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The World of Probiotics: A Bird's Eye View

Shalini Mishra[1], Anjali Thakur[1], Dhwani Upadhyay[1], Prasad Andhare[2], Indrani Bhattacharya[1]
1Department of Biotechnology, Parul Institute of Applied Sciences, Parul University, Post Limda, Waghodia, Gujarat, 391760
2: Assistant Professor, Parul Institute of Applied Sciences, Parul University, Post Limda, Waghodia, Gujarat, 391760
3: Assistant Professor, Biological Sciences, PDPIAS, Charotar University of Science and Technology,
*Corresponding Author: Dr.Indrani Bhattacharya;
Email: indrani.bhattacharya82083@paruluniversity.ac.in

ABSTRACT
Human body is home to billions of microorganisms. Recent developments in the field of medicine and improved hygiene have resulted in the decline of the body's microbial population due to which the quality of life as we know it, is deteriorating and this poses a threat to the humankind. The past few decades have made it clear that food is not just a source of energy but contributes also to our health and well-being. The association of probiotics to well-being has a long history. The functional food sector is on the rise due to the increase in the nutritional awareness among the consumers. According to the FAO/WHO, any live microorganisms which when administered in adequate quantities confer health benefit on the host can be termed as probiotic. In the last two decades probiotics have gained the attention of the scientific community. Extensive research has provided us with evidence that point towards the beneficial effects of probiotics on human health. Their mechanism of action is diverse which makes their applications just as diverse like medicine, food, agriculture, poultry to name a few. The purpose of this paper is to review the concept of probiotics, their possible beneficial properties and how they will help humankind shape a better future.
KEYWORDS*: Probiotics, Lactobacillus, Bifidobacterium, medicine, food.*

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INTRODUCTION

Human body consists of trillions of microorganisms, outnumbering human cells by 10 to 1. Some organisms that colonize humans are commensals i.e., they co-exist without harming humans. One such commensal is the genera *Lactobacillus.* Itis a Gram-positive, rod- shaped, microaerophilic or facultative anaerobes. They are predominantly found in gastro-intestinal and urinary tract of humans. Gastro-intestinal microflora plays an important role in human and animal health [1].

The taxonomic hierarchy of Lactobacillus is shown in Table 1. There are about 170 species and 17 subspecies of Lactobacillus. Some examples are *L. brevis, L. plantarum, L. acidophilus, L. fermentum, L. buchneri, L. reuteri etc.*

The nutritional requirements of *Lactobacillus* is complex (for e.g., proteins, carbohydrates, fatty acids, salts, nucleic acid derivatives and vitamins). Based on carbohydrate fermentation pathways, they are divided into three groups: (a) obligately homofermentative, responsible for fermentation of hexoses to lactic acid; (b) facultative heterofermentative lactobacilli, responsible for conversion of hexoses entirely to lactic acid, or lactate, formic acid, ethanol and acetate; and (c) obligately heterofermentative lactobacilli that converts six-carbon sugars to lactate, ethanol, carbon-dioxide and/or acetate.

Russian Nobel laureate, Elie Metchnikoff believed that the western diet shortened the human life expectancy because it was not able to mitigate the effects of the autotoxins produced by harmful microorganisms. It was Metchnikoff who hypothesized that lactobacilli are pivotal for human health and longevity. He observed that despite living in extreme poverty and harsh climate, the rural population of Bulgarian, lived to very old ages. Metchnikoff associated the longevity to the lactobacilli present in the fermented milk they drank. He received Nobel Prize for Medicine, in 1908, for demonstrating that replacing harmful bacteria with beneficial microbes was a key to treat intestinal illnesses. Extensive scientific study is being carried ever since to find ways in which to modulate the indigenous intestinal flora by live probiotic microorganisms. Probiotics are defined as any live microorganism that has the

ability to confer health benefits on its host. The overall health of humans is subjected to a number of physiological functions exerted by the intestinal microflora. Therefore, any disturbance caused to the ecological balance of the gastro-intestinal system can be detrimental to health. The rise of nutritional awareness among consumers combined with the beneficial properties of probiotics, have garnered the attention of the scientific community that is carrying out extensive research to understand the probiotic mechanism and make it safe for human consumption. Evidence suggests that the intestinal microflora is not a separate entity, but is constantly interacting with the host's environment. A state of disease ensues when this delicate balance is disturbed. Maintenance of balance of the intestinal microflora is crucial to our well-being and probiotics provide us with means to ensure the said balance. There are various ways in which this balance can be restored but they can be proven only with controlled human trials. Some of the proposed ways are stabilizing the gut mucosal barrier function to prevent infections caused by pathogens and counteracting local immunological dysfunctions, etc.

Probiotic family

Microorganisms that have probiotic properties are mainly either bacteria or fungi [2]. Some of the most important microorganisms are listed in Table 2. As far as nutrition is concerned the most commonly consumed probiotics are those classified as Lactic Acid Bacteria and among them those belonging to the genera *Lactobacillus* and *Bifidobacterium* exhibit the most important properties in an applied context which makes them the most studied probiotics as well [3]. Most commonly used probiotic microorganisms are enlisted in Table 3.

