

Research Paper

Food Fermentation: Traditional Practices and Modern Applications in Food Industry

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Paper No.: 285

Received: 11-03-2024

Revised: 28-05-2024

Accepted: 06-06-2024

ABSTRACT

Fermentation at the beginning used to maintain foods, fermentation now carried out to improve their physicochemical, sensory, nutritional, and safety attributes. Fermented dairy, alcoholic drinks like wine and beer, fermented greens, fruits, and meats are all particularly precious due to their elevated garage balance, decreased risk of meals poisoning, and superior favor. Through the years, medical studies associated the consumption of fermented merchandise with stepped forward fitness reputation. The fermentation manner allows to breakdown compounds into greater effortlessly digestible paperwork. Fermentation additionally helps to lessen the toxins and pathogens in food. Additionally, fermented foods include probiotics, which can be beneficial microorganisms that help the frame to digest meals and take in nutrients. These days global, non-communicable sicknesses including cardiovascular ailment, type 2 diabetes, cancer, and hypersensitive reactions improved. On this regard, clinical investigations have established that moving to a diet that contains fermented foods can lessen the risk of non-communicable illnesses. Furthermore, within the ultimate decade, there has been a growing interest in fermentation generation to esteem food waste into precious via products.

Keywords: Industrial Food Fermentation, Fermented Dairy, Enzyme Production, Fermented Meat, Waste Valorization

For the manufacturing of the next era of food additives and merchandise, fermentation stands out amongst different strategies like mobile or a-mobile products, eatable biomass, and eatable insects. Compared to standard farming, the production of fermented merchandise requires decreased land, generates fewer greenhouse gasoline emissions, and consumes much less water (Achi & Asamudo, 2019). Fermented food related with fitness blessings together with to low cholesterol levels, boosting the immune device, protecting in opposition to infections, most cancers, osteoporosis, weight problems, diabetes, allergic reactions, atherosclerosis, and reducing lactose sensitivity. The beneficial results of fermented meals frequently credited to bioactive peptide

fractions produced at some point of fermentation thru microbial protein breakdown. Fermentation is a time-commemorated approach used for ages to lengthen the shelf existence of food and augment its dietary. It used to hold numerous, animal derived, seafood, and plant originated meals. Center Japanese, European, and Indian cultures advanced cheese, cultured milk, and fermentation-based totally milk products. At the contrary, animal husbandry became greater restricted to Japanese countries inclusive of japan, Korea, and china (Adams, 1998). An extensive

How to cite this article: Mujahid, M., Wakeel, M., Ali, A.M., Saeed, S., Nawaz, A.S. and Hafeez, K. (2024). Food Fermentation: Traditional Practices and Modern Applications in Food Industry. *Int. J. Food Ferment. Technol.*, 14(01): 239-273.

Source of Support: None; Conflict of Interest: None



range of ingredients used to supply alcoholic beverages and fermented meals additionally influenced with the aid of cultural, social, spiritual, and monetary variables. Therefore, fermented meals that originated in Asia tended to base on rice and grains, greens, fish, and soybeans, whilst in Africa, native cereal grains including millet, sorghum, maize, and wheat represent famous fermenting. The regulated action of microorganisms on a meals substrate is at the foundation of fermentation. Fermentation can be spontaneously brought on by means of microorganisms usually discovered in raw components. Conventional sauerkraut, sourdough bread, and Kimchi end result from fermented meals rendered through spontaneous fermentation. Advances in biotechnology have made fermentation into a longtime method. The usage of beginning cultures allow for obtaining a standardized food product (Adebo *et al.* 2017). For meals applications, strain engineering often entails harmless microorganisms like *Bacillus* spp., yeast like *Saccharomyces cerevisiae*, *Komagataella phaffi*, *Kluyveromyces* spp. or filamentous fungi. Particular food components like antioxidants, colorants, favors, enzymes, and vitamins can also be synthetic through. Antioxidants, bacteriocins, pigments, enzymes, and other food factor. Antioxidants, bacteriocins, pigments, enzymes, and different food components are increasingly more being synthetic using meals waste as a fermentation substrate. A direct connection exists between putting off food waste and developing innovative, excessive-fee assets generated by making use of an under or untapped useful resource. In the bargain, medical investigations have ensured insights into the use of fermentation generation to produce fermented suitable for eating insects to promote food protection. There are already available fermented insect-containing fit for human consumption arrangements such as sauces, powder, paste, and fermented dishes containing bugs with the possibility of extension. Examples of such fermented sauces include those made using *Locusta migratoria* and *Galleria mellonella*. These sauces were very exceptional compared with traditional seafood sauces. Fermentation further improves compound extraction

efficiency, alters the antioxidant profile, and generates novel bioactive compounds from the food matrix. These days, there is an emerging information that precision fermentation represents a key innovation within the meals industry's impending fourth industrial revolution. Modernizing meals production with precision fermentation is becoming increasingly more popular (Adebo *et al.* 2018). Due to its potential to reduce waste and increase the efficiency of protein, lipid, and carbohydrate production. This assessment will talk fermentation's cultural importance and ecological significance, technological advancements of fermented beverage and meals worldwide, health advantages, nutritional cost, and microbiological insights into various fermented ingredients. We are able to examine awesome kinds of fermented ingredients of animal, plant, microalgae, and safe to eat insect starting place. For each form of product, bacteria worried in fermentation, purchasers' reputation, location of foundation, and intake will mentioned. There may be also a dialogue of how the industrial revolution impacted the procedure of fermented meals and how fermentation is used to price meals waste (<https://www.ncbi.nlm.nih.gov/books/NBK234703>).

Traditional Practices of Fermentation

Fermentation, a traditional food preservation method, has been used for centuries to extend the shelf-life of food products and enhance their flavor, texture, and nutritional value. Fermentation involves the breakdown of food components by microorganisms, such as bacteria, yeast, and mold, which produces lactic acid, acetic acid, and other compounds that inhibit the growth of spoilage microorganisms. Fermented foods have been a staple in many cultures around the world, with popular examples including sauerkraut, kimchi, yogurt, cheese, and bread. Fermentation has been used for centuries in various forms, including Lactic acid fermentation, which is the most common type of fermentation, where lactic acid bacteria (LAB) convert sugars into lactic acid, which acts as a natural preservative. Examples of lactic acid fermented foods include sauerkraut,

yogurt, and cheese. Alcoholic fermentation is type of fermentation involves the conversion of sugars into ethanol and carbon dioxide, which is used in the production of beer, wine, and bread. Also Acetic acid fermentation involves the conversion of sugars into acetic acid, which is used in the production of vinegar and other fermented foods.

Lactic acid fermentation

Lactic acid Fermentation is a type of fermentation that involves the conversion of sugars into lactic acid by the action of lactic acid bacteria (LAB). This process occurs in the absence of oxygen and is a natural preservation method that has been used for centuries to extend the shelf life of food products. In Mechanism of Lactic Acid Fermentation Lactic acid fermentation occurs in two stages: (1) Glycolysis: In this stage, the sugars present in the food are converted into glucose, which is then broken down into pyruvate. (2) Lactic Acid Production: In this stage, the pyruvate is converted into lactic acid by the action of LAB. Lactic Acid Bacteria (LAB) LAB are a group of bacteria that are responsible for lactic acid fermentation. They are Gram-positive, non-sporing, and non-motile bacteria that are found in various environments, including soil, water, and the gastrointestinal tract of animals. The most common species of LAB used in fermentation are: *Lactobacillus plantarum*, *Lactobacillus brevis*, *Lactobacillus acidophilus*, *Bifidobacterium bifidum*.(6) Lactic acid fermentation is used to produce a variety of food products, including:

- ❑ **Yogurt:** Milk is fermented with LAB to produce yogurt, which is a popular dairy product.
- ❑ **Cheese:** Milk is fermented with LAB to produce cheese, which is a nutritious and flavorful food product.
- ❑ **Sauerkraut:** Cabbage is fermented with LAB to produce sauerkraut, which is a popular condiment.
- ❑ **Kimchi:** Vegetables are fermented with LAB to produce kimchi, which is a popular Korean side dish.

- ❑ **Pickles:** Cucumbers are fermented with LAB to produce pickles, which are a popular condiment.
- ❑ **Miso:** Soybeans are fermented with LAB to produce miso, which is a popular Japanese seasoning.

Preservation, Nutritional Enhancements, flavor and Texture Enhancement and Health benefits are some benefits of lactic acid.

Alcoholic Fermentation

Alcoholic fermentation is a kind of fermentation that involves the conversion of sugars into ethanol and carbon dioxide by the action of yeast or different microorganisms. This procedure occurs inside the absence of O₂ and is a natural renovation method that has been used for centuries to produce alcoholic beverages which includes beer, wine, and bread. Alcoholic fermentation occurs in two levels in mechanism: One is glycolysis in this stage, the sugars gift inside the food are transformed into glucose, that is then broken down into pyruvate. Other is ethanol production: on this stage, the pyruvate is transformed into ethanol and carbon dioxide by using the motion of yeast or other microorganisms.

Yeast is a single-celled fungus this is chargeable for alcoholic fermentation. The most not unusual species of yeast used in fermentation are: *saccharomyces cerevisiae*, *saccharomyces pastorianus*, *saccharomyces bayanus*. Different microorganisms such as bacteria and mildew also can be used for alcoholic fermentation, but yeast is the maximum typically used (Adesulu & Awojobi, 2014). Alcoholic fermentation is used to produce an expansion of food products, including beer: grains which includes barley, wheat, and rice are fermented with yeast to provide beer, wine bread, spirits, Alcoholic fermentation has numerous advantages, including: preservation, flavor and texture enhancement, nutritional enhancement. Economically alcoholic fermentation is an important enterprise that gives employment and earnings for lots humans round the sector (<https://www.sciencedirect.com/topics/>).

Acetic Acid Fermentation

Acetic acid fermentation is a kind of fermentation that entails the conversion of sugars into acetic acid by using the action of acetic acid microorganism (AAB). This system happens in the presence of oxygen and is a herbal protection method that has been used for centuries to supply food products consisting of vinegar, soy sauce, and pickled vegetables.

Acetic acid fermentation takes place in two levels: One is glycolysis, on this degree, the sugars gift inside the meals are converted into glucose, which is then damaged down into pyruvate. Other level is acetic acid production in which the pyruvate is transformed into acetic acid by means of the action of AAB.

AAB are a set of microorganism (Adunphatcharaphon *et al.* 2021) which might be responsible for acetic acid fermentation. They are gram-bad, cardio bacteria which are determined in diverse environments, which include soil, water, and the gastrointestinal tract of animals. The most not unusual species of AAB used in fermentation are: acetobacter aceti, acetobacter pasteurianus, gluconobacter oxydans. Acetic acid fermentation is used to produce an expansion of meals merchandise, consisting of vinegar, soysauce, pickled vegetables and natto.

Technology advancements in fermentation

The manner of fermentation encompasses the biochemical activity of organisms throughout their life cycle, from growth to loss of life. Commercial-scale manufacturing of food, prescribed drugs, and alcoholic drinks makes use of fermentation era powered by way of those organisms. Commercial fermentation generation based on the essential principle of cultivating organisms in optimal conditions. This done through supplying the desired raw materials, inclusive of carbon, nitrogen, salts, trace factors, and nutrients, critical for his or her increase. Additionally, the temperature, pH, and oxygen concentrations have to control in an effort to make sure the highest feasible yield of the desired product. The fermentation procedure likewise carefully monitored

to make certain that the organisms not exposed to any toxins or pathogens that might potentially affect the outcome. The mounting recognition on environmental conservation and renewable energy has sparked a surge of interest in the retrieval of fermentation products, which includes industrial chemical compounds, natural acids, and feed or food components. This upswing has induced a proliferation of products past the normal high-fee, low volume pharmaceuticals, with fermentation now rivaling the synthesis of commodity chemical compounds itself. Businesses ought to optimize efficiency and decrease waste with the aid of-products to remain competitive in producing low-cost, excessive-volume chemicals. Currently, medical groups are keenly exploring the biotechnological potential of agro-industrial remnants. Emerging fermentation-primarily based technologies have revolutionized the food industry in various ways. It become pronounced that sulforaphane yields have been elevated through 16 instances while broccoli florets had been pre-heated at 65 °C for three -min observed by way of maceration and lactic acid bacteria fermentation in a laboratory scale. Additionally, these technologies have paved the way for producing a pea, protein hydrolysate factor that enhances the saltiness of food. In the observation with the help of fermentation of carrot juice discovered to enhance the dietary profile of carrot juice by using the use of probiotic lactobacillus gasserii (Afzaal *et al.* 2021). Fermented immediately carrot juice determined to have a discount in sugar (27%) in keeping with their results. It is possible to enhance fermentation processes and tweak fermented meals' dietary and sensory attributes the usage of those strategies. To decorate fermentation, the following elements at each degree want to be addressed: selecting and designing of targets, strain optimization, bioprocess improvement, feedstock improvement, and very last product system and manufacturing. One fermentation approach used by various industries, together with food, prescription drugs, and textiles, is strong-nation fermentation (SSF), which includes using stable assist in place of a liquid to provide microorganism metabolites. SSF boasts numerous benefits: minimum waste

manufacturing and a reduced environmental effect, herbal solids as a medium with low power fees and capital investments, no sterilization requirement, advanced downstream techniques and reduced microbial contaminants.

Acidogenic fermentation (AF) is critical in producing precious chemical compounds like C1–C6 carboxylic acids and alcohol. However, low product titers have been a chronic venture because of thermodynamic limitations. Latest studies suggests that boosting the redox potential in AF can decorate metabolic pathways, permitting a smoother glide of electrons and lowering activation energy limitations. This improves substrate utilization rates, product yields, and speciation. Tis augmented gadget, referred to as electro-fermentation (EF), has extremely good capability to revolutionize fermentation era via providing an exogenous electricity deliver. Ultrasound waves that exceed 20 KHz have emerged as an eco-friendly alternative for processing agricultural meals. Tis sound era applies a cavitation system, during the formation of bubbles and their burst, main to a sterilization impact on food and drink merchandise. Ultra sonication aids within the deactivation of enzymes and microorganisms with the aid of disrupting the mobile membrane. Ultrasonic systems are without problems applicable on business scale as they do now not require immersion of the product into a liquid medium. This lets in hydrophilic nutritional compounds to maintained, permitting these structures to hire on a huge scale. Wineries have success fully hired this emerging technology to beautify wine aroma, choose, shade, and phenolic profile. Studies has uncovered the blessings of ultrasonic era on wine fermentation and getting older. Tis progressive approach improves wine nice with the aid of growing the important thing ageing signs which are include phenolic substances and shade intensities and deactivates microbes. Moreover, ultrasound software effects in more advantageous physiological, phytochemical, biochemical, and organoleptic characteristics of alcoholic drinks. Moreover, Zhang studied the physicochemical characteristics of crimson wine after

ultrasound remedy. 240 w of electricity ultrasound, a frequency of 80KHz and a temperature of 20 °C are considered greatest situations for ultrasound utility in pink wine processing. A big trade was observed in overall phenolic compounds, electric conductivity, and chromatic traits of the samples. However, pH or acidity titrable did now not fluctuate significantly. Those research provide proof that ultrasound treatment can be used as an effective tool to control the physicochemical characteristics of pink wine. The advantages of producing lactic acid from renewable resources have sparked much interest throughout unique fields. The petrochemical industry has embraced this method for its excessive yield and cost-powerful productivity the use of with no trouble to be had substrates. But, the disposal of biomass and waste substances from diverse assets poses a vast environmental task. An appropriate answer is an incorporated bio refinery platform that produces high-cost bio products whilst addressing waste control. The capacity packages of fermentation-produced optical pure lactic acid in the food, pharmaceutical, beauty, and the fabric enterprise have made it a rather promising choice for packaging substances. Poly lactic acid, derived from natural assets, is a green substitute for petro chemical-based totally bioplastics. Whilst biodegradability is a significant benefit, lactic acid's high charge manufacturing has hindered the great application of this material. In developing international locations, small-scale food fermentation technology were refined via sensible wisdom as opposed to medical innovation (Ahnan-Winarno *et al.* 2021). As a result, many producers need more actuality approximately modernizing and changing their fermentation processes. However, it is essential to enhance the safety and satisfactory of fermented foods while preserving their uniqueness and preserving manufacturing charges low. One practical method is the consortium method, which has efficiently stepped forward *tai* land's small-scale soy sauce fermentation. This method facilitates ongoing collaboration between industry and scientists, presenting the latter with the vital studies cognizance to assist the industry thrive. While the small-scale fermentation industry has hesitated to

embody starter cultures due to issues over the loss of particular prefer, cutting-edge molecular biology strategies have ushered in a brand new technology of tailor-made starter tradition improvement. In recent research, micro flowers from awesome product origins exhibited versions in sensory pleasant and com role, highlighting the capability for personalization. To assist this trend, a cellular financial institution is currently within the works as a resource for fermented red meat sausage, intending to ease the implementation of starter cultures in production.

