

FOOD FERMENTATION AS A BIOTECHNOLOGICAL PROCESS

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ABSTRACT

Biotechnology produces goods that improve human existence by utilizing biological systems, including microbes. Food fermentation, a well-known technique in biotechnology, helps preserve food by fostering an environment where helpful microbes outcompete dangerous diseases. Fermented foods are of extremely importance because they offer and preserve enormous amounts of nutrient-dense food in a wide variety of flavours, smells, and textures that enrich the human diet. The process has been in use and present since the arrival of human on this earth. In the world of cooking, fermentation is used in a variety of ways to produce a huge variety of foods and drinks. Bacterial fermentation gives dairy products like yoghurt and cheese their texture and flavour, while yeast uses carbohydrates to make bread and alcoholic beverages. Notably, fermentation contributes to the health advantages of fermented foods by increasing the bioavailability of nutrients, synthesising vitamins, and producing bioactive chemicals. Fermentation helps preserve food by fostering an environment where helpful microbes can overcome dangerous diseases. It can also lessen the allergenic nature of some meals and counteract antinutritional influences. The dynamic interaction of microbial communities during fermentation gives culinary traditions around the world variety and uniqueness. This chapter deals with the technology how microbes interact with food to extend its shelf life, ensure its microbiological safety, and possibly even improve some foods' digestibility.

Keywords- Fermentation; Biotechnology; Bioactive; Microbes; Nutrients

I. INTRODUCTION

The word "fermentation" originates the Latin word fermentum means to ferment. Zymology, historically known as the branch of biology that studies fermentation. The first zymologist was Louis Pasteur, who invented the yeast that causes fermentation. Food fermentation developed more accidentally than intentionally. Since the beginning of time, people have utilised fermentation to preserve and transform food. Up to the 19th century, fermentation activities were conducted for thousands of years without any understanding of microbial mechanisms. Fruit fermentation is a natural process, and in this sense, it predates the history of humanity [1]. The breakdown of large organic molecules into the simpler ones by the action of microorganisms is known as the process of fermentation. For example, Proteins are transformed to peptides and amino acids by yeast enzymes, whereas sugars, starches, and proteins are turned to alcohol [2]. The distinct bacteria that are present in dietary raw materials spontaneously mediate the novel biotechnological process of fermentation. By increasing the microbiological stability of the food matrices, it was first focused on extending food shelf-life for long-term preservation of fruit- and vegetable-based goods at ambient temperatures [3]. Food may turn out to be more nutritious or digestible, safer or tastier, or some or all of these after the fermentation process [4]. The development of the bacteria naturally present in the raw material led to spontaneous fermentation, which was the basis for the earliest manufacture of fermented meals. The amount and kind of microorganisms in the raw material has an impact on the final product's quality [5]. In India, fermented sweets and snacks are frequently consumed. Additionally, several fermented grain products are produced and largely consumed during the holiday season or other special events. mostly to prepare these delightful dishes Cereals including wheat, rice, and barley are typically utilised as a main ingredient, and salt or sugar must be added to all fermented dishes. These diets only choose microbes that can survive in low water activity environments. In India, you can frequently find fermented sweetened products like jalebi, seera, kulcha, gulgule, and bhatura. The microorganisms that have been linked to these food products include *Lactococcus lactis*, *Streptococcus lactis*, *L. fermentum*, *L. buchneri*, *L. plantarum*, *L. acidophilus*, and *L. mesenteroides* [6]. Additionally helpful in preserving the proper microbiota composition of celiac disease, fermented food products can support physiological homeostasis and play a key role in disease prevention. Food products that have undergone fermentation can also be referred to as naturally energising foods [7]. Due to their health advantages and the part microbes play in the fermentation process, fermented foods have attracted

