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Microbial Diversity of Fermented Foods

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Fermentation is an age-old chemical process which plays a vital role in various aspects of food processing all over the world and helps in enhancing flavour, and value addition and provides many health benefits to the consumer. Fermentation has a multi-directional role and significance in food processing. Over the years, research on fermentation has continued to advance, demonstrating its potential use in the production of pharmaceuticals, a wide variety of bio-based products, and sustainable biofuels. Fermentation has lately attracted renewed interest as sustainable agriculture and food production have become more and more important. There are a variety of fermented products which are manufactured commercially and are being consumed by the mass population due to their several beneficial health aspects. The process of fermentation includes various steps such as introduction to microbes, breakdown of sugar, maintenance of pH and enhancement of flavour. This review provides information about various food products prepared by fermentation in food industries, their potential health benefits, value addition of raw materials and the science behind it. Although food was traditionally preserved by fermentation, this process is becoming increasingly popular today since it produces nutritious food items with benefits beyond just basic nutrition and flavour. Foods that have undergone fermentation increase the body's immunity against harmful bacterial infections and strengthen the immune system. During fermentation, a variety of biochemical changes take place that may have an impact on the nutritional components and, in turn, the end product's characteristics, such as digestibility and bioactivity.

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1. INTRODUCTION

Fermentation is a fundamental chemical process that breaks down intricate materials into simpler ones using the powerful actions of microorganisms or enzymes. These microscopic beings efficiently handle the metabolic aspects of fermentation, an integral part of human civilization which has played a pivotal role for countless centuries. Its indispensability is showcased by its significant influence on various facets of our daily lives like the manufacture of sustenance and beverages, as well as ground-breaking developments in biotech. Fermentation research has constantly evolved through the ages, proving its potential utility in producing sustainable biofuels alongside drugs and a diverse range of bio-based merchandise. Additionally, it occupies a crucial position in traditional food preservation techniques and flavour generation [1]. As we take strides into the 21st century, there remains a continued emphasis on exploring fermentation's ability to enhance food safety sustainability and wellness advantages [2]. It acts as an essential metabolic method for fermenting food. Microscopic organisms including bacteria yeast mould convert organic components during this complex biochemical process involving fermentation. These microbe workhorses utilize a range of substrates comprising sugars yielding varied end products such as alcohol organic acids gases. Often, these final goods are accompanied by an expanse of second-gen metabolites. Globally, a range of fermented products carrying exclusive characteristics and cultural worth have been produced due to the variety of fermentation procedures powered by a wide array of microorganisms [3]. As the importance of sustainable agriculture and food production grows, interest in fermentation has recently revived. Communities engaged in seeking more eco-friendly remedies for environmental issues have been attracted to their ability to convert agricultural waste into valuable bio-resources such as biofuels and bio plastics. The production of high-quality substances like therapeutic proteins, enzymes, and bioactive molecules has also gained from fermentation boosting innovation in the bio pharmaceutical domain. These revelations enhanced our grasp on fundamental mechanisms leading to new food processing techniques like precision fermentation and functional food creation. This comprehensive study is aimed at providing a current overview of fermentation processes from historical roots to its diverse deployments in twenty-first-century life, the role played by microscopic organisms and how fermentation impacts various food industries. Furthermore, we will scrutinize recent advances in fermentation technology alongside the hurdles and opportunities that still remain for us to harness this age-old yet ever-evolving biological process to its full potential [4].

2. MECHANISM OF FERMENTATION

Fermentation Mechanisms: Peeling back the science behind beloved products such as yoghurt, beer, and bread.

Microbial Metabolism: Microbes form the backbone of fermentation itself. Sugars and organic molecules become the diet for bacteria and yeast, converting them into simpler components. With this metabolic activity comes a range of by-products, effectively fueling bacteria. By understanding microbial metabolism in fermentation, industries like biofuels, medicinal drugs, and food production can gain a foothold. To make the most out of yields, quality control, and profitability during fermentation processes – it’s crucial to grasp the intricate dimensions of microbial metabolism. Glycolysis is one way where glucose changes into pyruvate while generating both ATP and NADH - an enduring process for fermentation. Alongside glycolysis are other vital pathways that play a role in microbial metabolism during fermentation like - tricarboxylic acid cycle (TCA) or pentose phosphate path. Diverse Microbial Lifeforms Various microorganisms - bacteria, yeasts & moulds – are used in fermentation processes due to their peculiar metabolic characteristics. For example, *Saccharomyces cerevisiae* or baker's yeast is renowned for its capability to generate ethanol- making it a significant player in the bioethanol industry [5].