Environmental friendly fermentation in meals industry

The rural and food processing industries face two principal demanding situations. On the only hand, it is important to restrict their effect at the surroundings to decrease weather change outcomes. Conversely, the insufficiency of superior alternatives to fitness-selling diets. Food shortages and environmental effects end result from lost and wasted agricultural output throughout processing and distribution. A excessive proportion of vitamins are located in plant-primarily based meals processing waste, such as pulp, peels, and silage, but these substances are

generally disposed of in landfills or washed into water bodies, inflicting the short depletion of dissolved O_2 . A high sugar, refined carbohydrate, processed meat, artificial additive, and trans-fats food regimen is also linked to weight problems, kind 2 diabetes (t2d), hormonal imbalances, and cardiovascular sickness. Meals fermentation era has some of blessings, consisting of environmental and fitness advantages. In fermented foods, microorganisms and enzymes are involved within the enzymatic transformation of food materials, emphasizing microbial changes as the distinguishing feature. A practical microorganism affords the fitness advantages of antibacterial, antioxidant, and peptide synthesis in FFS. Additionally, fermentation can produce nutritious foods and sustainable food elements. As compared to traditional chemical synthesis techniques, fermentation is more bendy, value-effective, and environmentally friendly (Fig. 1). There has been more investigation into fermentation based totally synthesis, optimization, and downstream of drug treatments, bio fertilizers, and biodegradable polymers. Microbiological fermentation converts inexperienced waste into valuable merchandise. Meals waste is taken into consideration safe to eat or inedible fractions originating from animals or plant life generated earlier than or after intake.

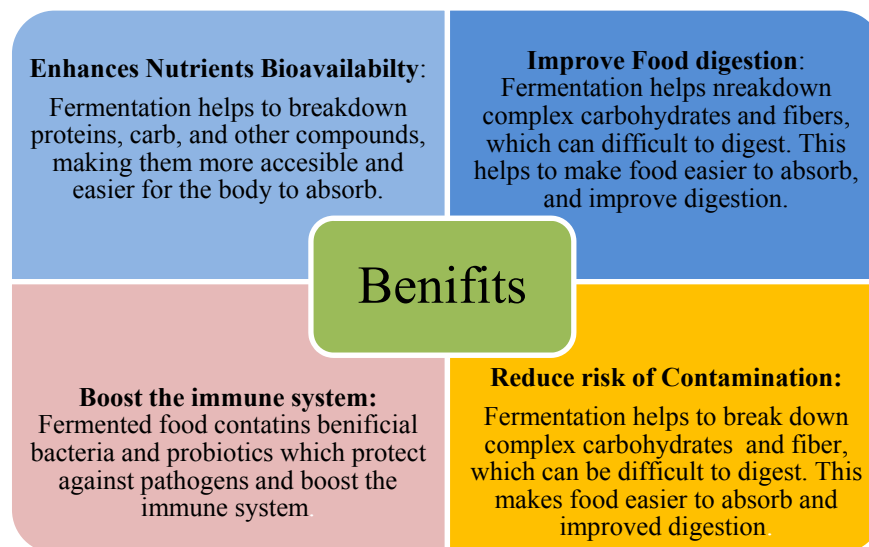


Fig. 1: Fermentation's primary benefits

Fermentation method for bioconversion is extensively stimulated by the type of meals waste used. Strong-state fermentation is frequently completed on strong substrates to enhance nutrient performance, even as submerged fermentation is generally used on liquid substrates. Because of its low price, high productivity, and simplicity, submerged fermentation is greater normally utilized in industrial-scale fermentation. Food waste is taken into consideration an exquisite enter for microbial fermentation due to its abundance of phenolics, proteins, fatty acids, minerals, and numerous bioactive elements. Consequently, the biotransformation of those wealthy resources lets in fee-brought outputs without waste treatment. Food processing wastes may be used to provide enzymes, biofuels, oligosaccharides, boom-promoting dealers, Polysaccharides, bioplastics, proteins, and bioactive compounds (Akbar *et al.* 2019).

Lipids extracted from waste substances also can be pre cursors to bioethanol synthesis (96%) through fermentation. Reducing waste, growing power production, and growing other healthcare products are all more suitable by way of reworking organic waste into value-brought bio products. Bio products along with protease enzyme had been produced with the help of microbial fermentation of meals waste. β -glucosidase enzyme using brewer's spent grain as substrate, antioxidant peptides the use of microorganism fermentation (*Aspergillus oryzae*) and turbot skin as substrate. A examine to develop ellagic acid the use of polyphenols from orange peel wastes thru submerged fermentation. This observe demonstrated the effectiveness of this approach for changing molecules found in orange waste to produce high-value merchandise like ellagic acid. It is difficult to estimate the bio-products produced through bioconversion processes because of the unidentified exact quantities of bioactive content of food waste. So revolutionary biotechnology strategies should employed to optimize the reutilization and recycling of meals-processing and agricultural wastes. Consumers' choice for more healthy meals drives manufacturers to be searching for out new methods of preparing food (Alapont *et al.* 2014). While FFS

have been to begin with evolved to lengthen foods' shelf-life, they're now normally used to enhance food safety, sensory quality, and dietary value. Fermentation nice relies upon strongly on the hobby of the microorganisms concerned inside the method and the substrate used in fermentation. As prebiotics, fibers beautify fermentation bacteria's microbial population, while also influencing the biochemical profile of the very last products with health benefits. Intestinal health can be definitely impacted by way of short-chain fatty acids inclusive of butyric acid, propionic acid, and acetic acid derived from nutritional fiber fermentation. Fermentates might also provide some health benefits of FFs.

Food fermentation by using microbes

Fermentation allows to maintain meals, making them remaining longer and making them less difficult to digest. It additionally adds flavor, texture, and nutrition to foods, making them greater appealing to consumers. Additionally, fermentation enables to interrupt down complex compounds into less complicated forms that may be greater effortlessly absorbed with the aid of the frame. During meals fermentation, complicated components are broken down into simpler components, many of which may be biologically active, using microorganisms. To be had medical records imply that many fermented foods include each nutritive and non-dietary components that could manipulate unique target methods in vivo related to consumer well-being and health. The presence of microorganisms in fermented foods can provide consumers with severa fitness advantages, which includes seasoned biotic properties, antibacterial residences, antioxidant properties, and peptide synthesis. Consequently, regular intake of fermented ingredients might also considerably make a contribution to stepped forward human health. Fermentation is a widely used process within the meals industry, and its merchandise are various and useful to our health. The most not unusual category, primarily based at the microorganisms chargeable for the fermentation and its product, is acetic acid (vinegar), lactic acid

(dairy products, greens, cereals, meat), ethanol/ alcohol (baking, brewing, wine-making), alkaline (eastern natto) (Alessandria *et al.* 2014). Fermentation usually entails the utilization of compounds from the feedstock through microorganisms together with yeast and lactic acid bacteria (LAB) like lactobacillus, lactococcus, pediococcus, enterococcus, and streptococcus, typically discovered in fermented milk merchandise. These microorganisms produce an expansion of compounds, inclusive of alcohols, acids, and gases, during the fermentation technique. Those compounds can be used to produce a variety of merchandise, consisting of fermented dairy products and alcoholic beverages. As a subfield of bioengineering, fermentation has received growing attention from a spread of fields, together with microbiology, chemical engineering, genetic engineering, cell engineering, mechanical engineering, software, and pc hardware. There is no doubt that fermentation is a vast field of research and that its capacity packages are nonetheless increasing. Fermentation can be implemented to fabricate pharmaceuticals, chemicals, and biofuels, and produce meals, beverages, and animal feed. It is an green and value-powerful system, and also can be used to produce renewable energy. A couple of microbe interactions cause fermented foods, more often than not traditional fermented foods. During food fermentation, favor-energetic compounds shape because of proteolysis and hydrolysis of peptides, with the conversion of amino acids and the formation of fashion enhancing amino acid compounds. Many fermented filtrates or extracts have potential fitness advantages, which includes high nutritional fee, antioxidant hobby, gut micro biome stability, and immune enhancement. Noticeably selective bio catalytic processes modify complicated systems of biochemical reactions. It should be mentioned, however, that now not all enzymes are a hundred% selective. Proteases, for example, can freely bind to many substrates with comparable chemical structures, reducing their efficiency. Accordingly, it is essential to take into account those capacity barriers when attempting to broaden bio catalytic techniques. To deal with this trouble, enzymes may be engineered

to be extra selective by altering the energetic web site of the enzyme or by using introducing allosteric regulation. Moreover, enzymes may be used in aggregate with substrate-binding proteins to growth their selectivity. Bio catalysis selectivity is improved by means of localizing the enzyme reaction to a specific compartment or environment. Gene expression regulates enzyme awareness chemically. As an example, the composition and sugar content of the fruit varies in line with species, level of development, and range. Genetic control of sugar metabolism to improve fruit pleasant is essential. Consequently, bio catalysis selectivity can improve by way of regulating gene expression in keeping with the surroundings, ensuing in stepped forward fruit best (Algonaiman *et al.* 2022).

Probiotics and starters

A probiotic is a stay microorganism that gives health advantages to its host when administered in enough amounts. In an effort to develop and form colonies in the digestive tract, probiotics must be proof against belly acid and bile. It's far usually below stood that probiotics are derived from a heterogeneous group of lab (*Lactobacillus*, *enterococcus*) which include lactic acid microorganism and people commercially available for human consumption. Despite the fact that yeasts play a main position in meals and are widely dispensed, they have no longer but been well investigated as capacity probiotic applicants. As probiotics, yeasts and different microbes also are being developed. Foods containing such bacteria belong to the useful foods category, which describes foods which have a health benefit. Inside the Nineteen Eighties, japan first used the time period "useful meals" to describe foods enriched with ingredients which have physiologically useful effects. As well as producing proteinaceous antimicrobial marketers, labs also produce bacteriocins. Bacteriocins are peptides that showcase antibacterial pastime against meals spoilage organisms and foodborne pathogens however do no longer affect producer organisms. Scientific relevance of probiotics become first said inside the literature for the treatment of diarrhea,

ulcerative colitis. There are two important elements when deciding on a probiotic candidate regarding capability fitness advantages. Viability and amount upon ingestion, survival and balance inside the digestive gadget. Identified stress 1. Plan tarum q823 as a possible probiotic candidate to be used all through fermentation of quinoa-based totally liquids. Regardless of growing in quinoa-based totally products, this strain survives and colonizes the human ogi tract. Akkermansia muciniphila has attracted immoderate attention lately and is considered a ability probiotic because different research verified a causal relationship with weight problems, irritation, cancer, and metabolic abnormalities. As indispensable industrial starter cultures, LABs play an vital component in food fermentation by way of breaking down carbohydrates into greater minor metabolites, including lactic acid, acetic acid, or carbon dioxide. Fermented food producers can get starter cultures without difficulty available in a extraordinarily focused form or create a custom subculture. Selecting the proper manufacturing facility is determined by the quantity of merchandise that want to be produced (Table 1).

Table 1: Fermentation starter microorganisms in various products

Fermented products	Bacteria Involved in Fermentation	Type of Fermentation
Kefir	Lactic acid bacteria (LAB)	Starter culture
Sucuk	Lactic acid bacteria (LAB)	Starter culture
Kimchi	Lactic acid bacteria (LAB)	Spontaneous, added commercially

Factors which include the level of automation, microbiological understanding, manufacturing prices, and monetary concerns all come into play (Algonaiman *et al.* 2022). Additionally, microbial starter cultures play a crucial role in preserving a product’s great and capability, inclusive of taste, texture, ph, and alcohol content material. Commercial meals fermentation makes use of lactic acid yeast, and ongoing research is targeted on improving

them. A starter medium must have ideal houses such as durability in method, rapid growth, excessive biomass and yield, and unique organoleptic traits..

Extremophiles uses in fermentation

The time period “extremophile” describes organisms that live on underneath difficult environmental circumstances (temperature, pH, salinity, and pressure) and is receiving great hobby because of their capability for catalyzing reactions and the possibility of sensible usage in extreme environments. The various substrates they address are acidophilic, alkaliphilic, halophilic, xerophilic, thermophilic, psychrophilic, methylotrophs, and gaseous substrates. It’s far vital that a practical method to controlling afatoxin b1 (afb1) is advanced, as its presence in meals can be a critical health concern. Termophiles can also contaminate meals. Powdered milk merchandise can be contaminated by way of *Anoxybacillus favithermus* and *Geobacillus* spp. Lactase hobby is missing in geobacillus thermoglucosidasius and it grows slowly in fats-unfastened milk, depending on a. Favithermus presence to offer them with glucose and galactose for boom (Zhao *et al.* 2018). They deliver suitable nutrients and other substances, which includes beta-carotene, which can be used as a pigment or to provide diet a, as do halophiles. Furthermore, they can ruin fantastically acidic ingredients with low water hobby, which include de baryomyces hansenii, an extremophilic yeast.

As D. Hansenii outcompetes undesirable microorganisms for nutrients and produces antimicrobial metabolites, both extracellularly and intra cellularly, it inhibits the germination of *clostridium butyricum* and *c. Tyrobutyricum* in cheese brines. The capability of D. Hansenii to multiply in cheese and its capability to eat lactate, citrate, lactose, and galactose make it an amazing starter culture for generating cheese. Furthermore, numerous reviews suggest that D. Hansenii enzymes may be lively in meat fermentation, but they had minimum have an effect on at the formation of unstable substances important for aroma manufacturing in garlic-flavored fermented sausages and version mince. In

fermented ingredients, extremophilic lipases and esterases hydrolyze glycerols and fatty acids to provide polyunsaturated fatty acids. Additionally, piezophilic extremozymes are also useful for fermented meals products that require high strain.

Fermented dairy products

Fermented ingredients, especially dairy, constitute a swiftly expanding zone of the worldwide food market, making it vital to apprehend and understand dairy fermented meals inside the beyond and present. The phrase “ferment” derives from latin “fervere”, which means to boil, and is defined as “the chemical breakdown of a sub stance by way of microorganism, yeast or other microorganisms, commonly by foaming and releasing warmness”. Fermented meals are the products of controlled microbiological boom and enzyme changes of meals elements, and fermentation is a deliberate and managed approach of attaining favored qualities fermentation is the breakdown of organic molecules into less difficult forms by using microorganisms. With the aid of introducing positive microorganisms, fermentation can produce desired flavors and aromas, as well as decorate the nutritional cost and shelf-life of foods. Similarly, fermentation can help preserve ingredients with the aid of generating antimicrobial com kilos, such as lactic acid, that may save you spoilage.

