FERMENTATION ASSISTED FUNCTIONAL FOODS.

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Introduction

Food is a paramount basic need of life that clinches the nutritional requirement of an individual. The nutrients like fats, carbohydrates, proteins ,vitamins, minerals are needed for growth and maintenance, whereas non-nutrient factors (fiber, phytochemicals, antioxidants, probiotics, prebiotics, etc.) augment human health by positively modulating the host physiology and global epigenetic imprints . Dietary intake of selected categories of foods called as nutraceuticals or foodiceuticals or functional foods or medifoods regulate the disease controlling mechanisms either as prophylactics or therapeutics .

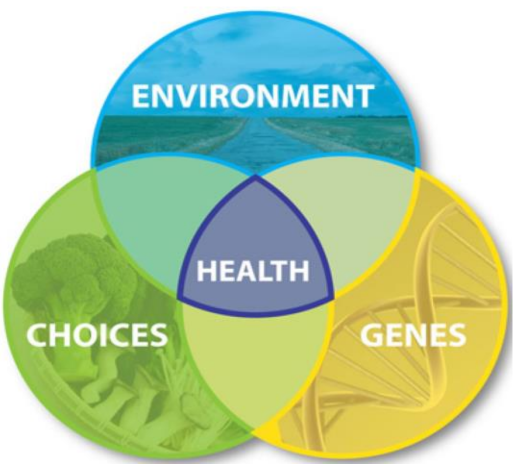
Food is the single strongest lever to optimize human health and environmental sustainability and there is an immense challenge to provide healthy modified diets using traditional food processing techniques. For much of human history and most of humankind, fermented foods have been traditionally valued and are sometimes categorized as “functional foods” due to their purported health benefits. The concept of functional foods has led to development of foods providing basic nutrition, warranting good health and longevity. Natural ingredients are the most influential drivers of functional foods and are part of the food industry. Fermentation desirably modifies food constituents by increasing the palatability, organoleptic properties, bioavailability of nutrients and alters the functional properties of food and frequently serve as carriers for probiotic bacteria.

The consumption of fermented foods containing live microorganisms has emerged as an important dietary strategy for improving human health .In general, bacteria , yeast and fungi contribute to food fermentations. There is a considerable confusion about which fermented foods actually contain live microorganisms, as well as in understanding the role of these microbes on the gut microbiome .Perhaps the easiest and most common way to introduce potentially beneficial microbes to the gastrointestinal tract is via consumption of microbe-containing foods, and fermented foods and beverages are a suitable option.

Many microbes associated with fermented foods may have the capacity to survive digestion, reach the gastrointestinal tract, and ultimately provide health benefits . The benefits of fermented foods has led to the development of synbiotic foods with prebiotics and probiotic bacteria for improved human health through modulation of the gut microbiome. New functional foods with positive health effects are in high demand due to changing eating patterns brought by urbanization and rising consumer knowledge of good diets.

Diet and Gut Microbiome

Modern lifestyle or various diseases lead to an impaired composition of human gut microbiota(HGM)



, contributing to gut diseases , metabolic disorders and neurological diseases. A healthy diverse diet with limited amounts of refined grains, highly processed foods and added sugars should enhance health and provide optimal nutrient intake . Global consumption of fruits, vegetables, nuts and legumes has increased with a decreased consumption of red meat and sugar among health conscious consumers . Modification of diet can prevent, treat, or alleviate some of the symptoms associated with obesity, celiac disease, and functional gastrointestinal(GI) disorders and improve general health.

Microbiome refers to the collective genomes of the microorganisms in a particular environment, and microbiota is the community of microorganisms themselves . A normal healthy gut microbiome is complex and consists a highly diverse collection of microorganisms (approximately 100 trillion)consisting of bacteria, viruses, fungi, parasites, viruses, protozoa, bacteriophages , archaea and other tiny organisms . The "human microbiome project" has reported the number of other bacterial cells in the human body to be about 10 times the number of human cells , with more than 1000 different metabolically active bacteria (*Bacteroides* and *Firmicutes* being the main dominant flora) .This flora is able to work with the host immune system to resist changes associated with stress and have a strong impact on control of energy metabolism, the metabolic functions , immune system ,nutrition and intestinal functions of the host . The residual exopolysaccharides of microorganisms, , microbial building blocks, proteins, or metabolites, are likely to directly or indirectly interact with human physiology as well as the human gut microbiome, thus influencing human health. Considering the significance of the gut microbiota on human health, there has been ever-growing research and commercial interest in various aspects of prebiotic and probiotic functional foods to counteract "dysbiosis" by replacing the harmful microflora with beneficial microorganisms ..

It is believed that harmful bacteria begin to predominate in various disorders, such as obesity, autoimmune diseases, and infections . Probiotics play a role in maintaining the immune balance in the GI tract through direct interaction with immune cells . Thus, probiotics can be considered as a potential adjuvant therapy .Significance of the microbiome gut–brain axis in the treatment of neurodegenerative illnesses has advanced in recent years. Research indicates the quick gut lumen communication with the brain after meals and the significance of the microbiota in controlling homeostasis and appropriate signaling with the finding of "neuropod cells". A positive correlation between maternal consumption of fermented foods and sleep duration in one-year-old infants was shown which probably could be the result of changes in the gut microbiota of expectant mothers owing to consumption of fermented foods . The gut microbiota plays a crucial role in the conversion of dietary flavonoids and the interaction between flavonoids and intestinal microbiota not only regulates the composition of HGM and the functional enhancement of probiotics but it significantly improves the bioavailability and bioactivity of flavonoids thus exerting a regulatory effect on intestinal diseases.

Dairy and non-dairy fermented foods could serve as carriers of probiotics, prebiotics, and/or bioactive compounds (phenolic compounds, antioxidants, bioactive peptides, etc.) and significantly impact the gut microbiota . During the fermentation process, primary and secondary metabolites that are considered bioactive compounds are produced, such as antibiotics, antimicrobial peptides, carbon dioxide, alcohol, vitamins, folates, and organic acids viz Short chain fatty acids (SCFAs) butyrate, acetate, and propionate. Bioactive compounds are molecules with therapeutic potential, are reported to be beneficial to the gut, they improve the intestinal barrier, inhibit pathogen development and the production of toxic elements and help prevent metabolic disorders.

