt-based drinks, liquid probiotics are the biggest probiotic supplements present in the market. Mother Diary, Amul, Nestle, Unique Biotech, Tablets India, Danone Yakult, Dr. Reddy Laboratories, Polchem Hygiene Laboratories are the major players in probiotic industry in India. Probiotic preparations are also sold in the form of capsules, syrups and pills. Some of the probiotics available in Indian markets is summarized in the Table 2.3.
8. *Human Breast milk*—Human breast milk is rich in prebiotics and probiotics, and is considered very important for the development of microbiota in the infant gut. Traditional breast milk was regarded to be sterile, but development of molecular and culture techniques confirms that breast milk continuously supply commensals and rarely, can also transfer infectious microbes to the infant gut from the mother's skin and gut.

   Approximately 600 different species belonging to Bifidobacteria, Lactobacilli, Enterococcus, Peptostreptococcus, Staphylococcus, Streptococcus, Corynebacterium, and/or an occasional Escherichia species are acknowledged to be present in breast milk that helps in the establishment of infant gut microbiota. Medically important probiotic strains present in human breast milk and their consequent effect on the neonatal growth are summarized in the Fig. 2.1.

Table 2.3 Probiotic functional food and Probiotic drug supplements available in market

Type of product	Company	Type of supplement	Probiotic present	Source
Probiotic functional food	Yakult Danone	Probiotic food	*L. casei*	https://www.yakult.co.in/india.php
	Amul	Drinking Yogurt	*L. acidophilus* La5 and *B. Lactis* Bb12	https://amul.com/products/amul-flaavyo-info.php
	Nestle	Nestle Actiplus Dahi Flavored milk	*L. acidophilus*	https://www.nestle.in/
	Mother Diary	B-Active Probiotic Curd Probiotic drink (Nutrifit) Fruit yogurt	*L. acidophilus* and Bifidobacterium	https://www.motherdairy.com/
Probiotic drug supplements	Unique Biotech	Probiotic blends	*B. coagulans, L. acidophilus, L. bulgaricus, L. casei, L. helveticus, L. reuteri, S. thermophilus*	http://www.uniquebiotech.com/
	Alpic Biotech Ltd	Abigut Capsules	*B. bifidum, B. longum, L. acidophilus, S. thermophilus*	https://www.alpicbiotech.com/
	Dr. Reddy Laboratories	Becelac Fortz Cap	Spores of Lactobacillus	https://www.drreddys.com/
	Tablets India Limited	Bifilac	Lactobacillus 50 million spores	http://www.tabletsindia.com/
	Tablets India Limited	Biors Sachet	*B. mesentericus, Clostridium butyricum*, Lactobacillus	http://www.tabletsindia.com/
	Merck	Ecobion Sachet	*B. bifidum, B. longum, L. acidophilus, L. rhamnosus, S. boulardii, and S. thermophilus*	https://www.merck.com/index.html

	Sanzyme	Sporlac	Sporolactobacilli, Lactobacilli solution	https://www.sanzyme.com/
	USV Limited	ViBact	Genetically modified *B. mesentericus*	https://www.usvindia.com/
	Elan Pharma Pvt Ltd.	Rinifol	Lactobacillus 50 million spores	https://www.zaubacorp.com/company/ELAN-PHARMA-INDIA-PRIVATE-LIMITED/U24230MH1997PTC108497
	Lupin Labs	Ubioz Powder	*B.longum, L. acidophilus, L. Casei, S. boulardii, S. thermophilus*	http://www.lupinpharmaceuticals.com/
	USV Limited	Vibact	*S. faecalis, C. butyricum, B. mesentericus and L. sporegenes*	https://www.usvindia.com/
	Herbs Nutriproducts Private Limited (Pure Nutrition)	Progut Capsules	*L. acidophilus, S. faecalis, Enterococcus faecalis, C. butyricum, L. plantarum, B. mesentericus, L. salivarius*	https://purenutrition.me/
	Promopharma	Lactoflora	*L. brevis, L. plantarum*	https://www.promopharma.it/en/