Fermented dairy products fall into two classes: traditional and non-traditional traditional fermented dairy products had been first produced about 10,000 –15,000 years in the past, while human life-style changed from amassing food to producing it. This change became because of the domestication of animals and the usage of their milk as a food source. The fermentation procedure was used to keep the milk and make it more palatable. Tis allowed for the manufacturing of a ramification of dairy products which includes cheese, yogurt. Societies in the course of the neolithic length consciously favored to consume exceptional animals’ milk for cultural and taste motives and processed this milk in diverse approaches (Alkema *et al.* 2016). Traditional fermentation has been employed for centuries in raw

milk processing. The technique is spontaneous, and a part of the fermented product is used to inoculate the brand new batch. In assessment, non-conventional fermented milk merchandise have these days been developed. Those products are produced with recognized microbial cultures primarily based on scientific ideas, and their exceptional can be optimized. Non-conventional fermented milk merchandise are extra constant in satisfactory as the addition of known microbial cultures creates a more controlled fermentation process. Tis manner also ensures that the goods are standardized and free of any capability health dangers related to uncooked milk. It’s been stated that probiotic-primarily based fermented useful meals are getting increasingly more famous since the early 2000s. From the past to the present, fermentation practices had been influenced with the aid of various factors inclusive of raw substances, climatic situations, production vicinity, social, cultural, non secular, and financial components. These factors have helped to shape the variety of fermented merchandise, and have additionally helped to steer the consumption of probiotic-based fermented useful ingredients. The reputation of these meals has been in addition bolstered by the health advantages related to them, inclusive of progressed digestion, accelerated nutrient absorption, and enhanced immunity. Milk and dairy merchandise at the moment are ate up global, basically in pasteurized and fermented bureaucracy. But, versions in intake quotes are resulting from according to capita profits and the effect of regional possibilities. This is because of the truth that those with higher earning can afford to buy greater nutrient-wealthy meals and have get right of entry to a spread of different substances to choose from. Additionally, regional possibilities play a vast role within the demand for certain food gadgets, as human’s taste and cultural possibilities vary from one region to another. Fermented foods with live microorganisms consist of yogurt, cheeses, miso, natto, tempeh, kimchi, , and some beers. A few ingredients are subjected to pasteurization, smoking, baking, or fltering after fermentation, causing live microorganisms to die or be eliminated. Sourdough bread (baked), shelf-strong pickles (heated), sausages

(heated), soy sauce (heated), vinegar (heated), most beers, distilled spirits (filtered), coffee and chocolate beans fermented products. Still, microorganisms have died or been eliminated from fermentation. Ingredients along with sparkling sausages, vegetables preserved in brine or vinegar, processed soy sauce, non-fermented dried meats and fish, and acidified cottage cheese are not taken into consideration fermented, as stay microorganisms are not worried in production. Fermented ingredients are from time to time referred to as “seasoned biotic ingredients” or “probiotics” and are used interchangeably. But, using these definitions interchangeably is wrong. Probiotics contribute to their useful outcomes while administered in enough quantities. They do no longer must take a selected form to have a wonderful effect on the host. Probiotics are stay microorganisms which have a useful effect at the host, while fermented foods are without a doubt meals which have gone via a manner of fermentation. The probiotic advantages of fermented ingredients come from the stay microorganisms gift within the food, which are not always found in sufficient quantities to have a fine effect at the host. Molecular components of probiotic-containing ingredients show prophylactic or therapeutic effects in opposition to disease-inflicting agents. These meals are typically called nutraceuticals, foodiceuticals, useful ingredients, or medifoods. These ingredients hobby clients based totally on their dietary and organoleptic properties and useful results on human health. The outcomes of those meals are attributed to the presence of bioactive compounds, which can be of plant or microbial beginning. These compounds, which includes antioxidants, polyphenols, vitamins, and minerals, have protecting results against sickness-inflicting marketers like microorganism and viruses (Al-Mohammadi *et al.* 2021).

The fermentation manner produces large quantities of lactic acid, alcohol, or acetic acid that inhibit different microorganisms. Additionally they preserve to breed unaffected by those generated materials, a manner called “amensalism”. These by using-merchandise generated by means of the fermentation system are

poisonous to different microorganisms, making them not able to reproduce. This offers the fermenting microorganisms a aggressive gain, allowing them to outcompete different microorganisms within the surroundings. Fermented merchandise are usually thicker than milk due to the fact acid precipitates milk proteins. Pathogens are inhibited by using high acidity and coffee pH. Fermented dairy merchandise have a completely unique, suitable choose, texture, aroma, and advanced digestibility as compared to the raw substances they produce. However, the wrong fermentation procedure poses a fitness risk. Unhygienic conditions or improper meals production lead to infection and spoilage. Foodborne issues are delivered on via spontaneous fermentation with the aid of unidentified microbes, which promotes the growth of undesired and even dangerous microorganisms. This can purpose food to be hazardous to devour, main to food poisoning. Signs and symptoms of food poisoning can variety from slight to excessive, and might also be life-threatening. Consequently, it’s far important for meals producers to take right steps to prevent contamination and spoilage. Propionic acid bacteria (PAB) and lactic acid bacteria (LAB) are microorganisms applied to make cheese and other fermented dairy merchandise. Lab is used to acidify milk, and pab is used for its aromatizing residences. Propionic acid bacteria are microorganisms that produce propionic acid and are worried in generating fermented propionic cheeses, together with swisscheese, with amazing adaptability to technological and physiological strain situations (Alves *et al.* 2017). The propionic acid fermentation in cheese causes function pores, cracks, and a slightly sweet flavor. Propionic acid bacteria also are accountable for the formation of carbon dioxide at some stage in the fermentation procedure, which offers cheese its airy, spongy texture. This additionally contributes to the desire of the cheese, as the carbon dioxide imparts a slightly bitter taste. Propionic acid bacteria metabolism differs significantly from lactic acid microorganisms. It is characterised by means of the production of carbohydrates all through fermentation, except for lactic acid, propionic acid, and acetic acid. As a result

of PABs metabolic sports, the product is enriched with natural acids, nutrients (b2, b12, ok, and folate), and other vitamins, increasing the steadiness and nutritional cost of meals merchandise. Fermented dairy products offer an excellent surroundings for probiotic microorganism to develop inside the human intestine. LAB include *lactobacillus*, *streptococcus*, *lactococcus*, *bifidobacterium*, *leuconostoc*, *enterococcus*, and *pediococcus*, which might be a few of the maximum not unusual traces of probiotic bacteria determined in fermented dairy products. Similarly, yeasts and molds which include debaryomyces, kluyveromyces, saccharomyces, geotrichum, mucor, penicillium, and rhizopus species are hired as fermenting microorganisms. Fermented milk merchandise are organized the usage of distinct starter cultures, and the types of microorganisms used in production are detailed within the regulations (desk three). Fermentation preserves probiotic residences whilst preserving microbial viability and manufacturing. This helps to make certain that the fermented milk merchandise are secure to eat and that they have got the preferred probiotic residences. This is because the starter cultures help to govern the growth of undesirable microorganisms while promoting the increase of useful ones. Because of their resistance to low pH, adaptability to take advantage of and other foods, and grass (normally identified as safe) repute, lactobacillus species are also extensively used. LABs are intentionally introduced to the product as starter cultures to lessen the ripening length and enhance sensory traits which include shade, want, aroma, and texture. Similarly greater, meals digestibility and product protection are more desirable by means of lab fermentation due to the inhibition of spoilage and pathogenic bacteria. Sure lab lines are taken into consideration probiotics due to their high quality results on the gastrointestinal system and human health and their enormous roles. Lactic acid bacteria regulate the release of fatty acids. Those houses of lab involve metabolic procedures regarding enzymes including lipases, proteases, and antibacterial proteins. Fermentation of yogurt and cheese effects in a pH lower due to the synthesis of metabolites along

with organic acids, lactic acid, hydrogen peroxide, bacteriocin, diacetyl, acetaldehyde, and reuterin.

Lactic fermentation and alcoholic fermentation are the 2 primary forms of fermentation carried out by microorganisms in fermented milk merchandise, respectively. In lactic fermentation, lactic acid microorganism are the dominant species. Lactic fermentation products are categorized in keeping with LAB traits as mesophilic fermented milk, together with buttermilk, thermophilic merchandise, inclusive of yogurt, acidophilic milk, and probiotic products. Alcoholic fermentation happens in merchandise which include kumys, and viili with the aid of yeasts and lactic acid microorganism. Microbial cultures, in particular the ones having proteolytic activity, are regularly employed in the dairy industry to provide cheese, yogurt, kefir, and other so-known as fermented milk merchandise. In production cheese, proteolytic enzymes are used to coagulate milk proteins and hydrolyze proteins. Proteolytic enzymes extract protein hydrolysates from milk to supply without problems digestible dairy products. Proteases produced by means of lactic acid microorganism used in lactic fermentation are able to reducing milk protein allergens, depending on the strain and the proteolysis procedure. Lactic acid microorganism are an awesome source of hydrolyzing allergenic proteins in milk, and one isolate (*Enterococcus faecalis* vb43) changed into suggested to be an excel lent ability agent for the production of hypoallergenic dairy products (Biscola *et al.* 2018). Lactic acid micro organism use β -galactosidase to hydrolyze lactose into glucose and galactose. The hydrolysis of lactose lowers the intestinal ph and promotes the manufacturing of lactic acid, which inhibits the growth of microorganisms that purpose putrifaction. Furthermore, lactic acid is vital for calcium absorption and growing organoleptic residence. The bioavailability of minerals together with calcium, potassium, zinc, magnesium, magnesium, potassium iodide, and phosphorus is expanded due to the fermentation method of lactic acid microorganism and acidity. Numerous research are currently being completed that can be beneficial for separating new

probiotics and growing fermented milk merchandise with probiotic homes. Tested seven lab strains remoted from breast milk for his or her probiotic houses and used *Lactobacillus plantarum* 5h1 and *Lactobacillus plantarum* 5l1 strains inside the production of probiotic fermented milk. Lab strains have a extensive range of antimicrobial activity against pathogenic microorganism and toxicogenic fungi. At some stage in the milk fermentation process, an growth in lactic acid content, a lower in milk pH, and an increase in general bacterial rely were found. Throughout storage, lab viability in fermented milk remained at 8-log_{10} cfu/ml. *Lactobacillus plantarum* 5h1 and *Lactobacillus plantarum* 5l1 exhibited significant antimicrobial hobby, sensitivity to antimicrobials, a extensive spectrum of enzymatic activity, adhesion to caco-2 cells, and reduction of salmonella enterica adhesion. Moreover, these selected lines remained feasible for the duration of fermented milk storage and fermentation at 4 °C. This shows that these strains are extremely hardy and have the capability for use as probiotics which can survive through the fermentation and storage method (Angeles-Agdeppa *et al.* 2020). The capacity of microorganisms in fermented milk products to gain the host is dependent on the presence of sufficient numbers of probiotic microorganisms in various products in addition to the capacity of adequate numbers of stay microorganisms to reach the human intestine. Thus, the law specifies the minimum variety of live microorganisms that should be found in fermented milk products. The whole quantity of microorganisms forming the starter tradition utilized in products named fermented milk, yogurt, alternate tradition yogurt, acidophilus milk, kefir, and kumys should be at least 10⁷ cfu/g, the range of yeasts have to be at least 10⁴ cfu/g, and the label should be at least 10⁶ cfu/g. The variety of stay probiotics at some point of the shelf existence of fermented dairy products varies relying on many factors. Those elements consist of the temperature of garage conditions, hydrogen peroxide (H₂O₂) produced by other microorganism gift, dissolved oxygen content material due to processing conditions, pH of the give up product, acidity, and pressure version. Mainly,

the decrease in pH during storage, the presence of dissolved oxygen, and the presence of preservatives within the very last merchandise are the important factors contributing to the loss of mobile viability. On the quit in their shelf existence, 22 of 36 business probiotic fermented milk merchandise sourced from the UK and European markets (sixty one.1%) contained greater than 10⁶ cfu/g of *Lactobacillus* strains according with the minimal encouraged healing level for probiotics. Rep-PCR become used to distinguish the isolated strains using the gtg-5 primer, and the remoted *Lactobacillus* species have been identified as *Lactobacillus acidophilus*, *Lactobacillus casei*, and *Lactobacillus paracasei* (Farahmand *et al.* 2021). Another study discovered many areas for development inside the range of cultures and accuracy of label information in business kefir merchandise. Greater qualified controls of fermented foods are needed to show and understand their ability fitness benefits for people. Purchasers should demand better degrees of accuracy and exceptional, and regulatory bodies need to behavior normal checks on these merchandise. The antibacterial pastime of lab in fermented milk samples towards salmonella typhimurium, *Staphylococcus aureus*, *Escherichia coli*, and *Listeria monocytogenes* changed into determined. *L. Lactis*. *Lactis* had a broader antimicrobial spectrum than the other isolates, and the probiotic assessment of *L. Lactis* confirmed that it could live to tell the tale at low pH (pH three) and 0.3–three% bile salts. It became concluded that lab with antimicrobial hobby is promising against food spoilage and pathogenic microorganisms in ingredients (Anggraini *et al.* 2018). Hikmetoglu said that the microbial content (*Lactobacillus* spp., *Lactococcus* spp., *Lactobacillus acidophilus*, *Bifidobacterium* spp., and yeasts) of traditional kefir expanded at some stage in fermentation and did now not change drastically at some point of bloodless garage of seven days. Lactose content material decreased all through fermentation, even as lactic acid step by step increased and remained consistent throughout garage. Galactooligosaccharides in kefir samples have been discovered to be strong in the course of garage. The fundamental lab species isolated and recognized

from traditional fermented milk in Ghana based on 16S rRNA gene sequencing were *ent. Faecium*, *lb. Fermentum*, *lb. Plantarum*, and *pd*.

Fermented foods also are valued for their stepped forward shelf existence, protection, nutritional fee, and other homes, and are the most widely fed on by means of humans. Fermented dairy products have several fitness blessings whilst fed on regularly and in a balanced and appropriate proportion. The various health advantages of yogurt, cheese, kefir, and different conventional fermented milk products had been considerably researched. Probiotic strains of bacteria present in fermented dairy products are beneficial for intestine fitness and may reduce the danger of sure diseases. Additionally, fermented dairy merchandise are a rich source of vitamins and minerals, such as calcium, potassium, phosphorus, and B nutrients. Fermented dairy products are a powerful remedy approach that contains natural ingredients with high dietary and digestibility, anti-hypertensive, hypo-cholesterolemic, antioxidant, immunomodulatory, and anti-inflammatory houses and less negative facet outcomes. Probiotic intake has been proven to positively have an effect on the reduction of ailments from diarrhea to most cancers. Regular kefir consumption has been linked to advantages for lactose intolerance and the digestive gadget, as well as antibacterial, antihypertensive, antiinflammatory, hypo-cholesterolemic effects, plasma glucose manipulate, antioxidant, anticarcinogenic, antiallergenic pastime, and wound recuperation. Koskinen observed that low-fat fermented dairy intake changed into inversely correlated with cardiovascular sickness threat. But, cardiovascular disease danger has been pronounced with very excessive consumption of unfermented dairy merchandise and milk. Zhang said that fermented dairy merchandise reduce cardiovascular ailment danger (Antone *et al.* 2022). Zhang mentioned that *Lactobacillus plantarum* b719 can be used as an alternative in treating number one put up menopausal osteoporosis at 24 and forty eight h, the interactions between distinct concentrations of kefir drink and u87 most cancers cells (glioblastoma),

the most severe shape of mind tumor, had been evaluated. As a end result, it become observed that kefir considerably reduced the increase price of u87 cells at growing concentrations and had a killing impact. It can be used as a complementary treatment.