the attention of scientists. Studies on lactic acid bacteria (LAB) focus on how they produce physiologically active peptides, synthesise vitamins and minerals, and filter out non-nutrients. These peptides provide numerous health advantages, such as antioxidant, anti-microbial, anti-fungal, anti-inflammatory, anti-diabetic, and anti-atherosclerotic action. They also include conjugated linoleic acids, exopolysaccharides, bacteriocins, sphingolipids, and bioactive peptides [8]. For some goods, the fermentation process happens spontaneously, without the use of specific starter cultures, and in uncontrolled or loosely controlled environments. Therefore, despite the fact that this low-cost technology offers many benefits, it may also be dangerous for your health. The failure of food safety systems to be implemented, particularly in low- and middle-income countries or for small-scale products (at the household level, in villages, and scale cottage industries), is caused by the use of low-quality ingredients, inadequate hygiene conditions in the manufacturing processes, and a lack of standards for safety and hygiene controls. This may lead to the inclusion of harmful microbes or their toxins in the food, which may then contribute to disease cases or even outbreaks. Additionally, poor handling during preparation and storage, as well as the terms of sale, impact food safety. Traditional fermented food consumption may not frequently result in foodborne disease reports, but this may be due, among other reasons, to a low rate of persons seeking medical attention or flaws in foodborne disease surveillance systems. Pathogens such enterotoxigenic and enterohemorrhagic *Escherichia coli*, *Shigella* spp., *Salmonella* spp., enterotoxigenic *Staphylococcus aureus*, *Listeria monocytogenes*, and *Bacillus cereus* have been found in fermented foods in many regions of the world, particularly in Africa and Asia. Hence check on the harvesting dates, weather, raw material quality, and disease-infected animals are crucial for food safety. Personal hygiene is also important, with access to clean water and optimal storage conditions. Adherence to the HACCP system, good manufacturing practices, and appropriate food processing plant design can reduce foodborne pathogens and improve procedures in developed countries [9].

II. FERMENTED PRODUCTS

CHEESE

In order to produce cheese and other fermented dairy products like Dahi, Lassi, yoghurt, sour cream, kefir, and koumiss, microorganisms such as bacteria, yeasts, and moulds or their combined are used [10]. One of the earliest biotechnology applications was cheese production,

which dates back to the Roman Empire [11]. Moulds, yeasts, and bacteria, are types of microorganisms, offer the enzymes and metabolites needed to generate these compounds. Homofermentative lactic acid bacteria (LAB) are the most significant of these organisms since their main metabolic byproduct, lactic acid, is directly related to the production of fermented dairy products [12]. Bifidobacteria isolated from human intestinal flora are used by the dairy industries of Japan, South Korea, and nations in Europe and North Africa to manufacture fermented milk products that are less sour than conventional yoghurt. Fluid milk, ice cream, and cheese may also include dairy-related bifidobacteria such *Bifidobacterium longum*, *Bifidobacterium bifidum*, *Bifidobacterium breve*, *Bifidobacterium infantis*, and *Bifidobacterium animalis* [13]. Even while milk contains vitamins, LAB fermentation frequently results in their enrichment, as is the case with propionibacteria's production of biotin, folic acid, and vitamin B12. Peptides generated as a result of LAB activity in fermented milk products have been shown to have antihypertensive, antibacterial, antioxidative, and immune-modulatory properties [14].

KEFIR

Lactic acid bacteria, yeast, and acetic acid bacteria work together to transform milk into the beverage known as kefir. This intricate concoction of microbes results in a particular fermented milk product with a special quality. A starter culture known as kefir grains or a fraction of a grain is added to milk to create kefir. Kefir grains are a complex mixture of proteins and carbohydrates embedded with a wide variety of bacteria and yeast [15]. The starters were either a blend of *Str. thermophilus* and *Lactobacillus bulgaricus* (for yoghurt culture) or *Str. lactis* subsp. *diacetylactis* and *Leuconostoc cremoris* (for lactic culture) [16] along with yeasts like *Kluyveromyces*, *Candida*, *Saccharomyces*, and *Pichia* [17]. Due to its alleged health advantages, it has long been popular in Eastern Europe, where it is frequently given to hospital patients and advised for infants and the elderly. It acquired popularity as a nutritious probiotic beverage in the USA, mostly as an artisanal drink made at home from communal grains, but more recently as a commercial product that commands shelf space in retail places. Similar circumstances existed when yoghurt was the newest healthy product in the 1970s. With encouraging results, research is being done on their potential for usage as leavening agents, food additives, wound therapy, and other non-beverage applications [18].