Anaerobic respiratory process: This is a fermentative activity that often takes place in the absence of oxygen. In situations where oxygen is scarce, bacteria turn to fermentation instead of oxidative phosphorylation. Microorganisms must undertake this switch in metabolism to survive across a range of environments. The significance of research into anaerobic respiration and fermentation extends beyond just biology to encompass the pharmaceutical sector as well. Penicillin is one among many antibiotics produced through fungal and bacterial fermentation. Another vital form of anaerobic respiration is lactic acid fermentation which can often be observed in muscles during intense physical exertion when there's limited oxygen supply. In this process, glucose gets converted into lactic acid causing muscle discomfort and fatigue [6].

Ethanol Production and flavour development: *Saccharomyces cerevisiae,* a kind of yeast, is well known for its function in alcoholic fermentation and the formation of flavour. Yeast converts carbohydrates into ethanol and carbon dioxide throughout this process. Beer, wine, and other alcoholic drinks are produced by this method [7]. In addition to preservation, fermentation can also improve flavour. The distinct flavour profiles of fermented foods and drinks are influenced by the metabolic byproducts of fermentation, such as alcohols, esters, and organic acids [8]. Baking also heavily relies on fermentation. When yeast breaks down glucose, carbon dioxide is released. This gas becomes trapped in the dough and causes it to rise. The airy and fluffy texture of bread is the result of this leavening process. Lactic Acid Fermentation: This is one of the most prevalent kinds of fermentation. This process, which results in the distinctive tanginess of yoghurt, sauerkraut, and kimchi, involves bacteria like Lactobacillus converting carbohydrates into lactic acid [2]. In the food business, lactic acid fermentation is also used to pickle vegetables in order to preserve them. The naturally occurring lactic acid bacteria on vegetables break down carbohydrates into lactic acid, which creates an acidic environment that prevents the growth of microbes that cause spoilage. Applications in biotechnology: Beyond the culinary realm, fermentation finds applications that go beyond food production. It has a pivotal role in creating biofuels, enzymes, and crucial medicinal proteins.

Probiotic Manufacture: Probiotics are live microorganisms which provide health benefits to the host when consumed in adequate amounts. Fermentation is fundamental to producing foods rich in probiotics, think yoghurt and kefir. These edibles host advantageous bacteria which have been known to improve gut health while boosting overall wellness. The popularity of probiotics - live microorganisms whose oral consumption is linked with documented health benefits only when ingested in sizeable quantities - has witnessed substantial growth owing to their potential ability to enhance general as well as gastrointestinal well-being. Probiotics help in improving gut health and the immune system. Examples of probiotics are yoghurt, kefir, kombucha, cheese, kimchi, miso and pickles [4].

Prebiotics: These are non-digestible food ingredients which help in the growth of beneficial microorganisms. For example, onion, garlic, soybean and chicory root.

3. FOOD ITEMS PRODUCED BY FERMENTATION

Kimchi: Hailing from Korea and proudly regarded as their national delight, serves as the genesis for our adventure. Kimchi, a traditional lactic acid-fermented vegetable product, is a staple of Korean cuisine and is made by combining Chinese cabbage, radishes, fish sauce, spices, and other ingredients. After being fermented by a number of different microbes, the combination is subsequently eaten raw all over the world. The key players in its creation include Napa cabbage and radishes, these are complexly combined with spicy chilli peppers, garlic and ginger to manifest a piquant fermented veggie amalgam that also has the additional perk of being rich in probiotics; wonderfully improving gut health whilst leaving your palate truly mesmerized [9].

Kombucha: It is a fizzy drink with a sweet taste made from bacteria, yeast, sugar and tea. It is a good source of probiotics. This tasty drink originated in northeast China. The next destination in our adventure is China and Russia, where kombucha has gained a wider reputation across the globe. Kombucha, a fizzy tea crafted by fermenting a mixture of yeast and bacteria called SCOBY is known for its refreshing taste with a tangy aftertaste that might be beneficial to your health [10].