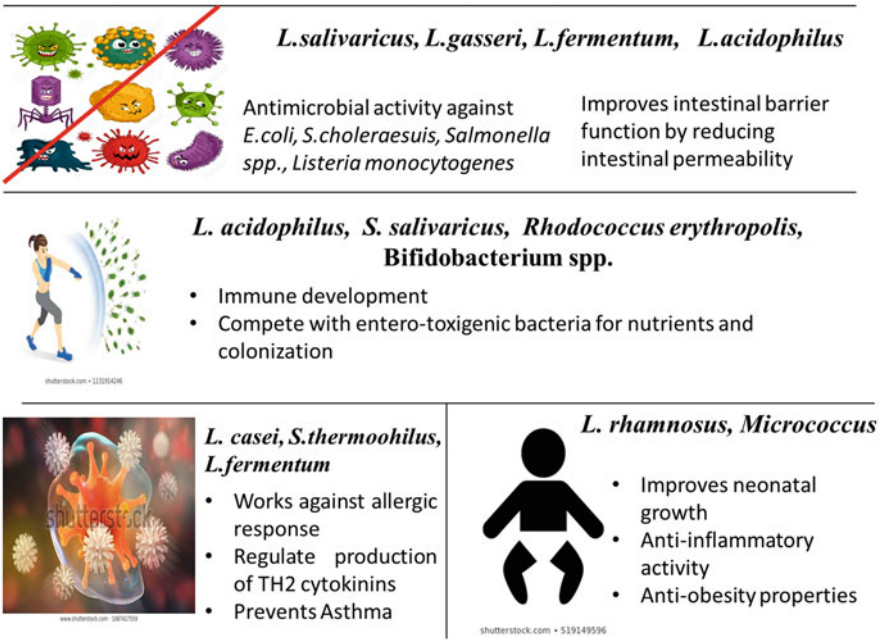

Fig. 2.1 Various probiotic bacteria present in Breast milk and their beneficial effects (Matsuzaki and Chin 2000; Donnet-Hughes et al. 2010; Gilliland and Speck 1977; Olivares et al. 2006; Vendt et al. 2006)

2.3 Selection Criteria for the Probiotics

The selection of a probiotic strain for human use should follow a systematic approach. This should be done with the objective that a safe and desired probiotic product is reached to the end users. General aspects like origin of the probiotic, genus and strain identification, biosafety, functional aspects like ability to sustain in gastrointestinal tract, health aspects and production aspects like acid production, proteolysis, and viability should be kept in mind before choosing a probiotic strain. Guidelines provided by ICMR-DBT, for the evaluation of probiotics in food, make it clear that it needs a "step-by-step" approach to test the functional ability of the microbe to be called as a "probiotic." It is recommended that the strain should be isolated from the targeted animal only, i.e., probiotics for human use should be ideally isolated from human intestine or breast milk. This is because they are better able to adhere to intestinal walls and proved to be safer for humans. Also, they can be isolated from various fermented food products discussed in the above section. The isolated strain should be tested for its probiotic potential and identified up to genus and strain level. The primary identification techniques should be followed by molecular and genetic techniques such as fatty acid methyl ester (FAME), 16SrRNA DNA Sequencing, Polymerase chain reaction (PCR) amplification and

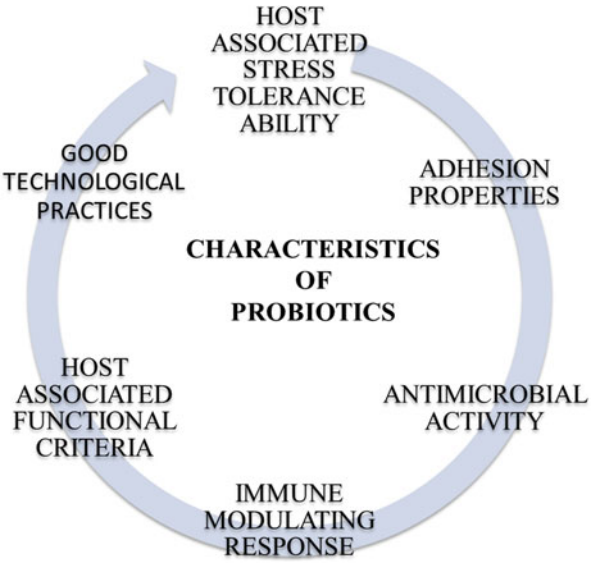

Fig. 2.2 Characteristics of probiotics

DNA and RNA hybridization, and DNA-DNA hybridization technique. For selecting a microbe to be used as probiotic, it should meet certain characteristics that are summarized in Fig. 2.2 and enlisted below:

1. *Host associated stress tolerance ability*—Upon ingestion the probiotic should be able to sustain through the different parts of digestive tract and tolerate various stress conditions in human body that includes the action of various digestive enzymes like lysozymes, amylase, pepsin, and chymotrypsin. The bacterial strain should have acid and bile tolerance, mild heat shock tolerance caused by internal body temperature. Different probiotic bacteria have found to have varying degree of resistance to the stress conditions. Ogunremi et al. 2015, Psani and Kotzekidou (2006) in their studies summarized that probiotic bacteria should be able to tolerate bile concentrations of 0.3–2.0% and pH range of 2–5.
2. *Adhesive properties*—The adhesion of the probiotic strain to the intestinal wall is very important in defining its probiotic potential because it ensures that the bacteria is not washed away, auto-aggregates to increase its cell density and biomass in the digestive tract. Adhesion is also important to ensure that the microbial cell forms a better interaction with human epithelial cells in order to produce various host associated functional effects on the host (defined below).
3. *Antimicrobial activity*—The probiotic strain should be able to fight and survive against the potential pathogenic microbes that may be present in the intestine. The prevention of pathogen survival in the gut is related to the competitive behavior of probiotic strain, where it prevent the adhesion of pathogens to the epithelial cells in the human body and due to the secretion of lacticins, alyteserin-1 a, bacteriocins Abp118, bacteriocin sakacin A, lactic acid, antibodies. Probiotic bacteria also employ increasing leukocyte phagocytic activity, increasing transepithelial

resistance, enhancement of cytoskeletal, and tight junctional protein phosphorylation activity to kill various pathogenic bacteria (Mathipa and Thantsha 2017).

4. *Immune modulating response*—Probiotic strain should be involved in production of metabolites that stimulate the maturation and functioning of the immune cells. These bacteria enhance the secretion of immunoglobulins, cytokine production (Rocha-Ramírez et al. 2017), IgA and IgM-secreting cells (Lammers et al. 2003). The probiotic strain should be selected depending upon the target host to stimulate the systemic immune response.
5. *Host Associated functional criteria*—One of the most important characteristics of the probiotic is the health benefits that it can provide to the host. The viability and colonization of the probiotic in the human gut should offer anticarcinogenic, anti-cholesterol activity, anti-depression, anti-anxiety, anti-obesity, anti-diabetic, and antioxidant activities to host besides protecting it against irritable bowel syndrome, gastroenteritis, and inflammatory bowel disease, diarrhea, infant allergies, cancer, lactase digestion, diabetes, and hyperlipidemia. Probiotic strains should be selected to inactivate enzymes (nitrate reductase, β-glucosidase, β-glucuronidase) involved in the activation of precarcinogens (Kumar et al. 2013). Additionally, the probiotic strain should be screened for secretion of conjugated linoleic acid production (dos Reis et al. 2017) and apoptosis induction activity (Ewaschuk et al. 2006) for possible anticarcinogenic activity.

   The efficiency of the probiotic strains for the reversal of depression and anxiety can also be studied in vivo on animal models. The anti-diabetic and anti-obesity activities of the potential strain can be analyzed by testing its ability to inhibit mast cell activation (Niers et al. 2005) and ability to break lipopolysaccharides (Alokail et al. 2013).

   Another major characteristic feature of the probiotic is the secretion of antioxidant enzymes (superoxide dismutase, glutathione dismutase), functional molecules (glutathione, melatonin, ascorbic acid), Vitamin-K, biotin, riboflavin, nicotinic acid, thiamine, pantothenic acid, and bioactive enzymes (lipases and amylases). The in vitro production of these components should be tested depending upon the objective of the product.
6. *Good technological properties*—The extent to which a probiotic can effectively deliver its benefits to the host will depend upon the capability of the strain to survive the storage period and maintain the same efficiency and viability. The probiotic bacteria should be able to grow quickly in different nutrient supplements (preferably cheap fermentation media), food matrices, and microaerophilic conditions. The stress adaptation of bacteria strain to withstand different physical handling techniques during food processing without losing the viability and efficiency is also important for its selection as the probiotic.