KOMBUCHA

A fermented tea with almost 2,000 years of history, kombucha, originated in China [19]. Kombucha fermentation is driven by a symbiotic culture of bacteria and yeast (SCOBY), including *Acetobacter* and *Saccharomyces* species [20]. Although only a few key bacteria, such as *Acetobacter* spp., especially cellulose-producing strains of *Acetobacter xylinum*, are involved in its fermentation, strains of *Gluconobacter* and *Lactobacillus* may be encountered. Contrarily, a wide range of yeast species, including varieties of *Brettanomyces/Dekkera*, *Candida*, *Kloeckera*, *Pichia*, *Saccharomyces*, *Saccharomycoides*, *Shizosaccharomyces*, *Torulospora*, and *Zygosaccharomyces*, have been reported [19]. This popular beverage is renowned for both its distinctive flavour and potential health benefits. This fermented product contains ethanol, carbon dioxide, a significant amount of acids (gluconic, acetic, and lactic), as well as a number of other metabolites that are beneficial to health. Therefore, it is said to be a helpful beverage in situations of digestive problems, diabetes, hypercholesterolaemia, high blood pressure, fending against stress and cancer, as well as bodily energizing [21].

SAUERKRAUT

Sauerkraut, originated in United States [22], also known as kraut, is made from healthy, mature heads of the cabbage plant (*Brassica oleracea* var. *capitata* L), which have been carefully trimmed and sliced. Salt (approximate 2-3 %) is then added, and the cabbage is then allowed to naturally ferment to cure it [23]. Lactic acid bacteria (LAB) that are naturally present in white cabbage are used in the spontaneous fermentation process that results in its production [24]. Other, less numerous, but potentially significant, microorganisms are also present and include species of *Leuconostoc*, *Lactobacillus*, *Pediococcus*, *Weissella*, *Streptococcus*, and *Enterococcus* [25]. In addition to its high nutritional content, a number of in vitro studies and certain epidemiological data point to the possible health benefits of sauerkraut. Strong data from experimental research showing that certain phytochemicals in sauerkraut have antioxidant, anti-inflammatory, and chemopreventive effects against certain forms of cancer lends support to these health-promoting characteristics [24].

KIMCHI

Traditional Korean food kimchi is a fermented dish that is made by a number of steps, including pretreating oriental cabbage (or radish), brining, mixing with different spices, and fermentation [26]. The proliferation of diverse lactic acid bacteria (LAB) during spontaneous kimchi fermentation in unsterilized raw materials causes variances in the flavour and sensory attributes of kimchi products. *Leuconostoc*, *Lactobacillus*, and *Weissella*-gene heterofermentative LAB are believed to be important participants in the fermentation of kimchi [49]. The ingredients used to make kimchi contribute to its increased nutritional value, including its high concentrations of vitamins like vitamin C, b-carotene, and vitamin B complex, minerals like sodium, calcium, potassium, iron, and phosphorus, dietary fibre, and other different functional ingredients like allyl compounds, gingerol, capsaicin, isothiocyanate, and chlorophyll. Due to the accompanying health claims, which include protective properties against several forms of cancer, cardiovascular and neurological disorders, study has recently concentrated on the polyphenolic and glucosinolate content. Regular kimchi eating may have positive effects on human inflammatory, lipid, and metabolic processes as well as obesity and cholesterol levels. Regular kimchi consumption promotes the growth and development of immune cells [27].