Sauerkraut: One of the oldest and most popular traditional fermented vegetables is sauerkraut, which has long been used for its therapeutic properties in China. When sauerkraut spontaneously ferments, several microbiological, chemical, and physical changes occur that may compromise the product's safety and quality. When cabbage ferments naturally through lactic acid bacteria, it becomes this zesty delicacy that carries healthy probiotics.

Kefir: Middle East/Caucasus: Kefir is a dairy-based drink that goes through fermentation giving it probiotic properties mostly found in the regions comprising of the Middle East and Caucasus. It's a silky-smooth drink with an acidic tinge having its origins in areas encircling the Black Sea produced essentially by fermenting milk using kefir grains [11]. Kefir has attracted interest recently due to its pleasing organoleptic qualities as well as its anti-hypertensive, anticarcinogenic, hypocholesterolemic, anti-inflammatory, anti-mutagenic, anti-allergenic, anti-bacterial, anti-diabetic, antioxidant, and probiotic effects.

Tempeh: A popular Indonesian food, is derived from fermented soybeans and presents a protein-rich profile. The distinct texture and satisfying umami flavour of this food product are contributed by Rhizopus oligosporus - an essential mould used in the fermentation procedure [12].

Miso: Miso paste is at the heart of Japanese cuisine as it serves as a crucial ingredient for flavorful dishes across the land of the rising sun. Combining soybeans, and salt with koji a mould-based agent- delivers an authentic taste to soups, sauces, and marinades alike [13]. It is also a rich source of probiotic bacteria; it is good for the immune system and works as an antiinfection agent in the body. It is prepared by mixing koji and cooked soybeans.

Cheese: The global diversity of cheese-making practices results in a dazzling array of sensational textures and flavours. This intricate craft perfectly illustrates the boundless possibilities that fermentation can bring to life - think creamy Brie from France or smoky blue cheese from the United States. In the process of making cheese, casein is broken down by the use of milk, rennet, starter culture, proteases, and peptidases from secondary microbial flora. These bioactive compounds are then employed in a variety of biological processes.

The effects of cheese in preventing and treating illnesses are mostly due to its vitamin and mineral content as well as bioactive peptides (antihypertensive, antioxidant, opioid, anti-proliferative and antimicrobial peptides and conjugated linoleic acids (CLA)) [14]. Furthermore, there is an extensive list of other intriguing food items awaiting exploration in future topics.

4. THE PROCESS OF FERMENTATION

Stage 1 - Introduction of Microbes: Fermentation commences with the introduction of specific bacteria into a substrate, usually sugars, which serve as the primary fuel source for these microorganisms. This crucial phase is often referred to as "inoculation". The choice of microbes varies depending on the desired end product, ranging from *Saccharomyces cerevisiae* in bread to *Lactobacillus* in yoghurt [2].

Sugar Breakdown in Stage 2: Once the microbes are introduced, they begin breaking down complex carbohydrates into simpler substances such as ethanol, lactic acid, or carbon dioxide. This metabolic transformation plays a vital role in the development of flavour, texture and overall preservation of the final product [15].

Flavor Enhancement in Stage 3: The ability to enhance food flavour profile is one of fermentation's most renowned attributes. The unique taste and enticing aroma that characterizes resulting products are brought about by a wide array of volatile compounds produced by microbes during this intricate process including esters, aldehydes and acids [16].

Step 4- pH upkeep: Maintaining the right acidity of the environment during fermentation plays a pivotal role in the whole process. To create surroundings that foster their growth and metabolic functions, microorganisms often modify the pH levels by producing acids or alkaline substances [15]. For example, when preparing sourdough bread, lactic acid bacteria reduce the pH, which gives it a distinctive tangy taste [17].

Control and Monitoring in Step 5: Precisely regulating and closely watching variables like temperature, humidity, oxygen levels etc are paramount for successful fermentation. These factors directly influence microorganisms' development, and activity and even slight fluctuations can significantly alter the final product's quality.

Time frame: Fermentation processes vary from weeks to months for products like matured cheeses or can be relatively quick such as hours required to raise bread dough. The duration depends on factors like the type of microorganisms involved and the desired characteristics of the end product. Fermentation can also act as a natural preservative while adding flavour. The acidity and production of antibacterial elements during fermentation allow many fermented foods to have longer shelf lives [18].