Companies, pronounced that ingesting fermented dairy merchandise reduces the danger of stroke and cardio vascular diseases, and ingesting yogurt reduces the chance of growing type 2 diabetes mellitus. However, there is inadequate proof that fermented milk or cheese intake protects against metabolic syndrome. It's far said that the to be had evidence on the effect of nutritional cheese and yogurt on high blood pressure is restrained and that consumption of smoked cheeses must be limited in hypertensive sufferers due to their excessive sodium content material. IT is remoted 3 isolates with probiotic ability (*enterococcus faecium* (ef), *enterococcus faecium* (chole1), and *Lactobacillus pento sus* (7mp) from yogurt and decided that amongst these three isolates, *enterococcus faecium* (ef) and *enterococcus faecium* (chole1) produced diet B12 in a truthful amount (1 ng/ml); whereas, *Lactobacillus pentosus* (7mp) had the highest cholesterol discount potential (forty eight%) as compared to the others (Anusha Siddiqui *et al.* 2022) (Table 2) Showing Microorganisms used as starter cultures in fermented milk products (CAC 2003).

Table 2: Microorganisms used as starter cultures in fermented milk products (CAC 2003)

Fermented Dairy Products	Microorganisms Used for Milk Production
yoghurt	<i>Streptococcus thermophiles</i> , <i>Lactobacillus delbrueckii subsp. bulgaricus</i>
Acidophilus Milk	<i>Lactobacillus acidophilus</i>

Fermented Meat Products

Meat fermentation is an historic upkeep approach broadly used to increase meat products' taste, aroma, palatability, color, tenderness, and shelf existence. Meat is exposed to microorganisms or enzyme sports at some point of fermentation, so suitable changes arise in meat biochemistry. The manner of fermentation

reasons proteins and fat to break down, resulting in a greater tender meat product and a more intense taste (Apriyantono *et al.* 1996). The breakdown of proteins and fats also helps to defend the meat from wreck age, thus increasing its shelf life. Meat physicochemical, biochemical, and microbiological changes run the fermentation procedure and support the formation of acceptable meat products. The fermentation manner is an essential metabolic procedure converting carbohydrates into acids, gases, and alcohol, resulting inside the conversion of raw meat to fermented meat merchandise via the sports of “cultured” or “local” microorganisms. This is due to the fact the anaerobic environment fashioned throughout the fermentation technique encourages the growth of some lactic acid bacteria lines. Those microorganism strains produce lactic acid that gives fermentation products their exclusive flavor and texture. Lactic acid additionally acts as a herbal preservative, extending the product’s shelf-life. Fermentation of meat products done by lactic acid bacteria on a “local culture” or “starter lifestyle”. The usage of local vegetation for meat fermentation may motive many issues, together with inconsistent first-rate. This trouble became solved by cultivating a commercial starter tradition in a controlled surroundings to hold the same exceptional. *Pediococcus cerevisiae* turned into the first starter lifestyle for meat fermentation. Then, the alternative species are *Lactobacillus sakei* and *Lactobacillus curvatus*

among the LAB *staphylococcus xylosus*, and *S. carnosus* a few of the coagulase-terrible staphylococci and *Debaryomyces hansenii* amongst yeasts had been also used for meat product fermentation (Asama *et al.* 2016). Labs produce bacteriocins that enhance meat high-quality and stability at some point of fermentation. Bacteriocins are proteinaceous compounds that showcase antibacterial hobby against pathogens. Bacteriocins display bactericidal consequences except for eukaryotic cells and are also tolerant of heat and salt. Because of this when those compounds are delivered to the fermentation procedure, they could assist to inhibit the boom of harmful microorganism even as additionally maintaining the flavor of the meat. Furthermore, the warmth and salt tolerance of bacteriocins guarantees that the beef will remain safe for consumption for a longer time frame. Sausages, courting again to 1500 bc, are the maximum famous and oldest meat merchandise ate up globally because of their want and dietary characteristic. Typically, sausages are comprised of salted minced or chopped meat. They are fashioned through filling seasoned raw meat with starter cultures into herbal or synthetic casings, then placing them to ferment and ripen. The starter tradition is typically a unmarried lab species or a lab blended with other microorganism (Ashokkumar *et al.* 2022). (Table 3) showing some of the common fermented meat products worldwide.

Table 3: Some of the common fermented meat products worldwide

Origin/region	Product name	Substrate/raw materials	Fermented meat group	Microorganisms involved in fermentation
Germany	Teewurst	Pork, beef	Fermented sausage	LAB
India	Kargyong Satchu	Pork or beef	Fermented sausage	LAB
Italy	Piacentino, Crespone, Mortadella	Pork	Salami	LB
Italy	Prosciutto, Pancetta	Pork	Fermented meat	LAB
Portugal	Alheira	Pork or beef	Fermented sausage	LAB
Spain	Androlla	Pork	Dry cured sausage	LAB and <i>Staphylococcus</i>

Microbial spoilage in fermented meats

Microorganisms found in the meat microbiota interact with every different and meat substrate during processing and storage. A small percent of those microorganisms developing on meat can go to pot ingredients via their metabolic sports. As an example, lactic acid microorganism (LAB) produce lactic acid from meat carbon sources. Lactic acid produced by using lab has diverse nice and terrible outcomes based at the sort of meat product. It additionally enables to shape suitable modifications in fermented meats, together with an acidic flavor and decreased pH. However, it may motive unwanted changes in different products (Augustin *et al.* 2023). Hence, microbial spoilage is a quite complex structure with varying houses relying on the microorganism, substrate, and the character of the fermented product. Even though numerous microbial metabolic pathways are recognised that result in adjustments inside the flavor, color, odor, or texture of meat merchandise and stimulate the technology of described spoilage compounds, the number one mechanism that leads to spoilage nonetheless needs to be absolutely resolved. Consequently, to apprehend this mechanism that leads to meat spoilage, it's miles crucial to begin with comprehend the microbial elements of meat, their interactions, and metabolic activities. To recognize the primary mechanism that results in meat spoilage, it's miles essential to research the microbial components of meat, their interactions, and their metabolic sports. This will help to discover the pathways and mechanisms that result in spoilage and may assist improve food protection and first-class.

Fermentation of end result as compared to plant-primarily based food products, fermentation end result are usually used as a beverage. Fermented fruit merchandise relate to a valuable and huge useful microorganism. Most of the people of the time, distinct native microorganisms present inside the raw additives spontaneously ferment various plant-primarily based substances to provide fermented products. The fermentation of culmination involves lactic acid bacteria, a small a part of the microbiota of

uncooked end result. Relying at the sort of vegetable, hetero- and homo-fermentative organisms from the genera pediococcus, enterococcus, weissella, lac tobacillus, and leuconostoc, had been variably detected. The maximum widely wide-spread species have been weissella cibaria/weissella confusa and lactobacillus plantarum. Fermented candy cherries, for instance, constitute the alternative source of indigenous microorganisms (Azizkhani *et al.* 2021). The microbiota from the end result is customized to the fermented brine answer making the microorganisms remoted from an ecosystem usually having technological residences, consisting of resistance to salt, high acidification rates, ph, temperature, and phenolics. Fermented cashew apples include oligosaccharides, which can be evaluated with *Lactobacillus johnsonii* to decide the diploma of polymerization. However, the fermented cashew apple remains considered to have an unsightly flavor to be ate up by way of human beings. The fermentation of fruit with *L. johnsonii* occurs because of the focal point on enzymatic synthesis, where glucose and fructose are used as enzyme acceptors. Uk customers drink cider, another beverage product from apples. This beverage is fermented via *L. brevis*, *L. paracollinoides*, *L. casei*, *L. diolivorans*. It's also under the identical situations as wine from grapes. In standard, fruit fermentation research is restrained, while the end result include useful microorganisms to discover deeply to understand the importance of microorganisms isolated for the generated food merchandise. Cider is produced by way of fermenting apples with positive species of lactic acid micro organism, which help to interrupt down the fructose and glucose in the apples into ethanol. Tis fermentation manner is much like the system used to supply wine from grapes, although the microorganisms used are barely exclusive. As a result, greater studies is wanted to higher apprehend the function of microorganisms in fruit fermentation and their potential to generate useful meals products. Fermentation of cereals most of the people of fermented ingredients product of grains are determined in Africa. The natural microbiota is employed to ferment grains like maize, millet, rice, or

sorghum. The grains are often cooked, overwhelmed, malted, and every now and then filtered. Many well-known cereal-based products have distinctive regional versions in content and coaching. African cereal products may be divided into a few primary sorts; beverages, porridges, (semi) stable prepared doughs, and liquid liquids, along with nonalcoholic gruels. The burkinabe dish of ben-saalga, a skinny porridge crafted from fermented pearl millet (*Pennisetum glaucum*) sediment cooked in water, is famous in Ghana. Natural fermentation is frequently ruled by using *L. fermentum*, *L. plantarum*, and *P. pentosaceus*, requiring the power density of fermented gruels derived from cereal; some *L. plantarum* strains can hydrolyze starch, which may be superb. Another product is ogi, (30) a well-known morning gruel historically made by means of certainly fermented maize grains to create a supplementary food plan for children. The proper composition will effect the end product's viscosity, fermentability, and content. It could additionally be prepared from sorghum or millet grains. Ogi is often ingested following heat treatment, eliminating the probiotic residences of lactic acid microorganism. It should be cited that these foods' practical residences are linked no longer simplest to how bioactive stay cells engage with the host but additionally in a roundabout way by ingesting bioactive chemicals generated at some stage in fermentation. Consequently, herbal fermentation is a viable manner to promote a healthful way of life via the intake of plant-based meals with antimicrobial homes. In numerous African international locations, alcoholic and non-alcoholic liquids are crafted from fermented sorghum and millet. They function the base grains for the non-alcoholic beverage bushera and the traditional alcoholic beverage muramba. *Lactococcus*, *Leuconostoc*, *Lactobacillus*, *Weissella*, and *Enterococcus* are chargeable for bushera manufacturing. Whilst Ethiopian customers are well-versed with barley meals and liquids, which include kunun-zaki, shorba, kinche, tihlo, shamet, chuko, beso, etc., is any other millet fermented beverage that is often enjoyed in northern Nigeria. Lactic acid fermentation is a standard, simple, and inexpensive technique for processing meals, together with starch,

to ferment cereal products. Cereal food merchandise' dietary and organoleptic price is stepped forward via lactic acid microorganism fermentation. The sensory qualities constitute the primary large development. Bread, loaves, confectionary, pastes, noodles, gruels, semi-digested beverages, and supplemental meals for infants and youngsters are produced by lactic acid fermentation of cereal substrate.

Mycotoxins in fermented meat

Meat and meat merchandise may be infected with toxic compounds, inclusive of mycotoxins, throughout production, garage, and distribution. Mycotoxins infection inside the final product can be associated with uncooked substances, spices, additives used in production, or unsafe environmental additives. Therefore, those toxic components that cause infection can adversely affect human fitness. Mycotoxins are produced through positive styles of fungi and may be found in vegetation, grains, and even in animal feed. When those contaminated uncooked substances are used within the manufacturing of meat and meat products, mycotoxins can be surpassed directly to the final product. Mycotoxins are secondary metabolites produced by using molds, answerable for acute and continual toxicity of people and animals. Mycotoxin contamination can arise in meat products in those ways; due to meats provided from animals fed with infected feed, the components including infected spices introduced to the beef merchandise, and might get up as a consequence of the pastime of molds growing on the floor of fermented meat are the maximum not unusual mycotoxins contaminating fermented meat products. Afb1 is the maximum not unusual liver carcinogen labeled in institution 1 through the international organization for studies of cancer (IARC). *Aspergillus favus* and *Aspergillus parasiticus* are known as responsible species for the manufacturing of Afb1. Ota is a set 2b carcinogen, and the genus of *Aspergillus* and *Penicillium* are chargeable for its manufacturing. Mycotoxigenic molds removed from fermented meat products can produce mycotoxins underneath diverse situations, such as environmental temperature, humidity, and

water interest at some stage in the ripening duration of meat products (Pleadin *et al.* 2015). Several studies have pointed out the possibility of the presence of mycotoxin contamination in fermented meat products as end result of inadequate control of production and storage conditions, indicating the need of prevention of contamination which could adversely affect human fitness (Bala *et al.* 2017).

Found significant aflatoxin B₁ and ochratoxin A (OTA) levels in “slavonski kulen” fermented sausages as 11.79±2.34 µg kg⁻¹, 16.13±3.32 µg kg⁻¹, respectively. OTA levels in Istrian, Lavonian, and Kulenova seka fermented sausages had been determined as 0.25±0.01 µg kg⁻¹, 0.27 µg kg⁻¹ and 0.26 ± 0.14 µg kg⁻¹, respectively (Kudumija *et al.* 2020). In another look at, OTA levels in Iberian ham have been observed as 3.20 µg kg⁻¹ (Rodríguez *et al.* 2015).

Biogenic amines in fermented meat

Biogenic amines are natural compounds found clearly in lots of food stuffs with an aliphatic, fragrant, or heterocyclic shape shaped because of microbial decarboxylation of amino acids or the amination of aldehydes and Ketones. These compounds are formed by way of the action of microbial enzymes on amino acids, and they can contribute to the desire, aroma, and texture of foods (Barile & Rastall, 2013). They also are crucial as they are able to act as pollutants, leading to food spoilage and protection issues. It's been recognized that high-awareness publicity to biogenic amines can result in poisonous effects on respiratory and cardiovascular structures. Biogenic amines are more frequently discovered in fermented meat and meat products because of their predisposition to amine decarboxylation with the aid of the herbal microbial flora. They can be produced during the fermentation level by using the hobby of microorganisms while the beef proteolysis. Insufficient hygienic best of raw material, re-contamination, and deficiencies in production and storage steps significantly impact the formation of biogenic Amines. In such situations, they also are used as a spoilage indicator and poor hygiene situations for meat merchandise. Lactic acid

microorganism that have grown and displayed their metabolic pastime on those fermented meat products have an essential characteristic in forming biogenic amines such as putrescine, cadaverine, histamine, and tyramine (Bartkiene *et al.* 2023).

Fermentation of fruits

Compared to plant-based food products, fermentation fruits are generally used as a beverage. Table shows a list of fermented fruits with responsible bacteria. Fermented fruit products relate to a valuable and large beneficial microorganism. The majority of the time, different native microorganisms present in the raw components spontaneously ferment diverse plant-based substances to produce fermented products. The fermentation of fruits involves lactic acid bacteria, a small part of the microbiota of raw fruits. Depending on the kind of vegetable, hetero- and homo-fermentative organisms from the genera *Pediococcus*, *Enterococcus*, *Weissella*, *Lactobacillus*, and *Leuconostoc*, were variably detected (Bastidas-Oyanedel *et al.* 2015). The most prevalent species were *Weissella cibaria*/*Weissella confusa* and *Lactobacillus plantarum*. Fermented sweet cherries, for example, represent the alternative source of indigenous microorganisms. The microbiota from the fruits is adapted to the fermented brine solution making the microorganisms isolated from an ecosystem typically having technological properties, such as resistance to salt, high acidification rates, pH, temperature, and phenolics.

Table 4: Fermented Fruits

Fermented Fruits	Fruit source	Bacteria Involved
Pickled juice	Fruits	<i>L. buchneri</i>
Pineapple pulp	Pineapple	<i>Meyerozyma caribbica</i>
Wine	Grape	<i>S. cerevisiae</i> and <i>S. bayanus</i>

Other fermented fruits in Table 4 are also found in other countries with different fruit sources. Fermented cashew apples contain oligosaccharides, which can be evaluated with *Lactobacillus johnsonii* to determine the degree of polymerization. However,

the fermented cashew apple is still considered to have an unpleasant taste to be consumed by humans. The fermentation of fruit with *L. johnsonii* happens due to the focus on enzymatic synthesis, where glucose and fructose are used as enzyme acceptors. UK consumers drink cider, another beverage product from apples. This beverage is fermented by *L. brevis*, *L. paracollinoides*, *L. casei*, *L. diolivorans*. It is also under the same conditions as wine from grapes. In general, fruit fermentation research is limited, whereas the fruits contain beneficial microorganisms to explore deeply to understand the importance of microorganisms isolated for the generated food products. Cider is produced by fermenting apples with certain species of lactic acid bacteria, which help to break down the fructose and glucose in the apples into ethanol. This fermentation process is similar to the process used to produce wine from grapes, although the microorganisms used are slightly different. As a result, more research is needed to better understand the role of microorganisms in fruit fermentation and their potential to generate beneficial food products.