MISO

It is believed that the first type of miso, known as kokusho (soybeans and grains fermented with salt), came from ancient China or possibly Japan thousands of years ago. Any miso made from a combination of rice, barley, and/or soybeans is considered mixed miso, as is any miso made from a combination of rice, barley, and/or soybean. Miso soup is the Japanese dish that makes the most use of miso. Complex interactions between sweetness, saltiness, umami, acidity, bitterness, and astringency create the flavour of miso. Typically, the salt-tolerant lactic acid bacteria *Tetragenococcus halophilus* and the salt-tolerant yeast *Zygosaccharomyces rouxii* are employed [28]. Miso is capable of curing gastrointestinal disorders and has anticancer, antihypertensive, antiobese, and anti-inflammatory qualities [29].

Table 1. Some of the Fermented Products used

NAME	MAIN INGREDIENT	MICROBES USED IN FERMENTATION	USES	ORIGIN STATE	REFERENCE
Cheese	Milk and Dairy Product	Lactic Acid Bacteria (LAB), Bifidobacteria	Cooking, Topping	Different regions of world	10, 11, 12, 13, 14
Kefir	Dairy Product	bacteria and yeast including Str. thermophilus and Lactobacillus bulgaricus or Str. lactis subsp. diacetylactis and Leuconostoc cremoris, Kluyveromyces, Candida, Saccharomyces, and Pichia	Beverages	Caucasus	15, 16, 17, 18
Kombucha	Fermented Tea Beverage	bacteria and yeast including Acetobacter and Saccharomyces species	Beverages	China	19, 20, 21
Sauerkraut	Cabbage	Lactic acid bacteria (LAB), Leuconostoc,	Condiments or side dish	United States	22, 23, 24, 25

		Lactobacillus, Pediococcus, Weissella, Streptococcus, and Enterococcus			
Kimchi	Cabbage	Leuconostoc, Lactobacillus, and Weissella-gene heterofermentative LAB	Side dish	Korea	26, 27, 49
Miso, Koji, Sake	Soyabean, Rice, Barley	Salt-tolerant LAB Tetragenococcus halophilus, Salt- tolerant yeast Zygosaccharomyce s rouxii	Soup, Side dish	Japan	28, 29

III. ADVANTAGES OF FOOD FERMENTATION

Food is often fermented as a result of microbial or enzymatic activity on its constituent parts, which causes the desired biochemical transformations that result in the food's substantial modification. Vitamins, vital amino acids, antinutrients, proteins, food appearance, flavours, and odour can all be improved naturally through fermentation. Additionally, fermentation contributes to the decrease of cooking energy requirements and the development of safer products [30]. The natural metabolic process of fermentation, which is mediated by bacteria, has several benefits for a variety of businesses. It helps preserve food, improve nutritional profiles, create distinctive flavours, and create bioactive substances. The advantages of this biological phenomena, which has been used for centuries by cultures all over the world, continue to influence contemporary practices.

One of fermentation's main benefits is food preservation. Microorganisms generate settings that prevent the growth of hazardous germs, extending the shelf life of many food items by producing substances like lactic acid, acetic acid, and alcohol. This benefit is best demonstrated by fermented foods such sauerkraut, kimchi, yoghurt, and pickles because they can be consumed for extended periods of time without the need of chemical preservatives. This not only lessens food waste but also satisfies consumers' growing need for natural meals with less processing [31]. The enhancement of food's nutritional value is still another significant benefit. Complex chemicals are broken down into simpler forms during fermentation, increasing the bioavailability and digestion-friendliness of nutrients. For example, fermenting soybeans into foods like tempeh and miso enhances the protein quality and nutrient absorption, addressing nutrient shortages and advancing general health [32].

The development of unique flavours and textures is another allure of fermentation. The distinctive smells and odours of microbes are caused by a variety of compounds they create, including esters, aldehydes, and alcohols. This advantage may be seen in the artisanal bread, craft beer, and wine industries, where the complexity produced by fermentation satisfies the palate [33].