5. VARIOUS ASPECTS OF FERMENTED FOODS

Fermented foods are rich in vitamins, minerals, proteins and fibre. These foods act as potential probiotics and antioxidants due to which we get numerous health benefits. Value addition is another significant role of fermented food products which leads to enhancement of flavour, improvement of texture, and shelf life and gives a diverse flavour with unique aroma.

Different types of microorganisms are used in the metabolic process of fermentation, including bacteria (e.g., Lactobacillus and Bifidobacterium), yeasts such as Saccharomyces and some moulds. Preservation of foods can be easily done by fermentation naturally.

In food industries, fermented foods are produced on a large scale with proper quality control, consistency and safety.

Table 1. List of fermented foods

Fermented foods	Health benefits	Value addition	Microorganisms involved	Raw materials used	References
Yoghurt	Probiotics for gut health, calcium source, protein	Flavour enhancement, texture improvement	Lactic acid bacteria (*Lactobacillus bulgaricus, Streptococcus thermophilus*)	Milk	Parvez et al. [19]. Tamang et al. [47].
Kimchi	Rich in vitamins (C, K), probiotics, antioxidants	Enhanced flavour, preservation	Lactic acid bacteria (*Lactobacillus plantarum*), wild yeast	Napa cabbage, radishes, spices	Cheigh and Park [20].
Kombucha	Probiotics, antioxidants, potential detox effects	Fizzy drink, a pleasant taste	Symbiotic culture of bacteria and yeast (SCOBY)	Tea, sugar, SCOBY	Dufresne et al. [21]. Vina et al. [48].
Sauerkraut	High in Fiber, probiotics, vitamin C	Improved flavour, preservation	Lactic acid bacteria (*Lactobacillus* species)	Cabbage, salt	Marco et al. [4]. Sanchez et al. [49].
Miso	Good source of protein, vitamins, and minerals	Umami flavour, extended shelf life	*Aspergillus oryzae* (for koji), Lactic acid bacteria (varies)	Soybeans, salt, rice/barley koji	Hutkins. [23]. Ray and Ward. [50].
Tempeh	Rich in protein, probiotics, vitamins (B2, B3)	Nutty flavour, firm texture	*Rhizopus oligosporus* (starter culture)	Soybeans	Steinkraus [24]. Hesseltine. [51].
Kvass	Probiotics, low alcohol content, vitamin C	Refreshing taste extended shelf life	Lactic acid bacteria (*Lactobacillus* species)	Bread, water, sugar, flavourings	Wang et al. [52]. Sanko et al. [53].
Sourdough Bread	Easier digestion, lower glycaemic index	Unique flavour, longer shelf life	Wild yeast (*Saccharomyces cerevisiae*), lactic acid bacteria (Lactobacillus species)	Flour, water	De Vuyst and Neysens. [25]. Steinkraus [54].
Pickles (Lactose-fermented	Probiotics, vitamin K	Tangy flavour extended shelf life	Lactic acid bacteria (*Lactobacillus* species)	Cucumbers, salt, spices	Fu 2020.
Natto	High in protein, vitamin K2	Unique flavour, sticky texture	*Bacillus subtilis* (starter culture)	Soybeans	Liu et al. [26]. Fox et al. [55].
Cheese	Good source of calcium, protein	Diverse flavours, extended shelf life	Various lactic acid bacteria, moulds, yeasts	Milk, rennet, specific cultures	McSweeney et al. [27]. Tamang et al. [47].

Fermented foods	Health benefits	Value addition	Microorganisms involved	Raw materials used	References
Fermented fish paste	Rich in protein, essential fatty acids	Unique taste, preservation	Salt-tolerant lactic acid bacteria, moulds	Fish, salt	Steinkraus [24]. Nishida et al. [28].
Cocoa	Improved flavour, potentially probiotic	Enhanced aroma, preservation	Wild yeasts, Lactic acid bacteria	Cocoa beans	Papalexandratou and Vuyst. [29]
Fermented soy sauce	Rich in umami flavour, antioxidants	Enhanced flavour, preservation	*Aspergillus oryzae* (for koji), lactic acid bacteria	Soybeans, wheat, salt	Luh. [30]

Yoghurt: Yoghurt is a salutary additive to one's eating pattern since it comes with probiotic characteristics that endorse intestinal wellness. Furthermore, it represents an excellent supply of protein and calcium. The noteworthiness of yoghurt is such that it enhances health as well as the tang and texture of nourishment. Moreover, its maturation procedure that commences with milk functioning as the initial material relies heavily on lactic acid bacteria, particularly *Lactobacillus bulgaricus* alongside *Streptococcus thermophilus* [19].