Characteristics of Probiotics

For a bacterial strain to be considered as an ideal probiotic some of the properties it must exhibit are listed below [4].

1) Acid and bile tolerance
2) Antimicrobial activity
3) Auto-aggregation and co-aggregation
4) Hydrophobicity
5) Bile salt deconjugation
6) Adhesion to mucosal and intestinal surfaces
7) Antagonism
8) Combat lactose intolerance
9) Remove cholesterol

All these properties are essential to the survivability of the probiotic inside the human host. The most important aspect of any probiotic is its ability to grow under manufacture and commercial conditions and retain its viability when brought back to normal conditions.

Mechanism of Probiotics

Probiotics exerts their effects through various mechanisms of action [4]. Some of studied ways in which they impart health benefits are listed below.

1) By producing bacteriocins i.e., small, helical, heat-stable molecules that confer anti-microbial activity.
2) They enhance metabolic functions by synthesizing enzymes such as lipases, esterases, lactase, protease etc.
3) They ferment the proteins to produce small peptides, amino acids, phenols and lactones that contribute to antioxidant and anti-inflammatory effects and also help in maintaining the energy balance.
4) By producing carbohydrate-digesting enzymes that the large and small intestine of humans lack and is a major player which converts indigestible carbohydrates to hexose sugar.
5) By producing growth factors like vitamin B12, vitamin K, thiamine, folate, riboflavin and pyrodixine etc.
6) They induce formation of biofilms made of exopolysaccharides that leads to the growth of useful bacteria in the gastrointestinal tract.
7) They influence the acquired and innate immune response via phagocytosis, IgA secretion and modifying T- cell responses.
8) They help the body maintain a healthy microbial community or help the body to recover to a healthy condition after they are disturbed.

Probiotic foods

Today with an increase in the knowledge of functional foods, development of functional foods with health benefits has seen a drastic bloom. A large number of industries are making probiotic food products. The section below summarizes the common applications of probiotics.

Dairy based – Milk and milk products like yogurts, cheese and ice-cream is one of the most consumed foodsand the fact that they can be stored at room temperature makes them the ideal carriers for probiotic bacteria. Dairy drinks were the first commercialized probiotic product. Yoghurt is original source of probiotics and is known for its nutritional value and health benefits. Factors like acidity, pH, dissolved oxygen content, hydrogen peroxide, redox potential, starter microbes affect the viability of the probiotic microorganisms. Due to their low proteolytic activity and inability to utilize lactose, *Lactobacillus* and *Bifibobacterium* grow weakly in milk. This is also due to the fact the milk and yoghurt lack certain components that are crucial for the growth of these bacteria. Substances like fructooligosaccharides (FOS), caseinomicropeptides (CMP), whey protein concentrate (WPC), tryptone, yeast extract, certain amino acids and encapsulation of probiotic bacteria in alginate beads has shown substantial increase in the growth and viability of probiotic bacteria in milk and yoghurt respectively. Some of the widely used probiotic bacteria in the manufacture of dairy-based probiotic beverages are *L. acidophilus, L. fermentum, L. casei, L. rhamnosus, L. plantarum*, *L. bulgaricus, L. delbreuckii.*

Plant based – With people shifting to vegetarianism there is high demand for the vegetarian variant of the probiotic products. Humans have fermented vegetables since time immemorial. Several vegetable juices like cabbage juice and carrot juice showed increased viability of probiotics and serve as a healthy beverage. Many studies have been carried out for the development of vegetable probiotic product. It was found the carrot juice provided viable growth conditions without ant nutrient supplementation. Cabbage juice and tomato juice are other examples of probiotic vegetable products that were successfully investigated for the viability of probiotics. Fermented foods like kimchi, sauerkraut and kombucha are rich in lactic-acid producing bacteria. In recent times, soybean has received attention of the scientific community for its high protein content and their health benefits in prevention of a plethora of diseases like cancer, atherosclerosis, osteoporosis to name a few.

Fruit based – Fruit juices are an ideal medium for probiotics due to the presence of beneficial nutrients. They are perceived as fresh and healthy and appeals to every age group which has resulted in increased interest and research towards the development of fruit based probiotic products. Fruits are rich in minerals, vitamins, antioxidants which constitutes for an ideal medium for probiotic bacteria butthe presence of probiotic cultures in fruit juices alter the taste profile which consumers do not prefer. Research is being carried out to combat the issue of the unpleasant odor and flavors in probiotic juices. In this front, encapsulation in Ca-alginate beads has shown exemplary results. Pomegranate juice showed desirable microbial growth of *L. plantarum* and *L. delbrueckii*. Similar products are listed in Table 4.