Indeed, numerous studies have demonstrated that bacteria from fermented foods can enter the digestive tract; however, this is likely to vary between products, and their residence in the gut seems to be temporary. However, by competing with pathogenic bacteria and producing immunoregulatory and neurogenic fermentation byproducts, these microorganisms may still be able to exert a physiological advantage in the gut. Second, metabolites produced during fermentation may have positive effects on health. For instance, lactic acid bacteria produce bioactive peptides and polyamines with potential benefits on metabolic, immunological, and cardiovascular health (applicable to both dairy and non-dairy fermented foods). Thirdly, certain substances may undergo fermentation and become physiologically active metabolites. For instance, phenolic substances (like flavonoids) can be transformed into physiologically active metabolites by lactic acid bacteria. Fourthly, nutrients present in fermented foods, like prebiotics and vitamins, may also have positive effects on health. Last but not least, fermentation can lower levels of toxins and anti-nutrients. For instance, fermentation of soybeans may lower levels of phytic acid, and fermentation of sourdough may lower levels of fermentable carbohydrates (such as fermentable oligosaccharides, disaccharides, monosaccharides, and polyols, or FODMAPs), which might boost the tolerance of

these products in patients with functional intestinal disorders like a condition called irritable bowel syndrome [34].

Beer and wine are produced as a result of yeasts converting carbohydrates into alcohol and carbon dioxide. This technique, which is steeped in tradition but has evolved to suit contemporary tastes, has produced a huge variety of alcoholic drinks with different qualities [35]. Fermentation shows potential for improving health and fitness through the creation of bioactive chemicals. Bioactive peptides with antioxidant, antihypertensive, and antibacterial characteristics are produced during fermentation by specific microorganisms. These substances have attracted a lot of interest because of what they might add to dietary supplements and functional foods [36].

Beyond food, fermentation has proven useful in waste reduction and bioremediation. Some microbes have the ability to breakdown contaminants, providing natural cleanup methods for the environment. Furthermore, organic waste products can be converted into beneficial resources such as bioenergy and fertilisers, in accordance with sustainable models and the circular economy's fundamental principles [37].

Fermentation has enormous advantages for the biotech and pharmaceutical industries. This method provides an essential basis for creating therapeutic chemicals such as antibiotics, vaccines, enzymes, and hormones. Large-scale synthesis is made possible by genetically modified microbes, which helps to provide affordable and widely available medical solutions [38].

Hence, fermentation is a beneficial process in many industries because of its benefits, which cover a variety of applications. The importance of fermentation is expanding, from its role in food preservation to its effects on health, sustainability, and the generation of distinctive flavours. Utilising this natural occurrence can result in more eco-friendly practices and cutting-edge goods that meet shifting consumer needs.

IV. LIMITATIONS OF FOOD FERMENTATION

Food fermentation is a centuries-old method of food preservation that involves microorganisms like bacteria, yeast, and fungi metabolically converting organic components. Different cultures have used this technique to produce a wide range of meals and drinks with improved flavour,

texture, and nutritional value. Food fermentation can have some drawbacks, though, and these can have an impact on the end goods' uniformity, quality, and safety.

Variability in Microbial Activity

The basic difficulty in microbial activity represents one important restriction of food fermentation. Microorganisms' growth and metabolism, which are regulated by variables including temperature, pH, and the availability of nutrients, are what drive the fermentation process. Unwanted sensory qualities and variable product quality may result from this fluctuation. The flavour, texture, and shelf life of fermented items, for instance, might vary depending on changes in fermentation time or temperature [39].

Safety Concerns

While a lot of fermented foods are safe to eat, there is a chance that pathogenic microbes could grow during the fermentation process. If suitable sanitation and hygiene procedures are not used throughout the fermentation process, contamination may happen. Even dietary staples like traditional fermented foods, which have been consumed for ages, can be dangerous if improperly cooked and preserved [40]. Manufacturers and people must follow the correct fermentation methods and food safety regulations in order to ensure safety.