Kimchi: Kimchi represents a customary Korean dish possessing probiotics, and antioxidants with nutrients like vitamins C & K among others. Besides enriching the flavour of victuals, it also functions as a preservation mechanism. Constituents like Napa cabbage coupled with radishes combined together with spices undergo fermentation under the influence of lactic acid bacteria specifically *Lactobacillus plantarum* allied to wild yeast [20].

Kombucha: The renowned fermented tonic kombucha gained notoriety for its probiotics, clutching antioxidants as well and probable purifying properties. It won acclamation for its fizzling palatable flavour. Generally, raw input constituents consist of tea along with sugar along with SCOBY in the fermentation process which makes use of a symbiotic culture comprising bacteria plus yeast (SCOBY) [21].

Sauerkraut: Sauerkraut owes its immense popularity to the abundance of fibre, probiotics, and Vitamin C that it possesses. The fermenting process helps enhance taste and extends shelf life. The fermentation of cabbage utilizing salt as its primary constituent is facilitated by various strains of lactic acid bacteria, prominently *Lactobacillus* species [22].

Miso: is a versatile fermented food, that also boasts of being a rich source of vitamins, minerals and protein. It prolongs the life span of products while adding an umami taste to dishes. Soybeans combined with salt and rice or barley koji form the raw materials during the fermentation along with *Aspergillus oryzae* for koji and different strains of lactic acid bacteria [23].

Tempeh: Tempeh derived from soybeans offers not only an excellent supply of protein but also probiotics and vitamins B2 and B3. Its solid structure paired with a nutty flavour makes it a favoured meat substitute option. To initiate the fermentation process *Rhizopus oligosporus* is used as a starting culture [24].

Kvass: Kvass is an exciting beverage option as it combines probiotic-rich attributes with low alcohol levels while ensuring high vitamin C content too. In terms of storage capability, it outranks others in its class while holding on to its distinctively pleasant flavour profile. Bread mixed with water sugar and flavourings are key contributors during fermentation together with lactic acid bacteria primarily *Lactobacillus* species.

Sourdough Bread: When compared to regular bread, sourdough bread's glycemic index is lower and easier to digest. It stays fresh for a longer period of time and has a unique taste. The primary ingredients used are wheat and water, requiring fermentation by naturally occurring wild yeast such as *Saccharomyces cerevisiae* plus lactic acid bacteria [25].

Pickles: Lacto-fermented pickles provide vitamin K and probiotics. They have a tart flavour and last a long time on the shelf. The fermentation process involves cucumbers being fermented with salt as well as spices using lactic acid bacteria primarily from the *Lactobacillus* strain.

Natto: Famous for its thick consistency and distinct taste, natto is packed with protein plus vitamin K2. Soybeans are utilized as raw material for fermenting it while *Bacillus subtilis* serves as the starting culture [26].

Cheese: Cheese is a dairy product that contains substantial quantities of calcium and protein. It has an extended shelf life plus various flavors. Basic ingredients utilized in its fermentation process include milk, specific cultures, and rennet while multiple types of lactic acid bacteria strains, yeasts, and moulds facilitate this process [27].

Fermented Fish Paste: Fish that has undergone fermentation produces an appetizing paste that is brimming with valuable protein and crucial fatty acids. Notably, it imparts a remarkable taste while serving as an effective method of preservation. During fermentation, fish and salt are employed as starting ingredients. This transformative process is facilitated by bacteria that can tolerate high levels of salt and moulds [28].

Cocoa Beans: Renowned for their taste enhancement and perhaps probiotic attributes, fermented cacao beans help maintain freshness and enhance aroma. During fermentation, wild yeasts and lactic acid bacteria are utilized. The raw material of choice is cocoa beans [29].