BOX 1: Glossary

- **Microbiome—**the collective genomes of the micro-organisms in a particular environment
- **Microbiota—**the community of micro-organisms themselves
- **Microbiota diversity—**a measure of how many different species and, dependent on the diversity indices, how evenly distributed they are in the community. Lower diversity is considered a marker of dysbiosis (microbial imbalance) in the gut and has been found in autoimmune diseases and obesity and cardiometabolic conditions as well as in elderly people

Food fermentation: ***Benefits, changes brought about in food and types of food fermentation***

Food fermentation is a practice that precedes human history and populations around the world obtain a considerable portion of their nutritional needs and incomes through fermented foods. The term “fermentation” comes from the Latin word “fermentum”, when applied to foods, fermentation has a much broader meaning as opposed the strict biochemical definition of “an ATP-generating process in which organic compounds act as both donors and acceptors of electrons”. Fermented foods and beverages include “foods that are made through desired microbial growth and enzymatic conversions of food components” It is estimated that over 5,000 varieties of fermented foods and beverages are produced and consumed around the world from diverse raw materials (substrates) such as cereals, roots and tubers, meat, dairy products, fish, fruits, vegetables and legumes . The microorganisms used in the production of fermented foods and beverages include bacteria (e.g. lactic acid bacteria (LAB) such as *Lactobacillus, Streptococcus, Enterococcus, Lactococcus* and *Bifidobacterium*) and molds (e.g. *Aspergillus oryzae, Aspergillus sojae, Penicillium roqueforti* and *Penicillium chrysogenum*), and yeasts (e.g. *Saccharomyces cerevisiae, Andida krusei* and *Candida humilis*). The emerging ‘biotics’ including probiotics, prebiotics, synbiotics, postbiotics, oncobiotics, paraprobiotics, pharmabiotics and psychobiotics have gained much attention in the recent years. Fermentation is increasingly being used for the production of probiotics, prebiotics and synbiotics with high viability and functionality. Most recently, fermented foods and ingredients have attracted growing interest because they can facilitate healthy gut microbiota and promote human well-being.

Benefits of food fermentation :

Science and technology face a major challenge in the creation, development and improvement of foods with additional health properties, the so-called functional foods, to meet consumer’s expectations. Food fermentation represents one of the “ancient biotechnology”, widespread around the world and is considered a good process for, improving sensory properties and nutritional properties.

Fermentation helps break down large organic molecules via the action of microorganisms into simpler ones and provide a solid guarantee to improve quality, nutritional value , organoleptic properties of many perishable foods and extend shelf life owing to the production of secondary metabolites with high biological value . Fermented foods attain their characteristic taste, flavor, colour, consistency, appearance, texture, improved vitamins, essential amino acids, anti-nutrients, proteins, shelf life and functional properties and health benefits through the effects of microbial assimilation, metabolites production, and enzymatic activities. Fermented foods can be considered as a dietary source of live organisms. The Indian food pyramid explicitly promotes the consumption of fermented foods testifying their significance in actual human nutrition framework by the direct and indirect inclusion in the dietary guidelines of several countries.

Fermentation is done with mono or mixed cultures such as bacteria, fungi, and yeasts, these microorganisms act parallel or in a sequential manner, changing dominant microbiota . For example, yeast enzymes convert sugars and starches into alcohol, while proteins are converted to peptides/amino acids. The microbial or enzymatic actions on food ingredients tend to ferment food, leading to desirable biochemical changes responsible for the significant modification to the food . Complex phytochemical compounds degrade into smaller, more bioactive polyphenols proving advantageous for the growth and metabolism of the microbiome , as well as for reducing inflammatory reactions and cytokine production . Additionally, reducing oxidative stress, reducing free radicals, controlling antioxidant enzyme activity, increasing immune system activity, and neutralizing free radicals are all plausible mechanisms for the beneficial effects of fermented foods. Consumption of kimchi and other fermented vegetables showed reduced incidence of asthma and atopic dermatitis ,improved fasting blood glucose and other metabolic syndrome symptoms in overweight and obese in Korean adults Reduced risks of Type 2 diabetes , high blood pressure and improved plasma triglyceride levels was seen on consumption of fermented soybean foods rich in phytoestrogens and bioactive peptides among Japanese adults . Strongest evidence is for yogurt in improved lactose tolerance, due to the release of β-galactosidase by the microbes.

Beyond the potential of fermentation, the type of raw material or substrate (cereal, pseudocereals, and legumes) used is seen of key importance for the optimal delivery of bioactive compounds for human nutrition.

Changes in food on fermentation: *microbiological activities and biochemical modifications and health impact*

Fermentation is a natural way of improving vitamins, essential amino acids, anti-nutrients, proteins, appearance, texture, improvement in shelf life and colour. Sensory properties of food also shape making food choices and the adoption of novel foods, the potential of fermentation to create palatable and delicious flavors and textures will be of high importance in shifting eating habits toward more sustainable options. Microorganisms are responsible to initiate the fermentation process of the food , which involves the chemical transformation of primary compounds into new secondary metabolites . Changes occurring during the fermentation may be classified into five stages (Figure 1). In a first stage, sugars are transformed into end products, such as simpler acids, carbon dioxide and alcohols. This in turn leads to an increase of the nutrients available in the food. In a second stage, polymers are hydrolyzed and bioactive compounds are enzymatically synthesized, such as antioxidants. In a third stage the bioavailability of nutritive compounds and the concentration of vitamins and amino acids is enhanced, and there is a greater bioavailability of phytochemicals and minerals. Later, in stage 4, the toxic and anti-nutritional compounds are degraded. Finally, the synthesis of promoters for absorption and uptake occurs

1. Food sources containing high fiber content , toxins, anti-nutritional factors(ANFs) such as phytic , oxalic acids , tannins, raffinose , alkaloids, lectins, pyrimidine glycosides (e.g. vicine and convicine) , protease inhibitors and trypsin inhibitors , that chelate metal ions , decrease the digestibility and reduce the bioavailability of other nutrients, can be transformed into palatable and nutritionally improved foods through fermentation.
2. Considerable enhancement in digestibility of proteins can be brought about by fermentation.
3. Reduction of the cyanide content to consumable levels in the roots and leaves of the cassava plant (*Manihot esculenta*), staple foods in many parts of the Global South and the removal of flatulence factors in legumes has been reported on its fermentation
4. Common dietary polyphenols undergo fermentation and produce biotransforming phytochemicals that are able to trigger favorable changes that promote microbial development .

5. The Short chain fatty acids (SCFAs) that are produced during fermentation , specifically the butyrate, have been associated to integrity maintenance of the intestinal mucosa ,reducing the risk of developing colon cancer by reducing cell proliferation and stimulating cell differentiation. It is also associated with maturation of the enteric neurons. In addition, SCFAs have been identified as important modulators of the immune system, helping chronic inflammation.
6. Microbial fermentation is a powerful tool for the *de novo* creation of delicious flavors and textures eg: different textures of cheese, the flavor of chocolate, soy sauce, wine, beverages, condiments, etc. Fermentation leads to the generation and accumulation of volatile and non-volatile aroma or aroma-active compounds including those related to bitter, umami, sweet, sour and salty tastes. The flavour changes can be attributed to the production of alcohol , aldehydes, amines, esters, fatty acids (especially those volatile species), ketones, lactones , terpenes, organic acids, phenols, thiophene, diacetyl , sulfur compounds, pyrazines and other nitrogen-containing compounds .
7. Fermentation conditions as well as microbial activities reduce the cell count of pathogenic organisms, either through changes in pH, by nutrient competition, or by the production of preservatives with anti-microbial or anti-fungal activity in fermented foods.
8. Fermentation increases the extractability of bioactive compounds from various raw materials and functional biomolecules which are part of the LAB/yeast metabolism.
9. Fermented milk and yogurt consist of higher in vitro antioxidant properties, owing to release of biopeptides that follow the proteolysis of milk proteins, particularly α-casein, α-lactalbumin, and β-lactoglobulin.
10. Microbial fermentation has also enabled synthesis of GABA (g- Aminobutyric acid) ,a chief inhibitory neurotransmitter of the central nervous system with a role to play in induction of antihypertension, prevention of diabetes, diuresis and tranquiliser effects .
11. Fermented foods could be a food-based alternative for delivering folic acid to at-risk populations in dealing with global deficiency problem.
12. Fermentation also helps in the reduction of the energy needed for cooking
13. Fermented foods are often safer to consume than their raw counterparts

14. The increased shelf life of many fermented foods enables the reduction of food loss across the food production value chain, ranging from overproduction at times, thus improving the efficiency and resource use of food production.