2.4 Conclusion

Fermented and non-fermented dairy products, fermented perishable vegetables and fruits, fermented cereals and soya products should be incorporated into the diet due to the presence of probiotic bacteria in it. The rise in the market potential of probiotics in India is driven by the rising lifestyle disorders and subsequently increasing the awareness of the consumers. The availability of the large number of commercial platforms providing probiotic functional foods and probiotic drug supplements has also contributed to the exponential increase in the use of probiotics in India. In the absence of any regulatory guidelines governing the probiotic industry, it is quite possible that the fake products with low or no health benefits are being marketed to the end users. To avoid such spurious products, the product must fulfill the above prerequisite conditions to be called or labeled as the "probiotic." Apart from this, efficacy studies should also be carried to prove its health benefits in humans. Manufacturing and handling practices should follow quality assurance so that the end users should get the product with claimed benefits.

References

Alokail MS, Sabico S, Al-Saleh Y, Al-Daghri NM, Alkharfy KM, Vanhoutte PM, McTernan PG (2013) Effects of probiotics in patients with diabetes mellitus type 2: Study protocol for a randomized double-blind placebo-controlled trial. Trials 14(1):195. https://doi.org/10.1186/1745-6215-14-195

Amara A (2012) Toward healthy genes. Schüling Verlage, Münster

Argyri AA, Zoumpopoulou G, Karatzas KAG, Tsakalidou E, Nychas GJE, Panagou EZ, Tassou CC (2013) Selection of potential probiotic lactic acid bacteria from fermented olives by in vitro tests. Food microbiol 33:282–291. https://doi.org/10.1016/jfm201210005

Atalay B (2006) Kaşgarlı Mahmut Divanü-Lügati't – Türk [translation]. Türk Tarih Kurumu Press, Ankara

Barus T, Suwanto A, Wahyudi AT, Wijaya H (2008) Role of bacteria in tempeh bitter taste formation: microbiological and molecular biological analysis based on 16S rRNA gene. Microbiol Indones 2(1):17–21. https://doi.org/10.5454/mi214

Beniwal RS, Arena VC, Thomas L, Narla S, Imperiale TF, Chaudhry RA, Ahmad UA (2003) A randomized trial of yogurt for prevention of antibiotic-associated diarrhea. Dig Dis Sci 48 (10):2077–2082. https://doi.org/10.1023/a:1026155328638

Björkroth KJ, Schillinger U, Geisen R, Weiss N, Hoste B, Holzapfel WH, Korkeala HJ, Vandamme P (2002) Taxonomic study of *Weissella confusa* and description of *Weissella cibaria sp.* nov. detected in food and clinical samples. Int J Syst Evol Microbiol 52:141–148. https://doi.org/10.1099/00207713-52-1-141

Cammarota M, De Rosa M, Stellavato A, Lamberti M, Marzaioli I, Giuliano M (2009) *In vitro* evaluation of *Lactobacillus plantarum* DSMZ 12028 as a probiotic: emphasis on innate immunity. Int J Food Microbiol 135:90–98. https://doi.org/10.1016/j.ijfoodmicro.2009.08.022

Chang CH, Chen YS, Yanagida F (2011) Isolation and characterization of lactic acid bacteria from yan-jiang (fermented ginger) a traditional fermented food in Taiwan. J Sci Food Agric 91 (10):1746–1750. https://doi.org/10.1002/jsfa.4364

Chen HC, Wang SY, Chen MJ (2008) Microbiological study of lactic acid bacteria in kefir grains by culture-dependent and culture-independent methods. Food Microbiol 25:492–501. https://doi.org/10.1016/j.fm.2008.01.003

Dahal NR, Karki TB, Swamylingappa B, Li Q, Gu G (2005) Traditional foods and beverages of Nepal-a review. Food Rev Int 21(1):1–25. https://doi.org/10.1081/FRI-200040579

Donnet-Hughes A, Perez PF, Dore J, Leclerc M, Levenez F, Benyacoub J, Serrant P, Segura-Roggero I, Schiffrin EJ (2010) Potential role of the intestinal microbiota of the mother in neonatal immune education. Proc Nutr Soc 69:407–415. https://doi.org/10.1017/S0029665110001898

dos Reis, S. A., da Conceição, L. L., Siqueira, N. P., Rosa, D. D., da Silva, L. L., & Maria do Carmo, G. P (2017) Review of the mechanisms of probiotic actions in the prevention of colorectal cancer. Nutr Res. 37: 1–19. https://doi.org/10.1016/j.nutres.2016.11.009

Ebringer L, Ferenčík M, Krajčovič J (2008) Beneficial health effects of milk and fermented dairy products. Folia Microbiol 53(5):378–394. https://doi.org/10.1007/s12223-008-0059-1