Inconsistent Quality

Due to the extensive interactions between microbes and substrates, the sensory qualities of fermented foods, such as taste, scent, and texture, can differ greatly even within the same batch. This variation might provide problems for manufacturers trying to maintain consistent product quality and satisfy customer demands [41]. To reduce these problems, it is crucial to implement quality control procedures including monitoring microbial populations and fermentation conditions.

Processing Time

Comparatively speaking, canning or freezing are quicker preservation techniques than fermentation. Depending on the type of food, the microbial strains used, and the fermentation environment, fermentation times might vary. This extended processing time may affect the logistics of the supply chain and production efficiency, thereby delaying the release of goods [42].

Limited Scope of Food Types

Although fermentation is a common food preservation technique, not all food kinds can benefit from it. The range of goods that can be made using this method is constrained by the compatibility of particular meals with particular microbes and fermentation conditions. Additionally, some foods could not change in a way that is desired during fermentation, which restricts the possibility of value addition [43].

V. NUTRITIONAL IMPORTANCE

Foods that have undergone fermentation can be healthier than their unfermented equivalents. There are at least three possible ways in which this could happen. In addition to catabolism, which involves breaking down more complex molecules, microorganisms also synthesize a variety of complex vitamins and other growth factors. The second significant method that fermented foods can increase their nutritional value is through the release of nutrients that have been imprisoned in plant cells and structures by indigestible substances. Enzymatic breakdown of indigestible polymers like cellulose, hemicellulose, and related ones into simpler sugars and sugar derivatives constitutes a third method by which fermentation might improve nutritional value, particularly of plant resources [44].

In one study it was found that, in soybeans and soybean meals, fermentation boosted protein content, removed trypsin inhibitors, and decreased peptide size. Soy meals may become more valuable in human diets as a functional food and advantageous to cattle as a novel feed element as a result of the impacts of fermentation [45]. Due to their partial hydrolysis during sprouting, which too is a fermentation process, stored proteins and starches are more easily digestible [46].

V. NUTRITIONAL ENRICHMENT OF FERMENTED FOOD

For the benefit of consumers who need a higher protein intake, fermentation offers a way to raise the protein content of high starch substrates. An adult or a toddler cannot ingest enough cassava to meet their protein requirements. However, if cassava is subjected to tape ketella fermentation, as it is in Indonesia, the protein content can be raised to at least 3% (wet basis), which would significantly improve the consumer's nutrition [47]. Amino acid Enrichment is also encountered in fermentation. One study showed that the microorganisms in the Indonesian tape fermentation not only selectively enrich the substrate with lysine, the first essential limiting amino acid in rice,

but also with protein. This translates to an improvement in protein quality. Methionine levels during Indian idli fermentation have been observed to rise from 10.6 to 60.0% by a number of researches.

Restoration is the process of reintroducing nutrients to processed foods in order to raise the nutrient's concentration to its original level. Ascorbic acid added to "instant" dried potatoes is one example. In the West, "enrichment" refers to the process of incorporating nutrients into particular meals that have been designed or made in order to promote public health. As examples, vitamin D is added to milk, vitamin A and D are added to margarine, and riboflavin is added to bread. The process of adding nutrients to levels that correspond with the appearance or position of the item in the diet is known as "fortification". Fruit juices can therefore be supplemented with ascorbic acid. Given that margarine is related to butter, adding vitamin A to it constitutes fortification [48].

VI. CONCLUSION

In conclusion, food fermentation has several advantages, including nutritional enrichment, flavour enhancement, and food preservation, but it also has drawbacks. The difficulties with food fermentation are a result of a variety of factors, including varying microbial activity, safety worries, uneven quality, limited control over the finished product, processing time, a narrow range of food varieties, and ethical or religious restrictions. The finest practices in food production and safety must be followed, along with scientific research and technology improvements, in order to overcome these constraints. The potential of fermented foods to improve nutrition, promote health, and lower the risk of many diseases is enormous [44].

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