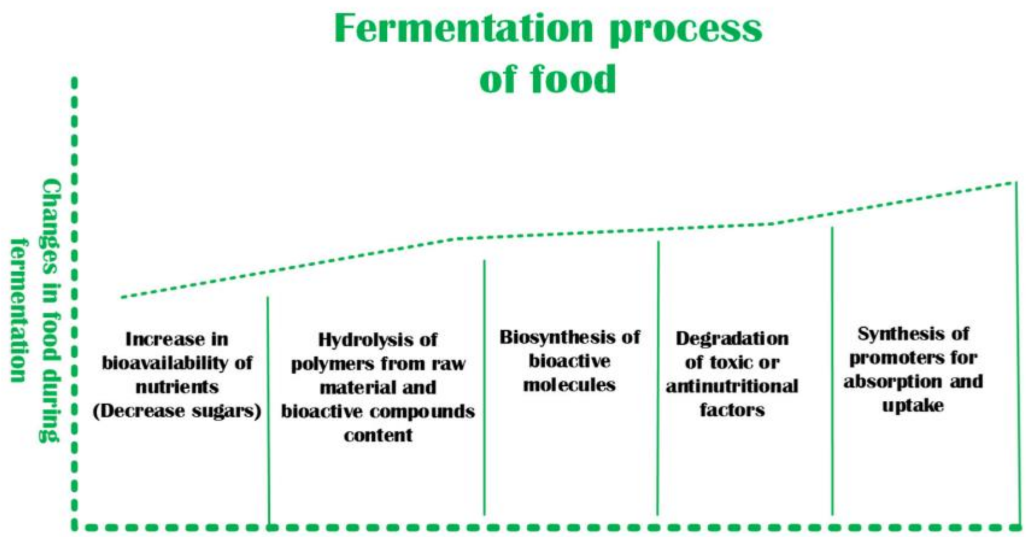


Fig.1. Changes during fermentation in food, into five stages. In first stage, sugars are transformed into end products (simpler acids, carbon dioxide and alcohols). This in turn leads to an increase of the nutrients available in the food. In second stage, polymers are hydrolyzed and bioactive compounds are enzymatically synthesized, such as antioxidants. In third stage, the bioavailability of nutrients and the concentration of vitamins and amino acids is enhanced, and there is a greater bioavailability of phytochemicals and minerals. In stage 4, the toxic and ANFs are degraded. Finally, the synthesis of promoters for absorption and uptake occurs. Source: R. B. Cuvas-Limon *et al*, (2021).

Table 1. Bioactive compounds and functional properties of fermented foods.

Functional properties	**Bioactive compounds**	**Microorganisms**	**Synthesized in fermented foods**	**Health benefits**
Antimicrobial Properties	Antimicrobial compounds (Bacteriocin) Bacteriocin Pediocin	LAB *Lactococcus lactis* BH5, Leuconostoc citreum GJ7, Pediococcus pentosaceus.	Vegetables Milk Kimchi	Protection of the GI tract by SCFAs production, pH modulation, hydrogen peroxide, and production of bacterial type inhibitory substances. Anticancer effects

	Nisin Z Antimicrobial compounds	Lactococcus lactis. Weisella cibaria.	Dahi (India) Fermented cabbage product	Antiviral effects
Antioxidant Properties	Antioxidants compounds, Peptides, Enzymes.	Bacillus, Lactobacillus, Bifidobacterium	Asian fermented soybean foods Soybean food of India and Nepal	Modulate circulatory oxidative stress Protect cells against carcinogen-induced damage Antioxidant Anti-inflammatory Anticancer
Immunomodulatory Properties	Bioactive peptides, Amino acids.	Proteolytic microorganisms (Bacillus), LAB.	Fermented beverages	Immune modulating effects Maintain the energy balance Contribute to antioxidant effects ,Anti-inflammatory effects
Inhibitory properties	Producing peptides and amino acids.	Enzyme (ACE)	Kefir Koumiss Yogurt	Minimize the risk of developing chronic or degenerative diseases.
Enhancement of metabolic functions	Lipases, Proteases, Esterases, Amylases b-galactosidase, Lactase	LAB, Bifidobacterium.	Fermented beverages	Help to improve the metabolism Improve nutrient absorption Mitigate lactose intolerance
Production of SCFAs	Acetate, Butyrate, Propionate.	LAB	Fermented beverages	Provides 60–70% of the energy needed by the colon, muscle and brain cells .Therapeutic effects : Anti-inflammatory bowel ,Anti-colon cancer ,Help to heart diseases protection ,managing obesity and diabetes.
Production of vitamins	Vitamin B12, Vitamin K, Vitamin B6,	Bifidobacterium, Lactobacillus.	Fermented beverages	Help to synthesize DNA Combat cardiovascular disease

	Cobalamin, Folate, Thiamin.			

Source: R. B. Cuvas-Limon *et al*, (2021).

Types of food fermentation:

Fermented foods are commonly described as foods or beverages processed by uncontrolled natural fermentation or with controlled starter cultures and enzymatic changes of primary and secondary components of foods through cost-efficient bioprocess. Various factors affect food fermentation, such as composition of the substrates, the fermenting microorganisms, food treatment and the length of fermentation during processing . Based on the nature of the matrices (substrate) subjected to fermentation, worldwide fermented foods are categorized into nine principal classes: (a) fermented cereals; (b) fermented vegetables and bamboo shoots; (c) fermented legumes; (d) fermented roots/tubers; (e) fermented milk products; (f) fermented and preserved meat products; (g) fermented, dried and smoked fish products; (h) miscellaneous fermented products; and (i) alcoholic beverages. The substrate must have a rich chemical composition, including high concentrations of mono and di-saccharides and the minerals necessary to start the microbial metabolism. But at the same time, it must not contain inhibitors such as toxins that inhibit the growth of these microorganisms. It is true that environmental conditions influence the fermentation process.