Fermented Soy sauce: With a high umami taste and abundant antioxidants, fermented soy sauce lifts the palate experience and ensures long-lasting quality. Raw ingredients employed in fermentation include soybeans, wheat, and salt along with the *Aspergillus oryzae* bacterium, a key ingredient for koji [30].

6. HEALTH BENEFITS OF FERMENTED FOODS

Control and prevention from chronic disease: Fermented foods and beverages are increasingly understood to have a variety of bioactive compounds and related mechanisms of action, despite the challenges in identifying which of the many functional components that make up a single fermented food or beverage may confer the potential health benefit. Studies on humans and animals that evaluate a variety of health-related outcomes at particular intake levels of fermented foods will be helpful in examining the co-regulation of lipid profiles, oxidative stress, cellular energy and metabolism, immune system function, and cognitive support. Information from both human and animal research has been included for a number of the fermented foods that are the subject of this discussion. Additionally, clinical trial methods, dosage schedules, and the incorporation of a variety of secondary endpoints are covered. Furthermore, we must stress that extrapolating an appropriate amount of fermented food and dietary intake level to humans from the current animal research is fraught with substantial complications. The potential health benefits of fermented foods for individuals with chronic illnesses might also be attributed to dietary patterns, the host nutrigenome, and the gut microbiota [31].

Cures blood pressure and hypertension: Blood pressure appears to be lowered temporarily but significantly when blueberries are fermented by Lactobacillus plantarum tannase-active probiotic strains [32]. Hypertension is a severe condition that is a significant risk factor for cardiovascular disease. It is characterized by a systolic blood pressure of more than 140 mmHg or a diastolic blood pressure of more than 90 mmHg. Systolic and diastolic blood pressure were both dramatically lowered after two weeks of consuming 2 grams of lacto-fermented blueberries per day, but they returned to hypertensive levels two weeks after the intervention finished, according to research using a rat model of hypertension [32].

Maintains glucose and insulin levels: Up to 50 ginsenosides have been found to date, and they may help regulate insulin and blood sugar levels. Red ginseng roots are another plant that contains bioactive components, such as saponins (ginsenosides) and nonsaponins [33]. It has been shown that ginseng roots may be fermented to boost the amount of saponins the plant naturally produces. For four weeks, those who took 2.7 g of fermented red ginseng daily saw lower levels of postprandial glucose and fasting insulin, and higher levels of both [33].

Controls diabetes: Discussion is warranted since a fermented papaya preparation (FPP) has proven bioactivity in adult diabetics with specific potential for immune modulation and antioxidants. By directly modulating the response of wound-site macrophages and the subsequent angiogenic response, Dickerson and colleagues provided the first experimental data suggesting that FPP may enhance diabetic wound outcomes [34]. Because FPP has been shown to be safe and has no negative effects on patients' hyperglycemia, the idea that it might treat abnormalities in the respiratory burst capability of peripheral blood mononuclear cells in type 2 diabetes mellitus patients has significance.

Acts as anticancer products: The goal of the therapeutic method is to activate natural killer (NK) cells, which mediate anticancer action through a nonspecific immune response, by fermenting isolated polysaccharides from rice bran by fungus. To be more precise, rice bran was broken down by the carbohydrolase that the Lentinus *edodes mycelia* produced. This produced a fraction of active polysaccharides that promote the proliferation of immune cell macrophages, with a focus on NK cell activation and anticancer activity [35].

7. DIFFERENT IMPLEMENTATIONS OF FERMENTATION

Yeast Fermentation for Bread Making: Saccharomyces cerevisiae, sometimes known as baker's yeast, is the yeast that is used to make bread. The primary products it produces from the fermentable sugars in the dough are ethanol and carbon dioxide. The kind of yeast and the presence of fermentable sugars in the flour, such as maltose from starch hydrolysis, determine how intense the fermentation will be [36]. Baker's yeast cells want to become osmotolerant in order to avoid fatal damage, but the development of osmotolerant strains of baker's yeast will require an understanding of the molecular mechanisms involved in high-sucrose stress lenience, such as the introduction of stress proteins, the accumulation of stress protectants, and the changes in membrane composition [37].