Fermentation of cereals The majority of fermented foods manufactured from grains are found in Africa. The natural microbiota is employed to ferment grains like maize, millet, rice, or sorghum. The grains are frequently cooked, crushed, malted, and occasionally filtered. Many well-known cereal-based products have distinctive regional variations in content and preparation. African cereal products may be divided into a few main types; liquids, porridges, (semi) solid prepared doughs, and liquid drinks, such as non-alcoholic gruels. Table 4 lists fermented cereals and microorganisms responsible for fermentation. The Burkinabe dish of ben-saalga, a thin porridge made from fermented pearl millet (*Pennisetum glaucum*) sediment cooked in water, is well-known in Ghana. Natural fermentation is often dominated by *L. fermentum*, *L. plantarum*, and *P. pentosaceus*, requiring the energy density of fermented gruels derived from cereal; some *L. plantarum* strains can hydrolyze starch, which can be advantageous. Another product is Ogi, a well-known morning gruel traditionally made by naturally fermented maize grains to create a supplementary diet for kids. The precise

composition will impact the end product's viscosity, fermentability, and content. It can also be prepared from sorghum or millet grains. Ogi is often ingested following heat treatment, eliminating the probiotic properties of lactic acid bacteria. It must be noted that these foods' functional properties are connected not only to how bioactive live cells interact with the host but also indirectly by ingesting bioactive chemicals generated during fermentation. Thus, natural fermentation is a viable way to promote a healthy lifestyle through the consumption of plant-based foods with antimicrobial properties. In several African nations, alcoholic and non-alcoholic beverages are made from fermented sorghum and millet. They serve as the base grains for the non-alcoholic beverage bushera and the traditional alcoholic beverage muramba. *Lactococcus*, *Leuconostoc*, *Lactobacillus*, *Weissella*, and *Enterococcus* are responsible for bushera production. While Ethiopian customers are well-versed with barley meals and beverages, including Kunun-zaki, shorba, kinche, tihlo, shamet, chuko, beso, etc. (Bengoa *et al.* 2019) is another millet-fermented beverage that is frequently enjoyed in Northern Nigeria.

Fermentation of Cereals

The majority of fermented foods made from grains are determined in Africa. The herbal microbiota is employed to ferment grains like maize, millet, rice, or sorghum. The grains are often cooked, beaten, malted, and now and again filtered. Many famous Cereal-primarily based products have specific nearby variations in content and instruction. African cereal products may be divided into a few essential kinds; liquids, porridges, (semi) Solid prepared doughs, and liquid beverages, including nonalcoholic gruels. Fermented cereals and microorganisms responsible for fermentation. The burkinabe dish of ben-saalga, a thin porridge crafted from fermented Pearl millet (*Pennisetum glaucum*) sediment cooked In water, is well-known in Ghana. Natural fermentation is frequently Dominated by way of *L. Fermentum*, *L. Plantarum*, and *P. Pentosaceus*, requiring the strength density of fermented gruels derived from cereal;

some *L. Plantarum* lines can Hydrolyze starch, which can be fantastic. Another product is Ogi, a famous morning gruel traditionally made by means of certainly fermented maize grains to create a supplementary food regimen for children. The specific composition will effect the end product's Viscosity, fermentability, and content. It may additionally be Organized from sorghum or millet grains. Ogi is regularly Ingested following warmness remedy, eliminating the Probiotic houses of lactic acid microorganism. It is thought to be cited that those ingredients' Functional residences are linked not most effective to how Bioactive stay cells have interaction with the host however also indirectly by consuming bioactive chemicals generated throughout Fermentation (Bertuzzi *et al.* 2013).

Thus, natural fermentation is a viable way To promote a wholesome lifestyle through the consumption of plant-primarily based foods with antimicrobial properties. In several African nations, alcoholic and non-alcoholic Beverages are made from fermented sorghum and millet. They function the bottom grains For the non-alcoholic beverage bushera and the traditional alcoholic beverage muramba. *lactococcus*, *leuconostoc*, *lactobacillus*, *weissella*, and *enterococcus* are Responsible for bushera manufacturing (Muyanja *et al.* 2003). While ethiopian customers are properly-versed with barley food and drinks, which includes kunun-zaki, shorba, Kinche, tihlo, shamet, chuko, beso, and many others is any other millet fermented beverage this is often loved in northern Nigeria. Lactic acid fermentation is an ordinary, simple, and affordable method for processing meals, including starch, to ferment cereal merchandise. Cereal meals products' Dietary and organoleptic value is stepped forward via Lactic acid microorganism fermentation. The sensory characteristics Constitute the first significant development. Bread, loaves, Confectionary, pastes, noodles, gruels, semi-digested Beverages, and supplemental meals for infants and kids Are produced by using lactic acid fermentation of cereal substrate (Bhutia *et al.* 2021). (Table 5) Showing some Fermented Cereals:

Table 5: Fermented Cereals

Fermented cereals	Cereal Source	Bacteria Involved
Bushera	Sorghum	<i>Lactobacillus ssp.</i>
Dosa	Red Sorghum grains	<i>L.fermentum</i> , <i>L. Lactis</i>
Koko	Corn, Pearl millet	<i>L.fermentum</i> , <i>L. plantarum</i>
Boza	Wheat, Milk,Corn	<i>LAB, yeasts</i>

Fermentation of Seaweeds

Seaweed fermentation has been formerly discovered in meals or remedy. The call for seaweed inside the Asian Market place, which has led to sharp will increase in aquaculture yields, has been a significant element inside the non-stop Rise in seaweed intake over the past few a long time. Worldwide seaweed harvesting became 29 million tones. The number one makes use of were synthesizing hydrocolloids for food and prescription drugs, animal feed, and human intake. Whilst early investigations Indicated fantastic yields, seaweeds are specially ideal for this cause due to the fact their improvement systems do not compete with plants and do not require sparkling water. Seaweed fermentation merchandise are maximum pertinent due to the fact the primary structural polysaccharides undergo Hydrolysis, producing a excessive quantity of glucose. Laminarin, alginate, and fucoidan are Located in brown seaweeds, agar and carrageenans in Crimson seaweeds, starch and ulvan in inexperienced seaweeds, and Laminarin, alginate, and fucoidan are found in brown Seaweeds. Brown seaweeds provide more fermentable sugars in the shape of mannitol and glucuronic acid that, furnished mannitol-fermented cultures had been used, can further Enhance the fermentable mash. These sugars and the hydrolyzed polysaccharides go through glycolysis to produce pyruvate, which is sooner or later fermented to supply both Lactic acid or ethanol and CO₂, as shown in Fig. 1 most Microbial cultures cannot use numerous seaweed sugars, consisting of mannuronic and uronic acids, fructose, rhamnose, and xylose, making ethanol fermentation of seaweed difficult, so genetically modified cultures have been created to convert seaweed sugars nicel

(Bilal *et al.* 2021). Seaweed has an intact protein complex, hydrolyzed after. Fermentation. The fermentation also bodily disrupts Seaweed cells and consequently breakdown the protein– Phenolic blends to launch the fermentation of diverse Seaweeds depending at the sugar content material in seaweeds to Pick out the bacteria concerned inside the fermentation procedure, Proven in desk 9. Seaweed *Gracilaria verrucosa* may be Fermented with *Hortaea werneckii*, *Lactobacillus spp.*, and *Staphylococcus*. The fermentation of seaweeds expanded Antioxidant and antimicrobial activity. The boom in antimicrobial activity implicated the protection of seaweeds from pathogenic and spoilage Microorganism and progressed the seaweeds’ dietary value by Lowering the insoluble and indigestible fractions. Parent 2 indicates the fermentation technique.

The fermentation system turns on the seaweeds’ antimicrobial activity which allows to guard them from microorganism and other contaminants. This manner also aids inside the Breakdown of indigestible components, making the seaweeds greater bioavailable and easier to digest (Bilo *et al.* 2018).

Table 6: Fermented seaweeds

Seaweed	Bacteria involved	Consumer Attitude
Fermented <i>Gracilaria gracilis</i>	<i>Lactobacillus sakei</i> , <i>staphylococcus</i>	Improving the nutritional value of the seaweeds.
Edible red seaweed	<i>Lactobacillus lus plantarum</i>	Consumed as special dietary food to improve hyperlipidemia and obesity.
Green seaweed	<i>Paradendryphilella salina</i>	As a promising source of functional and sustainable for food.
Edible Irish	<i>Lactobacillus plantarum</i>	As a functional food.

This makes them ideal to be used in a variety of applications, along with biofuels, dietary supplements, and prescription drugs. Furthermore, bacteria related to the fermentation Method can also make use of fungi found within the marine vicinity.

Reported the fermentation Of inexperienced seaweeds *Ulva spp.* hydrolyzed by using the marine Fungi *Paradendryphiella salina*. The outcomes confirmed an Growth in yield, protein, and amino acids. But, the Research at the fermentation of seaweeds for useful Meals still wishes to be finished. Similarly evaluation of fermented seaweeds’ effects on food processing is critical. Table 6 showing some Fermented seaweeds.

Coffee fermentation

Espresso is a widely fed on beverage organized from coffee beans. No matter fermentation being essential to put off the mucilage layer, subsequent heat-in depth processes (roasting and brewing) produce a drink this is near, all through espresso fermentation, parchment espresso’s mucilage need to be removed. Espresso mucilage includes starch, cellulose, and pectin. The mucilage may additionally make it tough to dry espresso beans and, in uncommon cases, may additionally promote mould increase, decreasing the very last espresso excellent. Spontaneous fermentation is frequently employed when you consider that it’s far explicitly executed to dispose of mucilage. Moreover, espresso beans already comprise all of the ingredients had to produce coffee flavor and perfume at some point of roasting. But, fermentation can expand the kind of chemicals that give coffee flavor and fragrance, consisting of more than seven-hundred risky and nonvolatile chemicals. In step with reports, yeast, lab, and enterobacteriaceae are predominantly answerable for wet fermentation, whereas acetic acid microorganism and pichia yeasts are responsible for dry fermentation Because the mid-1900s, several microorganisms had been isolated from moist processing fermentation. Considering that fragrant chemical substances are created while the mucilage layer in moist processing is eliminated, wet-processed coffee has better heady scent attributes than dry-processed coffee. Contemporary studies on espresso fermentation in the course of dry, semi-dry, and moist processing specializes in the usage of aromatic yeasts to create choose. A wide variety of microbial species (Table 10) are present at some point of espresso fermentation;

however, simplest a small variety of those native microorganisms have been selected due to their capacity results on the coffee's taste and perfume. Fermentation ought to be regulated to achieve this favorable final results (Bingol *et al.* 2014). The desire of suitable microorganisms that undoubtedly impact coffee desire and fragrance throughout fermentation is vital. So it is vital to properly alter fermentation in order to reap preferred flavor and aroma in coffee. The choice of the proper microorganisms is important because it's far those microorganisms that produce the compounds accountable for the want and aroma of coffee. Therefore, by means of regulating the fermentation manner, the preferred taste and aroma may be executed. Table 7 showing some fermented coffees.

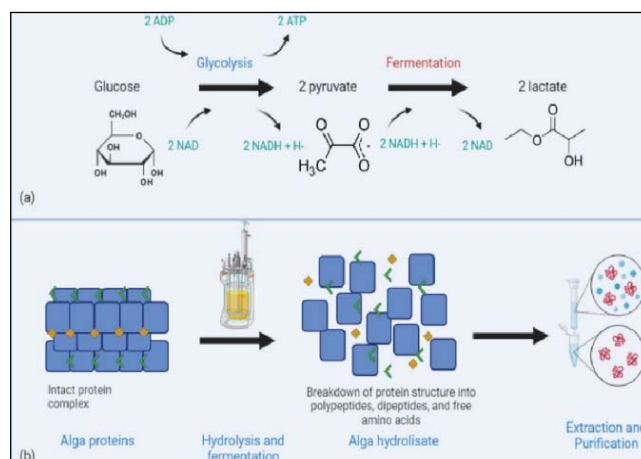
Table 7: Fermented coffees

Fermented coffee	Bacteria Involved	Consumer attitude
Wet fermented coffee	LAB, Enterobacteriaceae	Consumed for refreshment drink
Dry Fermented coffee	Acetic Acid bacteria and pichia yeasts	Consumed for refreshment drink

Valorization of food waste by using fermentation

Food waste (fw) accommodates complex carbohydrates, proteins, lipids, organic acids, enzymes, and nutraceuticals. Even though its definition has been extensively debated, consistent with the meals and agriculture agency (fao), it's far described because the "overall took place qualitative and quantitative food losses throughout the deliver chain technique, which takes place at the distinct levels like manufacturing, post-harvesting and processing". Fw is commonly considered a non-risky waste, except for animal-derived waste strictly managed via the ecu law (ec) no 1069/2009. Fw is turning into a growing and crucial hassle regionally and globally. In fact, in keeping with the fao, one-third of all meals manufacturing is misplaced or wasted globally every year. Fw is traditionally disposed of in landfills or incinerated for strength production. The disposal of fw in landfills is related

to several destructive environmental outcomes. In addition, fw is responsible for more than 20% of the whole worldwide production of greenhouse gases (ghc), such as methane (CH_4), nitrous oxide (N_2O), and vehicle bon dioxide (CO_2). Because of this, the prevention of its products, collectively with its valorization, is of important importance. Indeed, because of the developing public cognizance of the indiscriminate disposal of fw and its dangerous ecological effect, there may be an increasing hobby inside the recycling and bioconversion of fw, and for this, fw valorization is turning into an increasing enterprise. Valorization of fw refers to the techniques for changing meals waste materials into more than a few extra treasured products (Bintsis & Papademas, 2022).

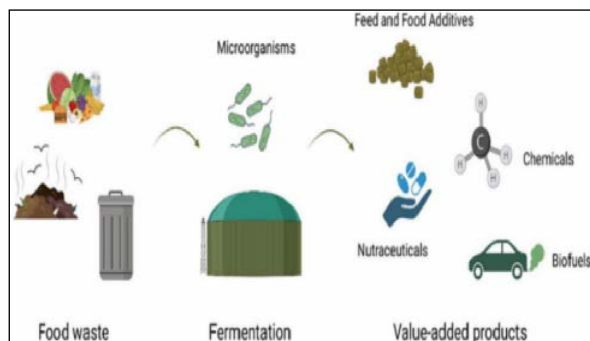


Sorurce: Maiorano et al. (2022) Food Fermentation.

Fig. 2: (a) Chemical fermentation path of the seaweeds, and (b) physical appearance of the fermentation of process in seaweeds

The recycling and the bioconversion of (fw) large opportunities to support sustainable development. Fermentation is one of the oldest procedures used for product transformation into value-introduced products the usage of microorganisms. In truth, with the aid of converting those by-merchandise thru the microbial fermentation manner, different cost-brought products may be produced, along with feed and meals additives, single mobile protein (spc), biofertilizers, bioplastics, chemicals, fuels, meals grade pigments and nutraceuticals.

Moreover, fw valorization will deliver financial, environmental, and social benefits thru, similarly to the manufacture of fee-added merchandise, the mitigation of environmental pollution, and overcoming the problems related to odor and the unfold of pathogens. Proceeding to valorize meals waste, numerous promising technologies the usage of acidogenic fermentation (Fig. 3) with anaerobic microbial communities are taking hold to generate exceptional price-delivered products from bio wastes.