Food fermentations are classified based on added or naturally present starter cultures as or **controlled** and **uncontrolled** (Natural/ spontaneous) fermentation and based on the product produced. Based on the dominant metabolic process, three fermentation processes include: acidic, alkaline, and alcoholic fermentation, each contributing in a unique way . Active research in the area of "**alkaline food fermentation**" began in the late 1980s, whereas lactic acid fermentation had benefited from detailed scientific research dated as far back as in 1950. Acid fermented products or alcoholic beverages are widely described with documented nutritional and health benefits , however, a relatively less is known on alkaline fermented foods (AFFs) , thus the focus here will be on AFFs.

1. **Acidic fermentation** : is mainly carried out by lactic acid bacteria(LAB) ,acetic acid bacteria (AAB) and yeast. Lactic acid is the main metabolite along with different types of organic acids in

LAB fermentation. Curd, Yogurt and sourdoughs are produced through lactic acid and yeast fermentation respectively. In a process designated as “oxidative fermentation,” which is a source of energy to the cells, AAB (mainly *Acetobacter*) are characterized by their ability to oxidize carbohydrates, alcohols, and sugar alcohols (polyhydric alcohols or polyols) into their corresponding acetic acid (vinegar) as the primary product, organic acids, aldehydes, or ketones.

2. **Alkaline fermentation** is carried out by different species of *Bacillus* and fungi and often occurs during seed fermentation. Eg. alkaline fermented foods such as dawadawa, ugba, bikalga, kinema, natto, iru ogiri and thua-nao.

3. **Alcoholic fermentation**, with AAB and yeasts (predominant organisms), results in the primary products of ethanol and CO_2.Eg. alcoholic beverages such as beer, wine, cider.

Alkaline-fermented foods (AFFs) : ***Nutritional significance of AFFs***

AFFs made from different raw ingredients, constitute a group of less-known food products in developing and a few developed countries. Alkaline-fermentation is defined as a fermentation process during which the pH of the substrate (usually protein-rich foods) increases to alkaline values(pH 8–10) and is due to degradation/ or hydrolysis of proteins (proteolysis) from the raw material into peptides, amino acids(essential) and further degradation of amino acids to ammonia by dominant microorganisms, *Bacillus* spp., or due to alkali-treatment during production . The rise in pH gives the food a strong ammoniacal smell. By limiting the growth and metabolism of the bacteria while not inhibiting the action of flavor generating proteolytic enzymes, production of ammonia can be restricted, and can be achieved by holding the fermented beans at sufficiently low temperature during maturation. This can also be attained by adding glycerol as humectant to partially fermented beans or by restricting oxygen supply. Proteolysis is considered to be the most important metabolic activity during alkaline fermentation.

Traditional AFFs of Africa and Asia are usually processed by spontaneous fermentation (depends on autochthonous or resident microorganism present in the raw substrate and/or surrounding environment) but can be developed by controlled fermentation also. Predominant microorganisms in AFFs include *Bacillus subtilis*, *Bacillus subtilis var. natto, Bacillus cereus, Bacillus megaterium, , Bacillus thuringiensis, Bacillus endophyticus, Bacillus licheniformis, Bacillus borstelensis, Bacillus pumilus, Bacillus coagulans, Bacillus circulans, Bacillus amyloliquefaciens,* *Bacillus firmus, , Bacillus megaterium, Paenibacillus polymyxa, Lysinibacillus sphaericus,* and *Lysinibacillus fusiformis*,but other secondary microorganisms such as *LAB, staphylococci,* and *micrococci* are also involved. *Bacillus spp.* are used as probiotic for human . Important features of alkaline-fermentations are changes which occur in the texture and color of the products during fermentation on softening . softening of plant based foods leading to the desired texture may be attributed to pectic and proteolytic enzymes that readily hydrolyze the pectin and protein . The color development may be due to non-enzymic browning reactions involving the amino groups of amino acids and the non-reducing sugar constituents and microbial activity. Various alkaline fermentations are characterized by the extensive production of sticky whitish mucilaginous polymers (assumed to be polysaccharides).

AFFs as functional foods: *Nutritional significance and health benefits of AFFs*

AFFs play significant roles in achieving dietary sufficiency in several traditional communities where they are produced and consumed. Plant-based substrates are usually used with soybean being the most common . Two main features of alkaline fermentation process include;

1. **Hydrolysis of macronutrient molecules** i.e., complex carbohydrates like oligosaccharides , proteins, and fats by enzymes produced by predominant bacteria, thereby enhancing nutrient bioavailability and digestibility of the fermented product compared with the unfermented substrate . For example, *B. subtilis* fermentation has been shown to effectively hydrolyse soybean proteins and polysaccharides, resulting in low-molecular-weight, water-soluble products that require little further degradation by gastrointestinal enzymes . Several studies have reported increasing levels of free amino acids, non-protein and soluble nitrogen content during alkaline fermentation ,increases in the concentration of cysteine, methionine, leucine, isoleucine, tyrosine, phenylalaline and even lysine which is limiting in plant foods is reported.

Most plant based sources used to produce AFFs are rich in carbohydrates of which a large proportion are non-digestible oligosaccharides such as galactamannan, stachyose, raffinose, verbascose, sucrose and arabinogalactan .They act as functional prebiotics and facilitate the action of beneficial microbes. Some of these non-digestible carbohydrates are associated with abdominal distension and flatulence in humans . During fermentation microorganisms hydrolyze starch and non-digestible carbohydrates into sugars (melibiose, fructose, galactose) which are readily digestible by humans and in addition positively influence the texture of the product by softening the tissue . *Bacillus spp.* are producers of amylase, galactanase, galactosidase, glucosidase, and fructofuranosidase, enzymes involved in degradation of carbohydrates during alkaline fermentation .

Crude fat content and fatty acid profiles change during alkaline fermentation.The dominant microbial species involved in the alkaline fermentations have been shown to possess lipolytic activity .Although most studies have reported increase in free fatty acid levels , very few have given contradicting results. The composition of the free fatty acids like saturated fatty acids, polyunsaturated fatty acids and monounsaturated fatty acids varies. The presence of palmitic, stearic, arachidic, behenic, lignoceric, linolenic, palmitoleic , myristic acids and gadoleic acids and high concentrations of linoleic and oleic acids have been reported in AFFs .The presence of linoleic and oleic acids which can be converted into polyunsaturated fatty acids enhance the nutritive value of the products since they are essential for human nutrition .

2. **Enzymatic degradation** resulting in significant reduction of naturally occurring toxic components, allergens, and ANFs in the raw food substrate, thereby transforming otherwise inedible, difficult to digest or potentially toxic raw materials into palatable and food products delivering essential nutrients. During fermentation, protease and amylase enzymes act upon protein and insoluble sugar, and therefore improve the nutritional value of fermented products.