Alcoholic Fermentation for Beer Production: Many modern brewers rely on dried yeasts, liquid or frozen preparations from yeast centres and strain collections, as opposed to traditional breweries that have been cultivating their own brewhouse yeast strains for decades or even centuries. In order to appeal to a growing market that values distinctive flavours, some conventional and experimental brewers utilize spontaneous fermentation and have developed their own culture collections over time. The potential of these strain collections is enormous, and an increasing number of brewers are daring to experiment with new and ancient yeasts to produce novel goods such as maltose-negative yeast strains-produced non-alcoholic beers [38].

Acetic Acid Fermentation for Vinegar Production: Two primary processes are used in the industrial production of vinegar: a quick submerged fermentation process and a slow procedure employing static surface acetic acid fermentation. Traditional vinegar manufacture often uses static fermentation. Although the fermentation process takes a while to finish, this method produces good-quality products at a low cost in terms of plant investment. Static fermentation of an alcoholic vinegary liquid (moromi) is done in suitable covered containers, which is thought to be a good method of avoiding bacterial infection. The moromi's surface is covered with a crepe pellicle of acetic acid bacteria within a few days, at which point the fermentation starts and lasts for almost a month. There are no rigorous sterilizing procedures in this process.

Fermentation for Biofuel Production: The low cost of biofuels has not materialized as promised. Although they have a lower energy density, alcohols are now a more promising biofuel than biodiesel or hydrocarbons because their synthesis routes don't rely as much on the supply of ATP and because they can ferment anaerobically. Large quantities of ATP are needed for the production of hydrocarbons and biodiesel, which is often limited to aerobic environments and whose productivities are extremely sensitive to the P/O ratio [39,40].

Fermentation in Pharmaceutical Industry (e.g., Antibiotics): The strong correlation that exists between particular illnesses and microbial activity justifies the function of microorganisms. Numerous discoveries and innovations, as well as significant developments in the pharmaceutical and medical sectors, have been made possible by microbiology. Though many microorganisms are important for the immune system and digestive system, they also cause a variety of microbial infections and infectious illnesses, including HIV. Pharmacists and microbiologists are collaborating to develop medication treatments that specifically target bacteria that cause opportunistic infections instead of the human body's host cells. Antibiotics are antimicrobial agents with the power to either stop or eradicate bacteria, fungi, and other microorganisms. These are the components that the bacterium produces and that work against the growth of other microorganisms. Due to advances in medical research, the majority of antibiotics used today are natural substances derived from microbes, such as penicillin and some fungi called Penicillium [41].

8. NUTRITIONAL ANALYSIS OF FERMENTED FOODS

Additionally, novel chemicals with the potential to modify health can be produced by fermentation. One such metabolite that is frequently produced at levels above 1% during LAB fermentations is lactic acid. It has recently been demonstrated that lactic acid (or lactate) decreases, in a dose-dependent way, the pro-inflammatory cytokine production of TLR-activated, bone marrow-derived macrophages and dendritic cells [42]. By lowering the load of reactive oxygen species in intestinal enterocytes, lactate also modifies the redox state [43]. As a result, if some lactic acid or perhaps other organic acids from fermented meals make it to the small intestine, those cell products may offer one of the main advantages of such foods.

Other compounds produced by fermentation that are obtained from microorganisms usually rely on the strain. Certain bacteria found in plant and dairy foods may manufacture the B vitamins, including folate, riboflavin, and B12, from a variety of non-vitamin precursors [44]. Fermentation also produces amino acids and their derivatives that have immunomodulatory and neurotransmitter properties, such as g-aminobutyric acid [45]. Furthermore, some exopolysaccharides and secreted proteins generated during food fermentations may have anti-oxidant properties, inhibit pathogen adhesion to the intestinal mucosa, or provide immunostimulatory or hypocholesterolemic effects. In addition to serving as prebiotics, certain polysaccharides are fermented to short-chain fatty acids by the gut flora [46].

9. CONCLUSION

This review depicts that fermentation in food processing plays an important role in enhancing the flavour of our food products and leads to value addition. We can conclude here that fermentation has bidirectional aspects with respect to food quality and plays an important role in the economy all over the world. We can say that fermentation is one of the most important chemical processes involved in food processing which leads to many health benefits and value addition of food products. Fermented food products and beverages are historically an important part of the human diet and provide many health benefits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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