Source: Ortiz Sanchez et al. 2023). Food Valorization

Fig. 3: Valorization of food waste by fermentation. "Created with BioRender.com

These strategies are frequently opportunity or supplementary to greater conventional ones and appoint anaerobic digestion. The transformation of bio products thru herbal processes is one of the enormous blessings. The resulting merchandise are secure and wholesome for human intake. Several are the products that can be recovered from fw. For instance, the carbohydrates inside the fw may be fermented to produce lactic acid, ethanol, unstable fatty acids (carboxylic acids with 1 to 4 carbon atoms, vfa) (Chai et al. 2020), or hydrogen and those products may be then extracted to function renewable commodity chemicals or liquid fuels. Furthermore, to mitigate the terrible impact, an more advantageous method to the waste management of the culmination and veggies processing enterprise is a important step in the transition to the bio financial system. It is now well known that agro-business interest creates more than one and special kinds of waste, which are at risk of being spontaneously fermented by the microbiota gift, of route, in

those via-products. Many research dealing with the fermentation of culmination and vegetable by way of-merchandise as an opportunity manner of valorizing food waste the use of one-of-a-kind microorganisms have been said within the literature. Several examples are suggested within the literature based on fermentation-based valorization techniques, inclusive of the anaerobic digestion of organic feedstock, date palm waste, cocoa by-products, and sourdough to provide lactic acid as an opportunity for raw material, enzymes, polysaccharides, drinks, and nutraceuticals. The bacteria usually used in controlled food manufacture are *Streptococcus thermophilus*, *Lactococcus lactis*, *Leuconostoc* spp., and *Lactobacillus* spp., for dairy merchandise and the genera *pediococcus*, *oenococcus*, and *weissella* play a pivotal role in plant-primarily based fermented products. These valorization techniques the use of these microorganism, which we can also confer with as lactic acid bacteria (lab), counted the production of lactic acid that could be replenished inside the meals chain, as well as enhancing the digestibility of proteins and the sensory properties of these plant with the aid of-products that could be used for meals ingredients. But, fermentation strategies and bioconversion techniques had been defined to increase digestibility, beautify nutritional value and decrease the degrees of antinutritional elements in those substrates, also using different bacterial species, yeast, and molds. Consequently, the fermentation of agro-feed residues through LAB, by myself or in aggregate with other microorganisms, paves the manner for developing new sustainable round economy techniques. Similarly to fermentation techniques using lab, other fermentative microorganism are pronounced to were applied to valorize vegetable through products and different vegetable sources, which include unique *clostridium* and *bacillus* bacterial species. Most of those applications focused on producing useful substances, which includes lactic acid, poly- γ -glutamic acid, bioactive peptides to be reintegrated into the food chain, and other com kilos like glycosidases or carporate of industrial hobby (Berka et al. 2007). Concerning the genus *bacillus*, *Bacillus coagulans*, *Bacillus amyloliquefaciens*, *Bacillus*

licheniformis and *B. subtilis* were used, on my own or in combination with different bacterial species and with fungi, to ferment merchandise derived from rice, soy, oak, fruit, sorghum (Tropea, 2022). Then again, it have to be noted that the clostridium bacterial species is mainly used in the fermentation fruit waste. As an instance, on this regard, a success fermentation method has been said the usage of both *Clostridium cellulovorans* and *Clostridium beijerinckii* traces to ferment mandarin orange waste. On this observe, it's been proven that, although usually, d-limonene blanketed in citrus end result inhibits yeast hobby and makes ethanolic fermentation difficult; however, the physiological attention of d-limonene does now not inhibit the boom of the 2 clostridium traces. Consequently, beginning from the isopropanol-butanol-ethanol fermenting potential of *C. Beijerinckii* and the cellulosic biomass-degrading capability of *C. cellulovorans* lets in biofuels to be made out of this particular fruit waste. Moreover, it's been highlighted the opportunity of the usage of vegetable and fruit waste to generate bioenergy within the shape of biofuel. Fruit wastes, especially, have been used in the production of bioethanol. As a substitute, vegetable wastes, high in cellulose, hemicelluloses, and lignin, were employed to supply 2d-era bioethanol (Ti *et al.* 2016). Moreover, soya by means of-products were in general subjected to solid-nation fermentation at 30–47 °C the usage of aspergillus niger and bacillus species or yeast employing lower temperatures (20–28 °C). Rather, barley bran and brewing waste were frequently inoculated with *Aspergillus trichoderma* and lab species. Some other example of using fermentation to valorize fw is reported by means of brancoli. The authors suggested a solid-state fermentation system performed by means of the safe to eat fungus *Neurospora intermedia* using bread waste as feedstock for generating a protein wealthy food product. In this research, that can make a contribution to highlighting how it is feasible to manage wasted bread more sustainably, it's been proposed that solid-nation fermentation may be used to recover the in any other case dis carded surplus bread (brancoli). Another opportunity is the possibility of using meals enterprise waste as animal feed. Tis opportunity

seems to be very thrilling, as it'd carry each environmental and public blessings besides lowering animal production prices. The various microbial cultures used inside the biotechnological methods to recover food waste, lactic microorganism have several blessings over other bacterial species, mainly in animal/fish processing wastes. They're, in reality, usually identified as secure (grass). Furthermore, it has been shown that the goods acquired upon the fermentation with lactobacillus also are pronounced to produce other beneficial outcomes on aquatic animal intestines, along with antimicrobial and antioxidative residences. Fermented fish waste appears as a liquid product, obtained from the liquefaction of tissues carried out by means of the enzymes already gift inside the fish and expedited via an acid pH. It has been discovered that these fish-derived products can unexpectedly adapt to the intestines of each aquatic and domestic animals, as a consequence making it feasible for them for use in probiotic aquaculture feeds (Biscola *et al.* 2016). As an example, studies are pronounced inside the literature in which fish by using-merchandise (non-edible parts such as head, viscera, skin, and bones) of *dicentrarchus labrax* are fermented by the microorganisms *S. cerevisiae* strains and lacto bacillus reuterilines. It has also been proven a fermentation technique using non-sterilized fish wastes, supplemented with lemon peel as a filler and prebiotic source, carried on via blended starter cultures of *Saccharomyces cerevisiae* and lac *Tobacillus reuteri*. In this technique, fish waster become bio converted right into a high protein content material supplement used for aquaculture feeds. The final fermented product changed into found to be bad in spoilage microorganisms and rich in wholesome microorganisms by displaying a lipid and protein content that makes it suitable for aquaculture feed. These results encourage fish waste and lemon peel con version into animal feed (Lee & Chen, (2018).

A observe has shown that the higher the carbohydrate content material of food waste, the better it is going to be valorized and converted into H₂. Research also display that meals waste is appropriate for methane production way to its physical and chemical

characteristics. Eventually it was performed to take a look at to assess the outcomes of the feed acquired via fermentation on final purchasers. On this take a look at, the authors assessed the impact of fermented discarded durian peel with lactobacillus casei, cellulase, and molasses alone or mixed in total combined rations on feed utilization, digestibility, ruminal fermentation, and nitrogen utilization in developing crossbreed tai local-anglo-nubians goats. The studies highlighted that the discarded durian peel fermented with molasses and *L. casei* had a miles more super digestibility and propionate concentration. Alternatively, this product caused much less methane and urinary nitrogen production (Biscola *et al.* 2018). Table 8 showing Food waste valorization.

Table 8: Food waste valorization

Food waste	Microorganism	Fermentation Process
Sweet potato, banana skin , mango waste	<i>Saccromyces sp.</i> , <i>saccharomyces cereviceae candida</i> <i>trapicalis</i>	Solid state Fermentation and Liquid Fermentation
Apricot pomace,apple pomace	<i>Aspergillus awamori</i> , <i>Aspergillus niger</i> and <i>Rhizopus oligoporus</i> , <i>punicagrantum</i>	Solid state fermentation
Pineapple	<i>Saccharomyces cereviceae</i>	Solid state fermentation
Rice bran, brewery waste	<i>Lactobacillus delbuieckii spp.</i> <i>Aspergillus niger</i>	Solid state Fermentation and Liquid Fermentation
Diary waste (whey)	<i>Cryptococcus albidus. ssp</i> , <i>Aerius xanthomonas citri</i>	Solid State Fermentation

Solid State Fermentation

Microorganisms have long played a major role in the production of food (dairy, fish and meat products) and alcoholic beverages. In addition, several products of microbial fermentation are also incorporated into food as additives and supplements (antioxidants, flavours, colourants, preservatives, sweeteners,...).

There is great interest in the development and use of natural food and additives derived from microorganisms, since they are more desirable than the synthetic ones produced by chemical processes. Solid-state fermentation (SSF) reproduces the natural microbiological processes like composting and ensiling. In industrial applications this natural process can be utilised in a controlled way to produce a desired product.

Flavours

Flavours incorporate over 1 / 4 of the arena market for food components. Maximum of the flavouring compounds are produced thru chemical synthesis or by way of extraction from natural materials. However, recent market surveys have proven that customers pick meals that may be labelled as natural. Vegetation were primary sources of vital oils and flavours but their use depends on herbal elements hard to control which include weather conditions and plant illnesses. An opportunity path for flavor synthesis is primarily based on microbial biosynthesis or bioconversion. Numerous microorganisms, including microorganism and fungi, are currently known for their capacity to synthesise exceptional aroma compounds. Tries to use those microorganisms in SMF resulted in low productiveness of aroma compounds, which hampered their industrial utility. SSF may be of high capability for this motive. Consequently, ferron reviewed the prospects of microbial production of food flavors and the endorsed SSF tactics for his or her manufacturing (Chai *et al.* 2019).

Enzyme Production

Recently, evaluated whether SSF is the pleasant gadget for generating enzymes. They observed that SSF is appropriate for the production of enzymes and other thermolabile products, mainly whilst better yields may be received than in SmF.

1. α -**amylase** : α -amylases (endo-1,4-a-d-glucan glucanohydrolaseEc three.2.1.1) are extra-cellular endo enzymes that randomly cleave the 1,4-a linkages among adjacent glucose devices

within the linear amylose chain and ultimately generates glucose, maltose and maltotriose units. When you consider that the Nineteen Fifties, fungal amylases were used to manufacture sugar syrups containing specific combinations of sugar that couldn't be produced via traditional acid hydrolysis of starch. Amylases are extensively hired in processed-meals enterprise which include baking, brewing, guidance of digestive aids, manufacturing of cakes, fruit juices, starch syrups, etc. (Zhao *et al.* 2016).

The manufacturing of α -amylases has typically been executed using smf; however, SSF systems seem as a promising technology. Currently used spent brewing grains in ssf for the production of α -amylase and decided that the complement of fermentation media with tween-80 or calcium ions greater α -amylase activity. This used banana Fruit stalk as a substrate in ssf with bacillus subtilis. Different factors along with initial moisture content, particle size, thermal remedy time and temperature, pH, Incubation temperature, additional nutrients, inoculum length and incubation length at the manufacturing of α -amylase had been characterized. Effects obtained for the optimization of process parameters truly shown their impact.

At the gross yield of enzymes in addition to their unbiased nature in influencing the organisms capability to synthesise the enzyme. It's miles recognized that particle size (precise Surface area) (Leroy & De Vuyst, 2014) is a critical issue in ssf. Banana fruit stalk debris of 400 μ m favoured maximal α -amylase manufacturing in comparison to large debris. A similar trend was pronounced for the manufacturing of glucoamylases with wheat bran and cellulases with coir pith of small particle size. These days, gelatinisation is coupled with liquefaction, that is possible via the movement of thermostable Amylases, that have been reported in both smf. and ssf. The productivity of thermostable amylases from bacillus sp. Changed into affected Through the nature of the strong substrate (wheat bran, rice Bran, corn bran and combination of brans), nature of the moistening agent, degree of moisture content material, Incubation temperature, presence or absence

of surfactant, carbon, nitrogen, mineral, amino acid and Vitamin supplements. Maximum enzyme manufacturing Changed into received on wheat bran supplemented with glycerol (1.0%, w/w), soyabean meal (1.0%, w/w), l-proline (0.1%, w/w), vitamin b-complicated (zero.01%) and moistened With faucet water containing 1% tween-forty. Lately, suggested the Use of coconut oil cake (coc) as a substrate for the production of α -amylase by using a. *Oryzae* below ssf conditions. Uncooked coc supported the boom of the lifestyle, Resulting inside the production of 1372 u/gds α -amylase in 24 h. Supplementation with 0.5% starch and 1% peptone To the substrate definitely enhanced the enzyme synthesis generating 3388 u/gds, proving coc a promising substrate for α -amylase production.

Lactic acid

Lactic acid fermentation has obtained tremendous attention considering long term (Benninga, 1990; Vickroy, 1985). It has extensive applications in meals, pharmaceutical, leather and fabric industries and as a chemical feed stock. It has two enantiomers l(+) and d() of which l(+) is used by human metabolism because of the presence of l lactate dehydrogenase and is desired for meals. In recent times, lactic acid is in wonderful demand because of its use as beginning material to supply biodegradable polymers utilized in clinical, industrial and purchaser merchandise. Soccol, marin, rimbault, and labeault the manufacturing of l(+)-lactic acid via rhizopous *oryzae* in stable-kingdom situations working with sugarcane bagasse as a aid. They obtained a barely better productiveness than in submerged cultivation. Also, richter and tra'ger (1994) investigated the l(+)-lactic acid manufacturing with the aid of lactobacillus paracasei in stable-nation conditions using candy sorghum as a support. Extra current have pronounced the production of l(+)-lactic acid by lactobacillus amylophilus gv6 below SSF situations using wheat bran as each assist and substrate.

Citric acid

Citric acid is one of the most typically used organic

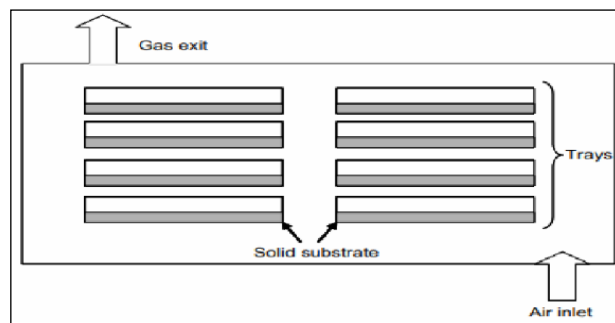
acids in meals and pharmaceutical industries. The meals industry is the most important purchaser of citric acid, the use of almost 70% of the total manufacturing, observed by using about 12% for the pharmaceutical industry and 18% for different programs. Its first-class taste, high solubility and flavour-improving homes have ensured its dominant role inside the market. Although citric acid can be obtained with the aid of chemical synthesis, the cost is lots better than using fermentation. It is specially produced by smf, through the filamentous fungus *A. niger* (Zhao *et al.* 2018). Currently, in an effort to growth the performance of citric acid manufacturing the use of a. Niger, ssf has been studied as a capacity alternative to smf. The production of citric acid depends strongly on an suitable stress and on operational situations. Oxygen stage is an essential parameter for citric acid fermentation. Numerous researchers have studied the influence of pressured aeration on citric acid manufacturing and the metabolic hobby of a. Niger in ssf by way of respirometric evaluation. They showed that citric acid manufacturing was favoured by way of a confined biomass production, which passed off with low aeration charges. Both works confirmed the feasibility of the usage of the strain *A. Niger* for citric acid manufacturing with the aid of ssf. Specific agro-business residues together with apple Pomace, coffee husk, wheat straw, pineapple waste, Combined fruit, maosmi waste, cassava bagasse, banana, Sugar beet cosset and kiwi fruit peel have been investigated for his or her capacity for use as substrates Similarly, ssf Gave high citric acid yield without inhibition associated with Presence of sure steel ions which include Fe^{2+} , Mn^{2+} , Zn^{2+} , and many others., even though shankaranand and Lonsane (1994) said that addition of those minerals Into the manufacturing media to a positive stage more desirable Citric acid manufacturing by using 1.4–1. Nine fold with appreciate to Smf. Therefore, SSF is a superb manner of using nutrient rich strong waste (Mok *et al.* 2019).