Natto with its distinct odor , flavor and stringy material (a polypeptide of glutamic acid and fructan) is one of the most popular alkaline-fermented soybean products. Natto contains nattokinase, a polypeptide composed of a total of 27 amino acid residues. During the production of fermented soy-based natto ,protein, lipids and minerals such as iron, zinc and calcium tend to increase with a decrease in lipid content. Another notable compositional change is the significant increase in vitamin K content in natto that has been attributed to vitamin K2 (menaquinone-7 or MK-7) synthesis by *B. subtilis natto* . Epidemiological studies have also shown positive correlation between increased consumption of Japanese natto with bone density among Japanese females as a result of increase in serum vitamin K and ϒ-carboxylated osteocalcin, both of which facilitate bone mineralization . Fermentation also increased thiamine and riboflavin contents by 3-folds and a 5-fold increase in vitamin B12 content compared to the raw substrate . Fermented soybeans are rich in isoflavone genestein and gammapolyglutamic acid (PGA), which is an aminoacid polymer giving the characteristic sticky texture to the product , acts as dietary fiber to reduce serum cholesterol level and improves calcium absorption. Isoflavone genestein acts as a chemopreventive agent against cancer .

Formation of aroma compounds in AFFs:

Flavor of traditional AFFs has mainly been attributed to various volatile compounds viz: Pyrazines (acetoin, 2,5–dimethylpyrazine, tetramethylpyrazine, 3-methylbutanal, 2-decanone, 3,5-dimethylphenylmethanol, ethyl linoleate , chlorobenzene), aldehydes, ketones, esters, alcohols, acids, alkanes, alkenes, benzenes, phenols, sulphurs, amines , pyridines and furans groups produced through the metabolic activities of *Bacillus* spp. during fermentation . The heat treatment during the production contributes to the flavor by formation of pyrazines originating from reactions between sugars and amino acids . Some volatile aroma compounds may be lost during sun-drying of AFF products.The profiling of volatile compounds production during controlled microbial alkaline fermentation of legumes is one of the steps which could give information for the future selection of starter cultures. The amino acid, in particular glutamate as well as peptides also contributes to flavor enhancement. Free fatty acids are also known to contribute positively to the production of characteristic flavors in food but high levels of free fatty acids may cause rancidity easily .

Food safety of alkaline fermented products

It is generally recognized that alkaline-fermentation produces safe products .For most AFFs, raw materials undergo a long cooking time (up to 40 h in some cases) prior to fermentation and this contributes to an elimination of non-spore–forming pathogenic bacteria. .In addition, the AFFs are stable and well-preserved due to the antimicrobial effects of the dominant microorganisms towards harmful bacteria and moulds. *B. subtilis* and *B. pumilus* isolated from AFF was able to inhibit and inactivate both Gram-positive and Gram-negative bacteria including *Micrococcus luteus, Staphylococcus aureus, Bacillus cereus, Enterococus facium, Listeria monocytogenes, Escherichia coli, Salmonella typhimurium, Shigella dysenteriae, Yersinia enterocolitica*, as well as *Aspergillus* mould. *Bacillus* strains isolated from another AFF is found to produce antifungal substances (iturin A, surfactin). In addition the high pH value and free ammonia present in AFFs makes it rather difficult for microorganisms which might otherwise cause spoilage of the product to grow .

Even though AFFs generally can be considered safe as mentioned above, they can sometimes involve a risk of food borne disease. This is a problem common to all types of traditional fermented foods. Further the fact that the production is made in homes using rudimentary equipment under poor hygienic conditions and no training on Good Manufacturing Practices (GMP) , can contribute to make AFFs unsafe. This allows a constant recontamination of the fermented seeds. Thus positive actions like adequate training on food fermentation under hygienic conditions based upon guidelines of GMP and hazard analysis critical control point (HACCP) , the development of better equipment i.e., improved fermentors constructed with maximum emphasis on maintenance, sanitation and reliability for the process with minimum capital investment and operating cost and development of desirable starter cultures for controlled fermentation can improve the safety of traditional AFFs with improved nutritional and hygienic quality as well as stability.

Spontaneous Versus Controlled Fermentation:

The fermentation process can occur spontaneously with uninoculated cultures (**Natural /Uncontrolled fermentation**) or can be triggered by adding starter cultures (**Controlled fermentation**).

Spontaneous Fermentation

Fermentation can occur as a natural(spontaneous phenomenon) as long as there is a raw material (substrate) available, either animal or vegetable, and a microorganism consortium naturally present in the substrates to begin fermentation activity. For so-called natural or spontaneous fermented foods, the microorganisms are autochthonous and are naturally present in the raw material , equipment or manufacturing environment.

The microorganisms may participate in parallel or act in a sequential manner with a changing dominant flora during the course of the fermentation. The common fermenting bacteria are species of *Leuconostoc, Lactobacillus, Streptococcus, Pediococcus, Micrococcus,* and *Bacillus*.The fungi genera *Aspergillus, Paecilomyces,Cladosporium, Fusarium,Penicillium,* and *Trichothecium* are most frequently found in certain products. Through various natural fermentation processes, lactic acid bacteria (LAB), yeasts, and/or fungi ferment various substrates of coarse cereals and legumes to produce various types of food .They typically result in products that contain very similar microorganisms (even the same species), regardless of provenance. For example, fermentations of cabbage and other green leafy vegetables are all initiated by *Leuconostoc mesenteroides* followed by *Lactiplantibacillus* species and *Levilactobacillus brevis*, independent of whether the product is called sauerkraut (Europe and North America), kimchi (Korea), suan-cai (China) or sinki (Nepal). This highly reproducible succession of fermentation microbiota in spontaneous plant based fermentations reflects the stable association of these organisms with the raw materials .Thus, provided that the raw materials and environmental conditions are consistent with the typical practices used for making that food and that salt concentrations, pH, atmosphere or other expected control measures are in place, unpredictable events, which constitute fermentation failure, are relatively rare . Spontaneous fermentations can also provide an opportunity to isolate strains that possess industrially relevant characteristics, including producing unique flavours . Incorporating these strains in mixed fermentations can improve the flavour of the resulting products, in addition to gaining more control over the process .As the popularity of spontaneous fermentations soars, it becomes equally important to characterise and understand their fermentation dynamics to gain control over the process in order to achieve improved quality attributes .

Since spontaneous fermentations involve a complex consortium of microorganisms, the phenotypic and genotypic behaviour of an individual microorganism is very much dependent on the community assembly, which is strongly influenced by biotic and abiotic factors that govern the fermentation ecosystem .Despite the great utility of spontaneous fermentation for the conservation of plant based foods, the chance of fermentation failure, in terms of inappropriate inhibition of spoilage or pathogen microbes, and nutrients composition, unwanted sensory traits and the risks of the implantation/domination of microbial strains dangerous for the human health, are significant. In the framework of heterogeneous microbiota of spontaneous fermentation, it is possible to find microbial pathogens and/or strains liable to synthetize toxic by-products such as mycotoxins, ethyl carbamate and biogenic amines. These microbial contaminants can reduce the safety of the corresponding fermented product.Thus relying on spontaneous uncontrolled fermentations poses serious challenges for the safety and the quality of fermented foods.

Controlled fermentation

Safety of fermented food associated with microbes in spontaneous fermentation can be conciliated with tailored starter cultures for specific productions in such a way to mimic protechnological microbial diversity associated to spontaneous fermentation .Selected starter cultures are used to bring about fermentation, the use of autochthonous cultures isolated from fermented products which are also regarded as probiotics, may speed up the fermentation process, guarantee prolonged shelf life and improved functional and organoleptic properties of the fermented foods, provide uniform quality products and render health benefits .