Ewaschuk JB, Walker JW, Diaz H, Madsen KL (2006) Bioproduction of conjugated linoleic acid by probiotic bacteria occurs *in vitro* and *in vivo* in mice. J Nutr 136:1483–1487. https://doi.org/10.1093/jn/136.6.1483

Fleming HP, Kyung KH, Breidt F (1995) Vegetable fermentations In: Rehm HJ Reed G Biotechnology volume9 Enzymes biomass food and feed, 2nd edn. VCH, New York

Gao J, Gu F, Abdella NH, Ruan H, He G (2012) Investigation on culturable microflora in Tibetan kefir grains from different areas of China. J Food Sci. 77:425–433. https://doi.org/10.1111/j.1750-3841.2012.02805.x

Gilliland SE, Speck ML (1977) Antagonistic Action of Lactobacillus acidophilus Toward Intestinal and Foodborne Pathogens in Associative Cultures. J Food Prot 40:820–823. https://doi.org/10.4315/0362-028X-40.12.820

Giri SS, Janmejay LS (1987) Microbial and chemical contents of the fermented bamboo shoot "soibum". Frontier Bot 1:89–100

Greenwalt CJ, Steinkraus KH, Ledford RA (2000) Kombucha the fermented tea: microbiology composition and claimed health effects. J Food Prot 63(7):976–981

Herrera T, Calderon-Villagomez A (1989) Species of yeasts isolated in Mexico from the tea fungus. Rev Mex Micol 5:205–210

Hesseltine CW (1965) A millennium of fungi food and fermentation. Mycologia 57:149–197. https://doi.org/10.2307/3756821

Ismaiel AA, Ghaly MF, El-Naggar AK (2011) Milk kefir: ultrastructure antimicrobial activity and efficacy on aflatoxin B1 production by *Aspergillus flavus*. Curr Microbiol. 62:1602–1609. https://doi.org/10.1007/s00284-011-9901-9

Jankovic I, Stojanovic M (1994) Microbial and chemical composition growth therapeutical and anti-microbial characteristics of tea fungus. Microbiologija 31(1):35–43

Karki T, Okada S, Baba T, Itoh H, Kozaki M (1983) Studies on the microflora of Nepalese pickles gundruk. Nippon Shokuhin Kogyo Gakkaishi 30:357–367

Karovicova J, Kohajdova Z, Greif G (2002) The use of PCA CA FA for evaluation of vegetable juices processed by lactic acid fermentation. Czech J Food Sci 20(4):135–143

Kumar M, Nagpal R, Verma V, Kumar A, Kaur N, Hemalatha R, Gautam SK, Singh B (2013) Probiotic metabolites as epigenetic targets in the prevention of colon cancer. Nutr Rev 71:23–34. https://doi.org/10.1111/j.1753-4887.2012.00542.x

Lammers KM, Brigidi P, Vitali B, Gionchetti P, Rizzello F, Caramelli E, Matteuzzi D, Campieri M (2003) Immunomodulatory effects of probiotic bacteria DNA: IL-1 and IL-10 response in human peripheral blood mononuclear cells. FEMS Immunol Med Microbiol 38:165–172. https://doi.org/10.1016/S0928-8244(03)00144-5

Lan WT, Chen YS, Yanagida F (2009) Isolation and characterization of lactic acid bacteria from Yan-dong-gua (fermented wax gourd) a traditional fermented food in Taiwan. J Biosci Bioeng 108(6):484–487. https://doi.org/10.1016/j.jbiosc.2009.06.009

Lee JS, Heo GY, Jun WL, Oh YJ, Park JA, Park YH, Pyun YR, Jong SA (2005) Analysis of kimchi microflora using denaturing gradient gel electrophoresis. Int J Food Microbiol 102(2):143–150. https://doi.org/10.1016/j.ijfoodmicro.2004.12.010

Liong MT (editor) (2011) Probiotics: biology genetics and health aspects Berlin: Springer-Verlag

Liu CH, Hsu SH, Lee FL, Liao CC (1996) The isolation and identification of microbes from a fermented tea beverage Haipao and their interactions during Haipao fermentation. Food Microbiol 13:407–415

Liu JR, Wang SY, Lin YY, Lin CW (2002) Antitumor activity of milk kefir and soya milk kefir in tumor bearing mice. Nutr Cancer 44:183–187. https://doi.org/10.1207/S15327914NC4402_10