SSF bioreactors

The design of an green business-level reactor for SSF is of importance because ssf is extra environmentally

friendly than smf. However, it indicates tremendous drawbacks together with switch resistance, steep gaseous awareness and heat gradients that broaden inside the medium bed, which might also adversely have an effect on stable-kingdom fermentor performances Agitation and rotation in SSF have been frequently completed to improve mass and heat transfers, however the shearing force as a result of agitation and rotation has damaging effects on medium porosity and disrupts fungal mycelia (Lee *et al.* 2016). There are four sorts of reactors to perform ssf procedures and every of their personal design attempts to make situations more favourable for fermentation below strong kingdom Situations. The bioreactors typically used, which can Be prominent by means of the type of aeration or the mixed system hired, consist of the subsequent:

Tray: it consists of flat trays. The substrate is spread Onto every tray forming a skinny layer, only a few centimetres deep. The reactor is saved in a chamber at consistent temperature via which humidified air is circulated (Fig. 4). The principle disadvantage of this configuration is that numerous trays and big quantity are required, making it an unattractive layout for big-scale manufacturing (Zhong *et al.* 2021).

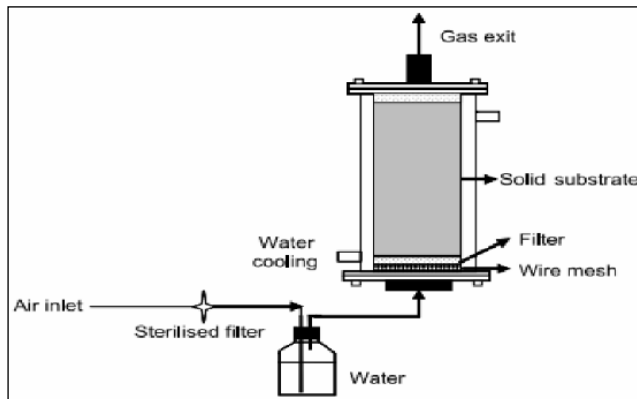


Source: Various agitation devices such as paddles and baffles (Domínguez,) Rivela, Rodríguez Couto, & Sanroman, 2011; Nagel, Bakker, & Rinzema, 20b; Prado *et al.* 2019

Fig. 4: Scheme of a tray bioreactor (passive aeration; static).

Packed-mattress: additionally it is composed of a column of glass or plastic with the stable substrate retained on a perforated base. Through the mattress of substrate humidified air is constantly. It can be

fitted with a jacket for flow of water to control the temperature at some stage in fermentation (Fig. 5). This is the configuration typically hired in industrial manufacturing. The primary drawbacks associated with this configuration are: difficulties in obtaining the product, non-uniform boom, poor warmth elimination and scale-up problems.



Source: Rivela, Rodriguez Couto, & Sanroman, 2021.

Fig. 5: Scheme of an immersion bioreactor (humidified air; mechanical)

Horizontal drum: this design permits ok aeration and mixing of the substrate, while limiting the damage to the inoculum or product. Blending is executed with the aid of rotating the complete vessel or via numerous agitation devices which include paddles and baffles (Dominguez, Rivela, Rodriguez Couto, & Sanroman, 2001; Nagel, Tramper, Bakker, & Rinzema, 2001a, Nagel, Tramper, Bakker, & Rinzema, 2001b; Prado *et al.* 2004; Stuart,) its foremost drawback is that the drum is crammed to simplest 30% capacity, in any other case blending is inefficient.

Fluidised bed: so that you can keep away from the adhesion and aggregation of substrate particles, this layout resources a keep agitation with pressured air. Even though the mass heat transfer, aeration and mixing of the substrate is multiplied, harm to inoculum and heat construct-up via sheer forces may also have an effect on the very last product yield. The exclusive negative aspects detected within the abovementioned bioreactor designs to perform SSF strategies.

Have promoted the need of growing new bioreactor configurations or enhancing the already existing designs. These bioreactor configurations need to be able to perform in continuous mode with excessive productivity for extended intervals of time without operational troubles In addition to allow the size-up of the manner. Our research organization has been working in this area, resulting in the layout of a brand new bioreactor, called immersion bioreactor. This bioreactor consists of a jacketed cylindrical glass vessel with a spherical backside, interior which numerous twine mesh baskets full of guide colonized via the fungus are positioned. They moved upwards and downwards by way of a pneumatic gadget, remaining more time out of doors than in the medium. It is noteworthy that this bioreactor configuration became also able to run in non-stop mode with out operational troubles, achieving high ligninolytic enzyme sports.

Distinctive research have been carried out for the manufacturing of natural meals and additives derived from microorganisms in unique bioreactor configurations. As an example, the production of aroma compounds by using k. Marxianus grown on cassava bagasse in strong kingdom fermentation the usage of packed mattress reactors, testing different aeration charges became studied by using Medeiros. Headspace evaluation of the tradition by means of gas chromatography showed the manufacturing of 11 compounds. The main compounds had been ethyl acetate, ethanol and Acetaldehyde. The fruity aroma was attributed to the productions of esters. Recently, navarrete-bolan˜os, jime˜nez-islas botelloalvarez, rico-martı˜nez, and paredes have employed a modular rotating drum bioreactor (prepared with inlet air injection, variable speed pumps, humidifier, and gasoline analyser) for xanthophylls extraction from marigold plants (Zhong *et al.* 2021). Marigold extracts had been commercialised across the world and are used as components for chicken feed, as they provide shiny colours in egg Yolks, skin, and fatty tissues. Because of this, they're used as an additive in several food and pharmaceutical industries. Based on experimental layout strategies, most useful

operation values have been determined for aeration, Moisture, agitation and marigold-to-inoculum ratio in SSF of marigold flora by using combined lifestyle of three microorganisms (*flavobacterium iib*, *acinetobacter anitratus*, and *Rhizopus nigricans*), main to a xanthophylls Yield of 17.8-g/kg dry weight. This price represented a Sixty five% increase with regards to the manage. Milagres, santos, piovan, and roberto have shown that thermoascus aurantiacus turned into capable of produce a high level of thermostable xylanase whilst sugar cane bagasse turned into used as a substrate in a tumbler-column Reactor with pressured aeration. The airflow fee had a considerable impact on enzyme pastime, while initial mass of Bagasse had none. The highest yield of xylanase (1597 u/g) become obtained running within the bioreactor at the most advantageous situations: airflow price (6 l/h g) and substrate (8 g). A packed-mattress bioreactor with 4 degrees become constructed and operated for microbial production of citric Acid via a. Niger the usage of apple pomace as a substrat beneath the optimised conditions, 124 g citric acid was constructed from 1 kg dry apple pomace with yield of 80% based totally on overall sugar as a substrate (Leroy & Vuyst, 2014).

Refining traditional fermentation

With the advent of refrigeration, extended shelf existence changed into not the principle motive for fermenting food, yet those products stay highly famous attributable to their complex flavor, texture, and patron call for natural control over and predictability of the otherwise random nature of fermentation to enhance meals safety and standardization (Fig. 6) (Acuna-Arguelles *et al.* 1994). Commonly, starter cultures offer the meals substrates with the important microorganisms required for propagation and colonization even earlier than fermentation begins. Lab, as an instance, hastily growth acidity and thereby inhibit undesirable microbes from growing. Similarly, saccharomyces produces alcohol that inhibits other microorganisms. Starter cultures additionally confer crucial functions such as bacteriophage immunity, exo polysaccharide

formation, or amino acid biosynthesis, which prevent spoilage and enhance the flavor and texture of the fermented merchandise. Once more, higher knowledge of the metabolic talents of the organisms concerned would help to enhance any of these aspects (Nam *et al.* 2012).

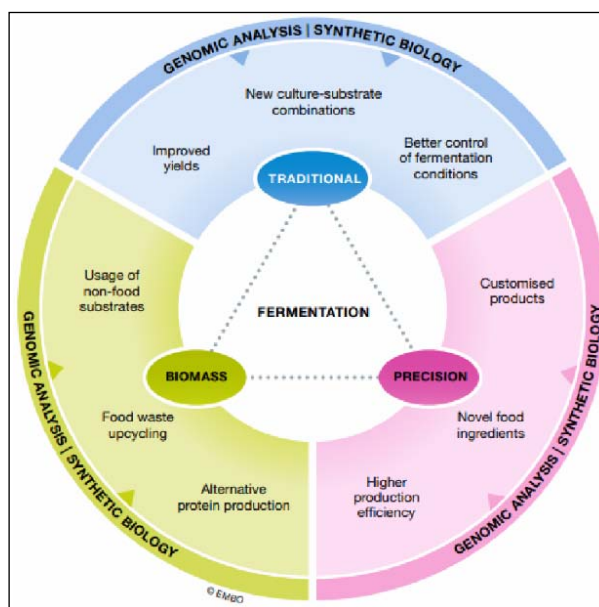


Fig. 6: The potential of genomics and synthetic biology to further improve applications

Fermented meals merchandise still occupy entire supermarket cabinets: beer and wine, kimchi, cheese, yogurt, soy sauce, lemonade, and so on. These are all produced with the aid of conventional fermentation that either uses microorganisms naturally gift on the substrate wild yeasts that develop on grapes, for instance—or controlled fermentation with a starter tradition, or through so-referred to as backslapping through the usage of a small quantity of a preceding fermentate to inoculate fresh substrate (Acuna-Arguelles *et al.* 1995). Some of the favored outcomes include probiotics, phytochemicals, short-chain fatty acids, peptides, nutrients, and amino acids with antihypertensive, blood glucose-reducing, anticancer, and anti-weight problems houses. As sugars are converted into other metabolites, fermented meals also are considered low-caloric. Furthermore, fermentation creates a complex taste and texture profile from amino acid and lipid degradation,

extracellular polysaccharide manufacturing, or mycelium boom. As an instance, tempeh production starts off evolved with breaking down antinutritional factors at the same time as increasing nutritional content material. The fungal biomass remains within the final product and contributes to its taste and texture. Similarly, one-of-a-kind microorganisms additionally create the complicated texture, taste, and smell enjoy of stilton cheese or a riesling wine.

"...fermentation creates a complex taste and texture profile from amino acid and lipid degradation, extracellular polysaccharide production or mycelium growth."

Huge-scale manufacturing of fermented foods typically employs the usage of starter cultures: a set of 1 or greater microorganism consisting of *saccharomyces*, *lactobacillus*, *lactococcus*, *streptococcus*, or *enterococcus* to inoculate the substrate. Starter cultures allow No matter the advantages of using starter cultures, many artisanal and small manufacturers nonetheless choose spontaneous fermentation with the aid of microbes from the surroundings. The presence of a couple of species and lines has further capacity for symbiotic utilization of different metabolic pathways, which ends up in progressed sensorial homes. Moreover, indigenous microbiomes have a notably diverse gene pool along side adept metabolic capabilities that could offer useful results. As an instance, the bacterial populations gathered from artisanal *doenjang*, (Alkorta *et al.* 1998) a fermented soybean paste, are more complex than the ones accrued from its business counterparts. However, an undefined starter composition introduces large variabilities to the fermentation manner. The final composition of the microbiota heavily depends at the environmental conditions, such as temperature, pH, or salinity, and it can bring about batch-to-batch versions when conditions change. Spontaneous fermentation necessarily effects in inconsistent excellent and might result in the boom of undesirable or even pathogenic microorganisms. It is, therefore, vital to refine each spontaneous and inoculated fermentation to growth predictability and safety.

As the fast improvement of sequencing technology has drastically decreased sequencing price and led to a rising variety of posted genomes in public databases, genomic studies of meals microbial groups have advanced substantially (Antier *et al.* 1193). Metagenomic evaluation the usage of hts may additionally assist to unveil the metabolic features and parameters that have an effect on the fermentation manner including substrate usages, enzyme production, or metabolic outputs. Metabolic modeling coupled with flux stability evaluation ought to then permit simulation of microbe growth and metabolite production in response to changes within the culturing surroundings.

But, it's smiles important to notice that information from hts exhibits only the capacity metabolic capabilities by means of the genes encoded, but those may not necessarily be expressed in the course of fermentation. Metatranscriptomic evaluation to supplement genomic analysis famous a greater accurate image of the metabolic activities. For instance, metabolomics, metagenomics, and metatranscriptomic anticipated that kimchi lab had high metabolic capacities in a heterotrophic lactic acid fermentation manner and that the fermentation changed into affected by bacteriophage infection (Antier *et al.* 1993). Altogether, metabolic evaluation and modeling might no longer simplest help to improve yield, flavor, or texture in business-scale fermentation primarily based on starter cultures however could also gain smaller, artisanal manufacturers to keep away from infection or spoilage by using suppressing the growth of unwanted microbes or metabolic features.

"...metabolic analysis and modelling would not only help to improve yield, taste or texture in industrial-scale fermentation based on starter cultures, but could also benefit smaller, artisanal producers to avoid contamination or spoilage..."

Modern techniques

Modern techniques of fermentation including: Controlled fermentation, Fermentation tanks, Starter Cultures and Monitoring & control.

(i) Controlled fermentation

It is a technique wherein fermentation is achieved beneath controlled situations to achieve a particular final results. This process includes cautiously tracking and regulating elements such as temperature, ph, oxygen stages, and nutrient availability to optimize the fermentation system.

As the point of view importance of managed fermentation managed fermentation is critical in diverse industries such as meals, beverage, and prescribed drugs, in which consistency and excellent are important (Nam *et al.* 2012). It allows for the *consistent taste and texture*: managed fermentation ensures consistent taste and texture in fermented products, that is important for client attractiveness.

Improved quality: managed fermentation enables to put off off-flavors and rancid-odors, ensuing in a higher high-quality product.

Increased efficiency: controlled fermentation reduces the danger of contamination and spoilage, resulting in elevated efficiency and decreased prices. *Scalability*: controlled fermentation permits for big-scale manufacturing of fermented merchandise, making it an critical technique in commercial settings.

Factors affecting fermentation: *temperature*: temperature influences the price of fermentation, with ideal temperatures various depending at the microorganism and product. *pH*: pH impacts the hobby of microorganisms, with most appropriate pH levels varying relying on the microorganism and product.

Oxygen levels: oxygen ranges have an effect on the kind of fermentation that happens, with cardio fermentation requiring oxygen and anaerobic fermentation occurring inside the absence of oxygen.

Nutrient availability: nutrient availability impacts the boom and interest of microorganisms, with premier nutrient tiers varying depending on the microorganism and product.

(ii) Controlled techniques for fermentation : They are temperature control, ph control, oxygen control.

Table 9 describes some Examples of managed fermentation.

Table 9: Describes some Examples of managed fermentation

1. Beer brewing:	Controlled fermentation is used to provide consistent flavor and texture in beer.
2. Yogurt production:	Managed fermentation is used to provide consistent taste and texture in yogurt.
3. Cheese production:	Managed fermentation is used to supply steady taste and texture in cheese.
4. Biofuel production:	Controlled fermentation is used to supply biofuels, such as ethanol and butanol.

(iii) Monitoring and manipulate

Monitoring and manipulation play a vital function in meals fermentation in the meals enterprise. Fermentation is a complex organic manner that entails the conversion of sugars into products together with alcohol, lactic acid, or carbon dioxide. To make sure constant and extraordinary merchandise, it's miles critical to monitor and manipulate various parameters in the course of fermentation. Right here are a few key components of monitoring and manipulate in food fermentation (Auria *et al.* 1992).

Monitoring parameters: *Temperature*: temperature influences the fee of fermentation, enzyme hobby, and microbial growth. Tracking temperature ensures that it remains inside the most advantageous variety for the precise microorganism and product (e.G., 20-25°C for lactic acid fermentation).

pH: pH influences microbial increase, enzyme interest, and product formation. Monitoring ph guarantees that it stays within the most effective range for the precise microorganism and product (e.G., ph 4.5-5. Five for yogurt production).

Oxygen levels: oxygen degrees affect the type of fermentation that happens (cardio or anaerobic). Monitoring oxygen ranges ensures that the desired form of fermentation occurs (e.G., cardio fermentation for beer manufacturing).

Sugar and nutrient levels: monitoring sugar and nutrient levels ensures that the microorganisms have sufficient assets for growth and product

formation (e.g., monitoring sugar tiers in wine production) (Tan *et al.* 2019).