Important criteria for selection of starter culture(s) to be used in the manufacture of functional foods include probiotics properties, antimicrobial properties, antioxidant , peptide production , fibrinolytic activity , poly-glutamic acid , degradation of antinutritive compounds, etc. The use of appropriate starter cultures would improve product quality through rapid accelerated metabolic activities, improved and more predictable fermentation processes, desirable organoleptic characteristics as well as improved safety and reduced hygienic risks. Starter culture technology represents a cornerstone in the assurance of quality and the safety of fermentation. Generally, the importance of the adoption of a starter culture regimen is to minimize the risk of food-borne diseases , to pursue personalized nutrition, to reach new health targets, to sustainably increase shelf life, particularly of artisanal, traditional, typical, organic and biodynamic productions, yield increase, and food security .

Functional foods :Prebiotics , probiotics , synbiotics and postbiotics in food fermentation

The interest in functional foods continues to increase rapidly around the world and synbiotic foods play important role in nutrition due to their health benefits. The demand for the food formulations containing nutrients such as dietary fibers, fatty acids, proteins, vitamins, minerals and flavonoids that are naturally present in foods or added later is increasing.

Definitions :

Prebiotics are defined by the International Scientific Association for Probiotics and Prebiotics (ISAPP),2010 as “selectively fermented ingredients that result in specific changes in the composition and/or activity of the gastrointestinal microbiota , thus conferring benefit(s) upon host health" . The definition of prebiotic was quite recently revised as "*a substrate that is selectively utilized by host microorganisms conferring a health benefit*"

Probiotics can be defined as "*live microorganisms that, when administered in adequate amounts, confer a health benefit on the host.*"

Synbiotics are a combination of prebiotics and probiotics , having a synergistic effect by inhibiting the growth of pathogenic bacteria and enhancing the growth of beneficial organisms

Post-biotics are the bioactive soluble by-products released following either through the metabolic processes of probiotics or through lysis of probiotics . A technical definition of post-biotics, as proposed by The International Scientific Association of Probiotics and Pre-biotics (ISAPP) is "*preparation of inanimate microorganisms and/or their components that confers a health benefit on the host*"

Prebiotics

Prebiotics are categorically functional foods, and can be defined as the non-digestible food ingredients. Their consumption as dietary ingredients, may positively affect the human gut microbiota (HGM) composition and metabolic functions at the level of small intestine and colon . Different prebiotics are responsible for modification of different bacteria at strain or species level.

Prebiotics, reach large intestine in an intact form as they cannot be broken down by digestive enzymes in the gut thus serving as a substrate (as a carbon or energy source) for the growth of gut probiotic bacteria, resulting in an increase in the probiotic count . Prebiotics act synergistically with probiotics with symbiotic action resulting in optimal repopulation of the flora and suppressing the pathogens, which consequently enhance the gastrointestinal functions and immune system. Prebiotics maintain the optimal pH in the intestine which is essential for the existence of the probiotics, stimulate the peristalsis and reduce the formation of gases . They increase the absorption of calcium and magnesium, influence blood glucose levels and improve plasma lipids .Diets with prebiotics, besides increasing the HGM diversity, influence both microbial metabolic activities and the formation of determined fermentative end products like SCFA's, branched-chain fatty acids, organic acids, peptides, ammonia, amines, phenolic compounds and gases . Prebiotics are also extensively studied as protectants for encapsulation of probiotic strains to enhance the probiotic viability

Most of the prebiotics are plant products, well recognized being carbohydrates apart from inulin, fructooligosaccharides (FOS), galactooligosaccharides (GOS), trans-galactooligosaccharides (TOS) , Mannan- oligosaccharides (MOS), and Xylo-oligosaccharides (XOS), lactulose, dietary fiber(soluble and insoluble)fiber ,gums and lafinose, while some peptides, proteins, and certain lipids are potential . The length of the chemical chain; the short chain, the middle chain or the long-chain determines where in the GI tract the prebiotic has an effect and how the host can feel the benefits . Breast milk oligosaccharides are considered to be the original prebiotic, however, other dietary sources include garlic, onions, guar gum ,leeks, shallots, asparagus, spinach, Jerusalem artichokes, jicama, chicory root , agave, peas, beans, lentils, raw oats, soyabeans, unrefined wheat, unrefined barley , yacon and bananas Plant cell wall polysaccharides and gentio-oligosaccharides have also gained attention as novel prebiotics. Marine poly-/oligo-saccharides, sugar alcohols(erythritol, xylitol, sorbitol, mannitol,lactitol, isomalt, maltitol , polyglycitols) .Algae and microorganisms are extensively studied for their prebiotic potential ,the most well known algal polysaccharides being alginates, laminarins and fucoidans (from brown algae), carrageenans and agar (from red algae) and ulvans (from green algae) . Food-grade bacteria are also a potential source of non-digestible carbohydrates and potentially bifidogenic prebiotics, hetero or homo-polysaccharides, as well as oligosaccharides such as dextran, mucan, and levan are produced by several species of *Lactobacillus, Streptococcus,* and *Leuconostoc* .

A **dietary substance** to meet the definition of prebiotics must fulfill specific criterias by *in vitro* and *in vivo* proven tests of non-digestibility (resistance to low pH gastric acid, enzymatic digestion, and intestinal absorption); fermentation by the intestinal microbiota; and selective stimulation of growth and activity of intestinal bacteria and should be unaffected by the food processing conditions and remain unchanged, non-degraded, or chemically unaltered and be available for bacterial metabolism in the intestine .*Currently,* ***fructooligosaccharides,***

galactooligosaccharides, lactulose, *and* ***non-digestible*** *carbohydrates are the prebiotics that fulfill these criterias .*

Probiotics :

The science of probiotics covers aspects from the field of microbiology to food processing. Probiotics are microorganisms that provide health benefits on the host when consumed in sufficient amounts. They reduce gastrointestinal infections, cause improvement in lactose metabolism, regulate the functions of intestinal epithelial cells and have antimutagenic and anti-carcinogenic properties. Also probiotic supplementation have a potential to reduce the severity or shorten the duration of the infections and have stimulating effects on the immune system. Right type and levels of exogenous dietary supplementation of probiotics of a species/strain can temporarily colonize the intestinal tract and stabilize the native microflora composition, thus restoring vital physiological function of a commensal flora . The multitude of health benefits of probiotics, are through their biological mechanisms in the body.