Lopitz FO, Rementeria A, Elguezabal N, Garaizar J (2006) Kefir: una comunidad simbiótica de bacterias y levaduras con propiedades saludables. Rev Iberoam Micol 23:67–74. https://doi.org/10.1016/S1130-1406(06)70016-X

Malbasa R, Loncar E, Djuric M (2008) Comparison of the products of Kombucha fermentation on sucrose and molasses. Food Chemistry 106(3):1039–1045. https://doi.org/10.1016/j.foodchem.2007.07.020

Malbasa R, Loncar E, Vitas J, Canadanovic-Brunet JM (2011) Influence of starter cultures on the antioxidant activity of kombucha beverage. Food Chem 127(4):1727–1731. https://doi.org/10.1016/jfoodchem201102048

Mathipa MG, Thantsha MS (2017) Probiotic engineering: towards development of robust probiotic strains with enhanced functional properties and for targeted control of enteric pathogens. Gut Pathogens 9(1):28. https://doi.org/10.1186/s13099-017-0178-9

Matsuzaki T, Chin J (2000) Modulating immune responses with probiotic bacteria. Immunol Cell Biol 78:67–73. https://doi.org/10.1046/j.1440-1711.2000.00887.x

Mayser PS, Fromme C, Leitzmann, Gruender K (1995) The yeast spectrum of the 'tea fungus Kombucha' Das Hefespektrum des 'Teepilzes Kombucha. Mycoses 38:289–295

Medrano M, Pérez PF, Abraham AG (2008) Kefiran antagonizes cytopathic effects of *Bacillus cereus* extracellular factors. Int J Food Microbiol 122:1–7. https://doi.org/10.1016/j.ijfoodmicro.2007.11.046

Murcia-Martinez AJ, Collins MD (1990) A phylogenetic analysis of the genus *Leuconostoc* based on reverse transcriptase sequencing of 16S rRNA. FEMS Microbiol Lett 58:73–83

Nguyen DTL, Van Hoorde K, Cnockaert M, De Brandt E, Aerts M, Vandamme PA (2013) Description of the lactic acid bacteria microbiota associated with the production of traditional fermented vegetables in Vietnam. Int J Food Microbiol 163(1):19–27. https://doi.org/10.1016/j.ijfoodmicro.2013.01.024

Niers LEM, Timmerman HM, Rijkers GT, Van Bleek GM, Van Uden NOP, Knol EF, Kapsenberg ML, Kimpen JLL, Hoekstra MO (2005) Identification of strong interleukin-10 inducing lactic acid bacteria which down-regulate T helper type 2 cytokines. Clin Exp Allergy 35:1481–1489. https://doi.org/10.1111/j.1365-2222.2005.02375.x

Nychas GJE, Panagou EZ, Parker ML, Waldron KW, Tassou CC (2002) Microbial colonization of naturally black olives during fermentation and associated biochemical activities in the cover brine. Lett Appl Microbiol 34(3):173–177. https://doi.org/10.1046/j.1472-765x.2002.01077.x

Ogunremi OR, Sanni AI, Agrawal R (2015) Probiotic potentials of yeasts isolated from some cereal-based Nigerian traditional fermented food products. J Appl Microbiol 119:797–808. https://doi.org/10.1111/jam12875

Olivares M, Diaz-Ropero MP, Martin R, Rodriguez JM, Xaus J (2006) Antimicrobial potential of four Lactobacillus strains isolated from breast milk. J Appl Microbiol 101:72–79

Oliveira A, Miguel ML, Peixoto MAL, Rosado RS, Silva AS, Paschoalin JT (2013) Microbiological technological and therapeutic properties of kefir: a natural probiotic beverage. Braz. J Microbiol 44:341–349. https://doi.org/10.1590/S1517-83822013000200001

Orgeron RP II, Corbin A, Scott B (2016) Sauerkraut: A probiotic superfood. Funct Foods Health Dis 6(8):536–543

Ozen M, Dinleyici EC (2015) The history of probiotics: the untold story. Benefic Microbes 6 (2):159–165

Psani M, Kotzekidou P (2006) Technological characteristics of yeast strains and their potential as starter adjuncts in Greek-style black olive fermentation. World J Microbiol Biotechnol 22:1329–1336. https://doi.org/10.1007/s11274-006-9180-y

Radita R, Suwanto A, Kurosawa N, Wahyudi AT, Rusmana I (2017) Metagenome analysis of tempeh production: Where did the bacterial community in tempeh come from? Malays J Microbiol 13(4):280–288