Cereal based – Wheat and rice is the staple food of most of the cultures around the world. Along with being good substrates for the growth of probiotic bacteria, cereals also consist of potentially prebiotic fibers. Strains of *L. plantarum, Candida rugosa*and *Candida lambica* isolated from traditional Bulgarian beverage was resistant in 2% bile concentration. Some of the most commonly found probiotics in fermented cereals are *L. plantarum, L. acidophilus, L. reuteri and L. fermentum.*

Human health benefits: There is increasing evidence that probiotics exert beneficial effects like improved intestinal health, enhanced immune responses, reduced serum cholesterol and cancer prevention [2,3,5,6]. The health benefits exerted by probiotic bacteria is strain specific which means that not all strains of a the same bacterial species will be effective against the same disease or disorder. A number of clinicians around the world use probiotic therapy for prevention and treatment of diseases. Table 5 consists of few such disorders which is being tested using probiotics.

Table 1: The taxonomic hierarchy to which Lactobacillus currently belongs

Domain	Kingdom	Phlyum	Class	Order	Family	Genus
Bacteria	*Monera*	*Firmicutes*	*Bacilli*	*Lactobacillales*	*Lactobacillaceae*	*Lactobacillus*

Table 2: Types of Probiotics

Bacteria	**Fungi**
Lactococcus *Streptococcus* *Lactobacillus* *Enterococcus* *Leuconostoc* *Bifidobacterium* *Propionibacterium* *Pediococcus*	*Saccharomyces* *Aspergillus* *Candida*

Table 3: Most common probiotic microorganisms

***Lactobacillus* sp**	***Bifidobacterium* sp**
L. rhamnosus *L. casei* *L. acidophilus* *L. plantarum* *L. pentosus* *L. brevis* *L. delbrueckii* *L. paracasei* *L. bulgaricus* *L. fermentum* *L. cripatus* *L. gallinarum* *L. gasseri* *L. johnsonii* *L. reuteri* *L. salivarius*	*B. lactis* *B. infantis* *B. adolescentis* *B. bifidum* *B. animalis* *B. longum* *B. breve* *B. thermophilum*

Table 4: Examples of Probiotic food

Dairy	**Plant**	**Cereal**	**Juice based**	**Fermented**
Milk	Onions	Adai	Tomato juice	Idli
Yogurt	Leeks	Injera	Beet juice	Dosa
Cheese	Almonds	Kisra	Ginger juice	Tempeh
Ice-cream	Apples	Togwa	Cabbage juice	Kimchi
Whey milk	Bananas	Kishk	Carrot juice	Kombucha
Whey cheese	Garlic	Burukutu	Cranberry juice	Pickles
	Asparagus	Llambazi	Pineapple juice	Sauerkraut
	Oats		Orange juice	Miso
			Green coconut water	Kefir

Table 5: Diseases in which probiotic therapy was used

Pathologies	Types	Potential probiotics
Gastrointestinal disorders	Antibiotic-Associated Diarrhea	*L. rhamnosus, S. boulardii*
		L. casei
	Infectious diarrhea	*L. rhamnosus GG, B. animalis Bb12*
		L. reuteri, L. caseiShirota
	Travellers' diarrhea	*L. rhamnosus, S. boulardii*
		L. acidophilus, B. bifidum
	Gastroenteritis	*L. reuteri, B. bifidum*
		S. thermophilus, B. lactis
	Inflammatory Bowel Disease	*L. rhamnosus GG, S. boulardii*
		L. acidophilus, L. johnsonii
	Helicobacter pylori infection	*Bifidobacterium BB-12*
		L. acidophilus La-5
	Lactose intolerance	*S. thermophilus*
		L. delbrueckii spp. Bulgaricus
	NetrotizingEnterocolitis	*L. rhamnosus GG*
		L. reuteri
Cardiovascular diseases	Obesity	*L. gasseri, L. paracasei*
		L. sporogenes. E. faecium
		Pediococcuspentosaceus
	Diabetes	*L. casei, B. longum, B. breve*
		L. acidophilus, L. plantarum
		L. reuteri
Other diseases	Cancer	*L. rhamnosus GG, L. gasseri*
		B. longum, B. lactis
		P. freudenreichii
	Allergy	*L. rhamnosus*
		L. fermentum, L. salivarius
		B. lactis
	Liver diseases	*L. casei, L. helvectius*
		L. rhamnosus GG, S. boulardii
		B. adolescentis, B. longum
	Bacterial Vaginosis	*L. acidophilus, L. fermentum RC-14*

DISCUSSION

Data from many researches support that when the human diet is supplemented with probiotics, they benefit the human health by producing wide range of metabolites and help maintain homeostasis. However, the development of probiotics for human consumption is still in its early stages. In-depth research is crucial to determine which probiotics and which dosages and the most efficient as well the safest. With increase in awareness among people, the future of probiotics in nutrition and medicine is promising. The probiotics industry is an ever-growing entity. The opportunities in the field of probiotics stems from our knowledge about the probiotic microorganisms influence the indigenous microbiota and interact with the host. Current technological advancements present us with exciting possibilities for probiotics research and applications. As early career scientists, we want to be a part of a world where humans and microorganisms live in harmony and make use of beneficial microbes to help solve global problems related to food, health and environment.

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

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