Food based probiotic functional foods can be divided into dairy products (e.g., cheeses, yogurts, ice cream, milk, acidified milks , creams) and non-dairy products(e.g., meats and meat products, cereal grain based bread or other fiber snacks, chocolates, fruit juices , other fruit preparations). Preserving the efficacy of probiotic bacteria and enhancing its viability during the development of functional food products is vital. International standards require that probiotic functional products claiming health benefits should contain a minimum of 10^6 -10^7 CFU/g viable probiotic bacteria when sold. To protect probiotic survival and viability , and help deliver bioactive ingredients both to the food matrix itself and to the GI tract several approaches have been undertaken which include immobilization technologies in various carriers, including composite carrier matrix systems, synbiotic combinations development, addition of osmo, thermo, or cryo-protectants to the drying or growth media, lyophilization , microencapsulation(ME) through food matrix modifications and exploitation of the adaptive mechanisms of the living cells for survival under conditions of stress.

Several bacterial species of *Lactobacillus, Lactococcus, Bacillus, Streptococcus, Bifidobacterium, Pediococcus,* and *Propionibacterium* are well-known probiotics. Yeast probiotics include *Saccharomyces cerevisiae, S. carisbergensis,* and *S. boulardii* and fungi such as *Aspergillus niger* and *A. oryzae* are also considered as probiotics. However, the most common probiotics are *Lactobacillus* and *Bifidobacterium* . In general, probiotics are orally administered and are commercially available in the forms of functional foods, dietary supplements, and drugs (medicinal probiotics). Probiotics have also been associated with nutrients to compete with pathogens, inhibit/block pathogenic bacterial adhesion in the colonic lumen, and improve mucus production, which in turn enhances the intestinal epithelial barrier for stimulation of the immune system . Probiotic supplementation has proven useful as a prophylactic regimen in cases of antibiotic-associated diarrhea (AAD) by enabling replenishment of the gut micro , has been found to reduce the allergies in children , decreasing *Helicobacter pylori* colonization of the stomach , managing relapse of some inflammatory bowel conditions , decreasing the risk of certain cancers by secreting specific anticarcinogenic and antioxidant metabolites , proven useful in dealing with periodontitis and oral *Candida* infections. Probiotics reduce toxins through bile salt hydrolase and increase the bioavailability of nutrients in the body through other enzymatic activities .

Specific mechanisms involved in probiotics-linked signaling of nerve functions in the central nervous system can promote potential therapeutic actions on neuropsychiatric disorders and stress-related diseases . Probiotics also relate to brain functioning , help to treat irritable bowel syndrome , and reduce the level of low-density lipoprotein in the blood , prevent vaginal and urinary tract infections (yeast/ bacterial) in women , prevent pancreatitis and improve pancreatic health , contribute to respiratory tract health , inhibit tumorigenesis , and contribute to metabolic homeostasis and aid in the treatment of metabolic disorders such as diabetes, non-alcoholic fatty liver disease and cardiovascular diseases .Apart from its physiologic effects , probiotics can enhance the bioavailability of micronutrients, they can help in the reduction of Fe^{3+} to Fe^{2+} (ferrous ions), facilitating an increased duodenal absorption of iron as well as calcium uptake and absorption. Probiotics are also involved in vitamin D synthesis and absorption.

Probiotic through their metabolic activity produce soluble factors, called **postbiotics** such as bioactive metabolites through non-specific mechanism such as SCFA's, vitamins (Vit-B_2 and Vit-K_2) , enzymes, lactic acid, bacteriocins , ketones, methyl acetates, carbon disulfides and also secrete antimicrobial peptides that kill pathogenic bacterial strains . Postbiotics exerts a beneficial effect on the host, directly or indirectly. As postbiotics do not contain live microorganisms, the risks associated with their intake are minimized.

Probiotics should possess GRAS (generally regarded as safe) status, be non-pathogenic, and without previous association with diseases such as infective endocarditis or gastrointestinal disorders , thus safety assessment of selected groups of potential probotic micro-organisms is important. Lactic acid bacteria , most largely used at the industrial level have the status of Generally Recognized as Safe (GRAS).

Table 1 Commercial Probiotic Products available

Brand	Description	Producer
Actimel	Probiotic drinking yogurt with L. casei Imunitass cultures	Danone, France
Activia	Creamy yogurt containing BifidusActiRegularis	Danone, France
Gefilus	A wide range of LGG products	Valio, Finland
Hellus	Dairy products containing L. fermentum ME-3	Tallinna Piimatoööstuse AS, Estonia
Jovita Probiotisch	Blend of cereals, fruit, and probiotic yogurt	H&J Bruggen, Germany
Pohadka	PohadkaYogurt milk with probiotic cultures	Valašské Mezirˇícˇí Dairy, CzechRepublic
ProViva	Refreshing natural fruit drink and yogurt inmany different flavors containing L. plantarum	Skåne mejerier, Sweden
Rela	Yogurts, cultured milks and juices with L. reuteri	Ingman Foods, Finland
Revital Active	Yogurt and drink yogurt with probiotics	Olma, Czech Republic
Snack Fibra	Snacks and bars with natural fibers and extraminerals and vitamins	Celigüeta, Spain
SOYosa	Range of products based on soy and oats andincludes a refreshing drink and a probioticyogurt-like soy–oat product	Bioferme, Finland
Soytreat	Kefir-type product with six probiotics	Lifeway, USA
Yakult	Milk drink containing	Yakult, Japan
Yosa	Yogurt-like oat product flavored with natural fruits and berries containing probiotic bacteria (L. acidophilus, B. lactis)	Bioferme, Finland
Vitality	Yogurt with pre- and probiotics and omega-3	Müller, Germany
Vifit	Vifit Drink yogurts with LGG, vitamins, and minerals	Campina, the Netherlands

Source: Adapted from Siró, I. 2008. Appetite, 51, 456–467.

Table 2. Differences between prebiotics and probiotic

Categories	Prebiotics	Probiotic
Content	Indigestible but selectively fermentable ingredients	Live microorganisms
Functions	Provide food for probiotics; increase number and improve activity of probiotics	Enhance the health and well-being of their host organisms' digestive trac
Health Benefits	Provide supportive function to probiotics	Reduce the number of pathogenic bacteria in the GIT and improve its function; improve immune system function; prevention of cellular damage from oxidative stress
Sources	Asparagus, Jerusalem artichokes, Bananas, Oatmeal, and Legumes	Yogurt, sauerkraut, Yakult, miso soup, fermented breakfast cereal and snack bars, soft cheeses, kombucha, kimchi, and sourdough
Side Effects	increase in fermentation, leading to increased gas production, bloating or bowel movement	Possibility of sepsis when given to immune compromised patients

Synbiotic approach towards functional foods:

Synbiotics are a combination of prebiotics and probiotics , having a synergistic effect by inhibiting the growth of pathogenic bacteria and enhancing the growth of beneficial organisms. A good synbiotic diet can strongly impact the gut microbiome. An appropriate synbiotic formula should have a prebiotic with an enhancing role on the probiotic microorganisms; and the prebiotic should particularly augment the growth of probiotics microorganisms. Synbiotics are designed to beneficially affect the host by improving survival and implantation of probiotics in the colon, selectively stimulating the growth or activating the metabolism of health-promoting beneficial probiotics in the colon along with maintenance of the intestinal biostructure, and improving the microbial composition of the gut and production of metabolites and bioactive compounds and the concomitant inhibition of potential pathogens present in the GI tract. Synbiotics may decrease the number of infections in postoperative patients, improving the outcome of irritable bowel disease(IBD), and presenting anticancer effects . Patients affected by small intestinal bacterial overgrowth (SIBO) treated with antibiotics and followed by synbiotic supplementation (containing *Bacillus coagulans* and prebiotics) obtained better responses than antibiotics alone. Synbiotic are also reported to lower the amount of undesirable metabolites, as well as the inactivation of nitrosamines and carcinogenic substances..Determining the best probiotic and prebiotic combination for each disease setting and each individual is a great challenge and warrants for a structured approach .