Ricci-Cabello I, Olalla Herrera M, Artacho R (2012) Possible role of milk-derived bioactive peptides in the treatment and prevention of metabolic syndrome. Nutr Rev 70(4):241–255

Rocha-Ramírez LM, Pérez-Solano RA, Castañón-Alonso SL, Moreno Guerrero SS, Ramírez Pacheco A, García Garibay M, Eslava C (2017) Probiotic Lactobacillus strains stimulate the inflammatory response and activate human macrophages. J Immunol Res. 2017:1. https://doi.org/10.1155/2017/4607491

Roussin MR (1996) Analyses of Kombucha ferments: report on growers Information Resources LC Salt Lake City Utah

Sachdeva A, Rawat S, Nagpal J (2014) Efficacy of fermented milk and whey proteins in Helicobacter pylori eradication: A review. World J Gastroenterol: WJG 20(3):724. https://doi.org/10.3748/wjg.v20.i3.724

Sarangthem K, Singh TN (2003) Microbial bioconversion of metabolites from fermented succulent bamboo shoots into phytosterols. Current Sci 84:1544–1547

Sesena S, Anchez-Hurtado IS, Gonz MA, Viñas MAG, Palop L (2001) Contribution of starter culture to the sensory characteristics of fermented Almagro eggplants. Int Food Microbiol 67 (3):197–205

Sonnenborn U, Schulze J (2009) The non-pathogenic Escherichia coli strain Nissle 1917 – features of a versatile probiotic. Microb Ecol Health Dis 21:122–158. https://doi.org/10.3109/08910600903444267

Steinkraus KH (1997) Classification of fermented foods: worldwide review of household fermentation techniques. Food Control 8:311–317

Tamang JP (2009) Himalayan Fermented Foods: Microbiology Nutrition and Ethnic Values. CRC Press, New Delhi

Tamang JP, Sarkar PK (1993) Sinki: A traditional lactic acid fermented radish tap root product. J Gen Appl Microbiol 39(4):395–408. https://doi.org/10.2323/jgam.39.395

Tamang B, Tamang JP (2007) Role of lactic acid bacteria and their functional properties in Goyang a fermented leafy vegetable product of the Sherpas. J Hill Res 20:53–61

Vendt N, Grünberg H, Tuure T, Malminiemi O, Wuolijoki E, Tillmann V, Sepp E, Korpela R (2006) Growth during the first 6 months of life in infants using formula enriched with Lactobacillus rhamnosus GG: double-blind randomized trial. J Human Nutr Diet 19:51–58. https://doi.org/10.1111/j.1365-277X.2006.00660.x

Vogel RF, Lohmann M, Weller AN, Hugas M, Hammer WP (1991) Structural similarity and distribution of small cryptic plasmids of *Lactobacillus curvatus* and *L sakei* FEMS. Microbiol Lett 84:183–190. https://doi.org/10.1016/0378-1097(91)90125-t

Wang CY, Lin PR, Ng CC, Shyu YT (2010) Probiotic properties of Lactobacillus strains isolated from the faeces of breast-fed infants and Taiwanese pickled cabbage. Anaerobe 16:578–585. https://doi.org/10.1016/j.anaerobe.2010.10.003

Witthuhn RC, Schoeman T, Britz TJ (2004) Isolation and characterisation of the microbial population of different South African kefir grains. Int J Dairy Technol 57:33–37. https://doi.org/10.1111/j1471-0307200400126x

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

Yanping W, Nv X, Aodeng X, Zaheer A, Bin Z, Xiaojia B (2009) Effects of *Lactobacillus plantarum* MA2 isolated from Tibet kefir on lipid metabolism and intestinal microflora of rats fed on high-cholesterol diet. Appl Microbiol Biotechnol 84:341–347. https://doi.org/10.1007/s00253-009-2012-x

Zanirati DF, Abatemarco M, Cicco Sandesb SH, Nicolia JR, Nunes AC, Neumanna E (2015) Selection of lactic acid bacteria from Brazilian kefir grains for potential use as starter or probiotic cultures. Anarobe 32:70–76. https://doi.org/10.1016/j.anaerobe.2014.12.007

Zemel MB, Richards J, Mathis S, Milstead A, Gebhardt L, Silva E (2005) Dairy augmentation of total and central fat loss in obese subjects. Int J Obes 29(4):391. https://doi.org/10.1038/sj.ijo.0802880