Difference Between Fermented Foods and Probiotics:

Traditional food fermentation is a practice that precedes human history. The International Scientific Association for Probiotics and Prebiotics (ISAPP) redefined fermented foods and beverages in 2019 as foods made through desired microbial growth and enzymatic conversions of food components.

It is expected that the majority of fermented foods sold commercially today do not belong in the "probiotic fermented food" category. Fermented foods and beverages are sometimes labelled as "probiotic foods" or "contains probiotics", these declarations might reflect efforts by manufacturers to communicate to consumers that living, health-promoting microorganisms are present in the product. Term 'probiotic' should only be used when there is a demonstrated health benefit conferred by well-defined and characterized live microorganisms. The health benefit must, at least in part, be due to the live microorganisms and must extend beyond any nutritional benefit of the food matrix. For these reasons, the terms 'fermented food' and 'probiotics' cannot be used interchangeably.

In the absence of strain-specific evidence of a health benefit for the live microorganisms in a fermented food, some fermented foods could be appropriately labelled as "contains probiotics" , can be supported if at least one of the strains in the food meets the criteria implicit in the term probiotic and if the strain is a member of a well-studied species known to confer probiotic health benefits via the principle of 'shared benefits'. Consistent with this view, certain jurisdictions recognize several common species for which the term 'probiotic' can be used in foods. For example, Health Canada recognizes more than 20 species of the *Lactobacillus* genus complex and *Bifidobacterium* provided they are delivered at a minimum of 10^9 CFU per serving . In Europe, health claims related to live yoghurt cultures and improved lactose digestion are approved by the European Food and Safety Authority based on the core presence of the lactase enzyme in yoghurt cultures (*Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*). However, even if the fermented food contains one or more of those species, the label "contains probiotics" should only be used when the strains in the fermented food are defined to the strain level, the genome sequences are known and the strains are present at an appropriate number during product shelf-life .

It is expected that the majority of fermented foods sold commercially today do not belong in the "probiotic fermented food" category. Instead, fermented foods and beverages often contain undefined microbial consortia, usually at variable levels, and their potential health benefits have generally not been demonstrated , it is suggested that manufacturers should state that their product contains "live and active cultures" provided the food is not processed to remove or kill the fermentation microorganisms and that these microorganisms are present at levels that are expected for foods of that type . For pasteurized fermented foods without live microorganisms in the final product, it is acceptable to label those foods as "foods made by fermentation" . Even when characterized cultures are used to perform fermentations and are understood at the strain level, those microorganisms are mostly selected based on performance characteristics, such as rapid acidification, substrate conversion, and flavour and texture properties, rather than on health-related functions.

Regulatory considerations for fermented foods

Guidelines that govern food fermentation are covered in international regulations and are mainly concerned with food safety. Strains developed by the use of recombinant DNA technology or those that are genetically modified ,the use of microbial cultures is regulated and includes criteria for establishing safety, such as the 'Generally Recognized As Safe'(GRAS) designation in the USA or the 'Qualified Presumption of Safety'(QPS) designation assigned by the European Food and Safety Authority to groups of microorganisms .The identification of core microbial components in fermented foods has the potential to lead to new regulations around the labelling of these foods. Regulations could be used to ensure that minimum requirements relating to the involvement of specific microbial taxa in the fermentation process are met. Only a few standards exist, mostly for cultured dairy products. For example, the Codex Alimentarius states that yoghurt should be made using a combination of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* and that kefir is a fermented milk consisting of *Lentilactobacillus kefiri* and species of the genera *Leuconostoc*, *Lactococcus* and *Acetobacter*, in addition to lactose-fermenting yeasts (*Kluyveromyces marxianus*) and non-lactose-fermenting yeasts (*Saccharomyces unisporus*, *S.*

cerevisiae and *Saccharomyces exiguus*). Similar standards could emerge as the microorganisms present in other fermented foods are identified (for example, kombucha and water kefir).

Recommendation of fermented foods as part of dietary guidelines

Consumption of fermented foods would not only provide important macronutrients, they could also deliver large numbers of potentially beneficial microorganisms to the gastrointestinal tract. Recently, the concept of "shared core benefits" was introduced to explain how and why phylogenetically related organisms could deliver similar health benefits. Fermented foods containing live microorganisms may be consumed on a regular or even daily basis and should be promoted around the globe as part of public health policy and be included in dietary guidelines for all the age groups. The Indian food pyramid explicitly promotes the consumption of fermented foods testifying their significance in actual human nutrition Although the microbes in fermented foods cannot, by definition, be considered probiotic, many of them are evolutionarily highly related to probiotic organisms, and they often share the same molecular mechanisms responsible for health-promoting properties in probiotic organisms.

Summary:

- The interest in functional fermented foods continues to increase rapidly around the world and probiotic foods play important roles in nutrition due to their health benefits. Fermentation improves quality, nutritional value and organoleptic properties of many perishable foods
- Fermentation is a biotransformation process involving two main factors: the starter culture (controlled fermentation) or indigenous microorganisms (natural or uncontrolled fermentation) and the substrate, as well as inherent factors such as the temperature and the pH conditions. The probiotic properties of many fermented foods are given by the presence of starter cultures or indigenous microorganisms
- Fermented food products can contribute to a complex rich traditional dietary diversity, with important food security and sustainability implications . Fermentations can be classified according to the type of microorganisms used: bacterial, based on yeast or fungi fermentations. Other classification, based in the food nature, divides it into eight groups, such as fermented cereals, vegetables, fruits, legumes, roots/tubers, milk, meat, and fish products. Based on use of starter culture

- During the fermentation process, primary and secondary metabolites are produced by microbial action (probiotic), such as antibiotics, antimicrobial peptides {angiotensin converting enzyme (ACE) inhibiting peptides}, carbon dioxide, alcohol, vitamins, folates, SCFAs, intracellular and extracellular polysaccharides of microbes , antioxidants compounds, enzymes(degrade complex compounds into simple ones), bacteriocins, and cell wall components, all known as postbiotics are considered bioactive compounds. These components can benefit the host directly or indirectly.
- Prebiotic substrates are components that enhance the effects of probiotic cultures when used in the production of probiotic foods. Prebiotics can increase the nutraceutical properties of foods , encourage the growth of beneficial bacteria in the intestines and play a protective role in the gastrointestinal tract for probiotics. Individually, effect of the probiotic microorganisms and prebiotics can increased by using them together as synbiotic.

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