Cell density and viability: monitoring cell density and viability ensures that the microorganisms are healthful and energetic, which is crucial for product formation (e.g., monitoring yeast cellular density in beer production).

Product formation: monitoring product formation ensures that the preferred product is being produced at the anticipated rate and pleasant (e.g., monitoring lactic acid production in yogurt manufacturing).

Benefits: *consistent product quality:* monitoring and manipulate make sure steady product high-quality with the aid of keeping most beneficial situations for fermentation.

Improved yield and efficiency: monitoring and manage optimize fermentation conditions, leading to improved yield and performance.

Reduced infection risk: tracking and control lessen the danger of infection, that is essential for consistent product best (Park *et al.* 2018).

Improved fermentation time: monitoring and manipulate optimize fermentation conditions, main to improved fermentation time.

Cost savings: monitoring and control reduce waste and improve performance, leading to fee savings.

CONCLUSION

In conclusion, food fermentation is a timeless practice that has evolved to meet the demands of the modern food industry. From traditional techniques to cutting-edge technologies, fermentation has proven to be a versatile and essential tool for food production. As the industry continues to innovate and expand, the importance of fermentation will only continue to grow, providing a bridge between heritage and innovation, and shaping the future of food for generations to come. With its unique ability to transform ingredients, enhance flavors, and improve nutrition, fermentation is poised to remain a vital component of the food industry, connecting tradition with modernity and flavor with function.

ACKNOWLEDGEMENTS

We would like to acknowledge the support and resources provided by University of Okara, Department of Microbiology and Molecular Genetics, Okara, Pakistan Specially, we thank to our department and mentors for their guidance and our team members for their contributions to this research. We also appreciate the all facilities provided by department that enabled us to conduct this study.

REFERENCES

- Achi, O.K. and Asamudo, N.U. 2019. Cereal-based fermented foods of africa as functional foods. *In: Mérillon JM, Ramawat K (eds) Bioactive molecules in food. Reference series in phytochemistry.* Springer, Cham. https://doi.org/10.1007/978-3-319-78030-6_31
- Acuña-Arguelles, M.E., Gutierrez-Rojas, M., Viniegra-González, G. and Favela-Torres, E. 1994. Effect of water activity on exopectinase production by *Aspergillus niger* CH4 on solid state fermentation. *Biotechnology Letters*, **16**: 23–28.
- Acuña-Arguelles, M.E., Gutierrez-Rojas, M., Viniegra-González, G. and Favela-Torres, E. 1995. Production and properties of three pectinolytic activities produced by *Aspergillus niger* in submerged and solid-state fermentation. *Applied and Microbiology Biotechnology*, **43**: 808–814.
- Adams, M.R. 1998. Fermented weaning foods. *In: Wood BJB (ed) Microbiology of Fermented Foods.* Springer, Boston. https://doi.org/10.1007/978-1-4613-0309-1_25.
- Adebo, O.A. 2020. African sorghum-based fermented foods: past. *Curr. Future Prospects Nutr.*, **12**: 1111.
- Adebo, O.A., Njobeh, P.B., Adeboye, A.S., Adebisi, J.A., Sobowale, S.S., Ogundele, O.M. and Kayitesi, E. 2018. Innovations in technologies for fermented food and beverage industries. *In: Panda S, Shetty P (eds) Food micro biology and food safety.* Springer, Cham. https://doi.org/10.1007/978-3-319-74820-7_4
- Adebo, O.A., Njobeh, P.B., Sidu, S., Adebisi, J.A. and Mavumengwana, V. 2017. Afatoxin B1 degradation by culture and lysate of a *Pontibacter* specie. *Food Control*, **80**: 99–103.
- Adesulu, A.T. and Awojobi, K.O. 2014. Enhancing sustainable development through indigenous fermented food products in Nigeria. *Afr. J. Microbiol. Res.*, **8**(12): 1338–1343.
- Adunpacharaphon, S., Petchkongkaew, A. and Visessanguan, W. 2021. *In vitro* mechanism assessment of zearalenone removal by plant-derived *Lactobacillus plantarum* BCC 47723. *Toxins*, **13**(4): 286.

- Afzaal, M., Saeed, F., Anjum, F., Waris, N., Husaain, M., Ikram, A., Ateeq, H., Muhammad Anjum, F. and Suleria, H. 2021. Nutritional and ethnomedicinal scenario of koumiss: a concurrent review. *Food Sci. Nutr.*, **9**(11): 6421–6428.
- Ahnan-Winarno, A.D., Cordeiro, L., Winarno, F.G., Gibbons, J. and Xiao, H. 2021. Tempeh: a semicentennial review on its health benefits, fermentation, safety, processing, sustainability, and affordability. *Compr. Rev. Food Sci. Food Saf.*, **20**(2): 1717–1767.
- Akbar, A., Sadiq, M.B., Ali, I., Anwar, M., Muhammad, N., Muhammad, J., Shafee, M., Ullah, S., Gul, Z., Qasim, S., Ahmad, S. and Anal, A.K. 2019. *Lactococcus lactis* subsp. *lactis* isolated from fermented milk products and its antimicrobial potential. *CyTA J. Food*, **17**(1): 214–220.
- Al-Mohammadi, A-R., Ibrahim, R.A., Moustafa, A.H., Ismaiel, A.A., Abou Zeid, A. and Enan, G. 2021. Chemical constitution and antimicrobial activity of kefir fermented beverage. *Molecules*, **26**(9): 2635.
- Alapont, C., López-Mendoza, M.C., Gil, J.V. and Martínez-Culebras, P.V. 2014. Mycobiota and toxigenic *Penicillium* species on two Spanish dry-cured ham manufacturing plants. *Food Addit. Contam. Part A*, **31**(1): 93–104.
- Alessandria, V., Rantsiou, K., Dolci, P. and Cocolin, L. 2014. Methodologies for the study of microbial ecology in fermented sausages. In: Toldrá F, Hui YH, Astiasarán I, Sebranek JG, Talon R (eds) Handbook of fermented meat and poultry. Wiley, pp 177–188. <https://doi.org/10.1002/9781118522653.ch21>
- Algonaiman, R., Alharbi, H.F. and Barakat, H. 2022. Antidiabetic and hypolipidemic efficiency of *Lactobacillus plantarum* fermented oat (*Avena sativa*) extract in streptozotocin-induced diabetes in rats. *Fermentation*, **8**(6): 267.
- Alkema, W., Boekhorst, J., Wels, M. and van Hijum, S.A. 2016. Microbial bioinformatics for food safety and production. *Brief Bioinform.*, **17**: 283 – 292.
- Alkema, W., Boekhorst, J., Wels, M. and van Hijum, S.A.F.T. 2016. Microbial bioinformatics for food safety and production. *Brief Bioinform.*, **17**(2): 283–292.
- Alkorta, I., Garbisu, G., Llama, M.J. and Serra, J.L. 1998. Industrial applications of pectic enzymes: a review. *Process Biochemistry*, **33**: 21–28.
- Alves, S.P., Alfaia, C.M., Škrbić, B.D., Živančev, J.R., Fernandes, M.J., Bessa, R.J.B. and Fraqueza, M.J. 2017. Screening chemical hazards of dry fermented sausages from distinct origins: Biogenic amines, polycyclic aromatic hydrocarbons and heavy elements. *J. Food Compos. Anal.*, **59**: 124–131.
- Ambrogi, V., Bottacini, F., Cao, L., Kuipers, B., Schoterman, M. and van Sinderen, D. 2023. Galacto-oligosaccharides as infant prebiotics: production, application, bioactive activities and future perspectives. *Crit. Rev. Food Sci. Nutr.*, **63**(6): 753–766.
- Angeles-Agdeppa, I., Sun, Y. and Tanda, K.V. 2020. Dietary pattern and nutrient intakes in association with non-communicable disease risk factors among Filipino adults: a cross-sectional study. *Nutr. J.*, **19**(1): 79.
- Anggraini, H., Tongkhao, K. and Chanput, W. 2018. Reducing milk allergenicity of cow, buffalo, and goat milk using lactic acid bacteria fermentation. 070010. <https://doi.org/10.1063/1.5062808>
- Antier, P., Minjares, A., Roussos, S. and Viniegra-Gonzalez, G. 1993. New approach for selecting pectinase producing mutants of *Aspergillus niger* well adapted to solid state fermentation. *Biotechnol. Adv.*, **11**: 429–440.
- Antier, P., Minjares, A., Roussos, S., Raimbault, M. and Viniegra Gonzalez, G. 1993. Pectinase-hyper producing mutants of *Aspergillus niger* C28B25 for solid-state fermentation of coffee pulp. *Enzyme and Microb. Technol.*, **15**: 254–260.
- Antone, U., Ciprova, I., Zolovs, M., Scerbaka, R. and Liepins, J. 2022. Propionic acid fermentation-study of substrates, strains, and antimicrobial properties. *Fermentation*, **9**(1): 26.
- Anusha Siddiqui, S., Bahmid, N.A., Mahmud, C.M.M., Boukid, F., Lamri, M. and Gagaoua, M. 2022. Consumer acceptability of plant-, seaweed-, and insect-based foods as alternatives to meat: a critical compilation of a decade of research. *Crit. Rev. Food. Sci. Nutr.* <https://doi.org/10.1080/10408398.2022.2036096>
- Apriyantono, A., Wiratma, E., Nurhayati, H.H., Lie, L., Judoamidjojo, M., Puspitasari Nienaber, N.L., Budiyo, S. and Sumaryanto, H. 1996. Analysis of volatiles of Kecap Manis (a typical Indonesian soy sauce). *Flav. Sci.* <https://doi.org/10.1533/9781845698232.1.62>
- Asama, T., Kimura, Y., Kono, T., Tatefuji, T., Hashimoto, K. and Benno, Y. 2016. Effects of heat-killed *Lactobacillus kunkeei* YB38 on human intestinal environment and bowel movement: a pilot study. *Benef. Microb.*, **7**(3): 337–344.
- Ashokkumar, V., Flora, G., Venkatkarthick, R., Senthil Kannan, K., Kuppam, C., Mary Stephy, G., Kamyab, H., Chen, W-H., Thomas, J. and Ngamcharussrivichai, C. 2022. Advanced technologies on the sustainable approaches for conversion of organic waste to valuable bioproducts: emerging circular bioeconomy perspective. *Fuel*, **324**: 124313.
- Augustin, M.A., Hartley, C.J., Maloney, G. and Tyndall, S. 2023. Innovation in precision fermentation for food ingredients. *Crit. Rev. Food Sci. Nutr.* <https://doi.org/10.1080/10408398.2023.2166014>
- Austin-Watson C, Grant A, Brice M (2013) Suppression of *Listeria monocytogenes* by the native micro-fora in teewurst sausage. *Foods* **2**(4):478–487. <https://doi.org/10.3390/foods2040478>
- Auria, R., Palacios, J. and Revah, S. 1992. Determination of the interparticular effective diffusion coefficient for CO₂ and

- O₂ in solid state fermentation. *Biotechnol. Bioengineer.*, **39**: 898–902.
- Azizkhani, M., Saris, P.E.J. and Baniasadi, M. 2021. An *in-vitro* assessment of antifungal and antibacterial activity of cow, camel, ewe, and goat milk kefir and probiotic yogurt. *J. Food Meas. Charact.*, **15**(1): 406–415.
- Babu, K.R. and Satyanarayana, T. 1995. α -Amylase production by thermophilic *Bacillus coagulans* in solid state fermentation. *Process Biochem.*, **30**: 305–309.
- Bachmann, H., Pronk, J.T., Kleerebezem, M. and Teusink, B. 2015. Evolutionary engineering to enhance starter culture performance in food fermentations. *Curr. Opin. Biotechnol.*, **32**: 1–7.
- Bachtarzi, N., Kharroub, K. and Ruas-Madiedo, P. 2019. Exopolysaccharide-producing lactic acid bacteria isolated from traditional Algerian dairy products and their application for skim-milk fermentations. *LWT.*, **107**: 117–124.
- Bai, Z.H., Zhang, H.X., Qi, H.Y., Peng, X.W. and Li, B.J. 2004. Pectinase production by *Aspergillus niger* using wastewater in solid state fermentation for eliciting plant disease resistance. *Bioresource Technol.*, **95**: 49–52.
- Bala, J.D., Kuta, F.A., Abioye, O.P., Adabara, N.U., Adelere, I.A., Abdulsalam, R., Al-Gheeti, A.A.S., Kaizar, H. and Onovughakpor, C. 2017. Microbiology and quality assessment of burukutu: a Nigerian fermented alcoholic beverage. *Niger J. Technol. Res.*, **12**(1): 103–108.
- Baldin, J.C., Munekata, P.E.S., Michelin, E.C., Polizer, Y.J., Silva, P.M., Canan, T.M., Pires, M.A., Godoy, S.H.S., Fávoro-Trindade, C.S., Lima, C.G., Fernandes, A.M. and Trindade, M.A. 2018. Effect of microencapsulated Jaboticaba (*Myrciaria cauliflora*) extract on quality and storage stability of mortadella sausage. *Food Res. Int.*, **108**: 551–557.
- Barile, D. and Rastall, R.A. 2013. Human milk and related oligosaccharides as prebiotics. *Curr. Opin. Biotechnol.*, **24**(2): 214–219.
- Barni, S., Liccioli, G., Sarti, L., Giovannini, M., Novembre, E. and Mori, F. 2020. Immuno-globulin E (IgE)-mediated food allergy in children: epidemiology, pathogenesis, diagnosis, prevention, and management. *Medicina.*, **56**(3): 111.
- Bartkiene, E., Zokaityte, E., Starkute, V., Zokaityte, G., Kaminskaite, A., Mockus, E., Klupsaite, D., Cernauskas, D., Rocha, J.M., Özogul, F. and Guiné, R.P.F. 2023. Crickets (*Acheta domesticus*) as wheat bread ingredient: influence on bread quality and safety characteristics. *Foods*, **12**(2): 325.
- Bastidas-Oyanedel, J-R., Bonk, F., Thomsen, M.H. and Schmidt, J.E. 2015. Dark fermentation biorefinery in the present and future (bio)chemical industry. *Rev. Environ. Sci. Biotechnol.*, **14**(3): 473–498.
- Bengoa, A.A., Iraporda, C., Garrote, G.L. and Abraham, A.G. 2019. Kefir micro-organisms: their role in grain assembly and health properties of fermented milk. *J. Appl. Microbiol.*, **126**(3): 686–700.
- Berka, R.M., Nelson, B.A., Zaretsky, E.J., Yoder, W.T. and Rey, M.W. 2004. Genomics of *Fusarium venenatum*: An alternative fungal host for making enzymes. *Appl. Mycol. Biotechnol.*, **4**: 191–203.
- Berka, R.M., Nelson, B.A., Zaretsky, E.J., Yoder, W.T. and Rey, M.W. 2007. Genomics of *Fusarium venenatum*: an alternative fungal host for making enzymes. *Appl. Mycol. Biotechnol.*, **4**: 191 – 203.
- Bertuzzi, T., Gualla, A., Morlacchini, M. and Pietri, A. 2013. Direct and indirect contamination with ochratoxin A of ripened pork products. *Food Control*, **34**(1): 79–83.
- Bhutia, M.O., Thapa, N. and Tamang, J.P. 2021. Molecular characterization of bacteria, detection of enterotoxin genes, and screening of antibiotic susceptibility patterns in traditionally processed meat products of Sikkim, India. *Front Microbiol.* <https://doi.org/10.3389/fmicb.2020.599606>
- Bilal, M., Xu, S., Iqbal, H.M.N. and Cheng, H. 2021. *Yarrowia lipolytica* as an emerging biotechnological chassis for functional sugars biosynthesis. *Crit. Rev. Food Sci. Nutr.*, **61**(4): 535–552.
- Bilo, F., Pandini, S., Sartore, L., Depero, L.E., Gargiulo, G., Bonassi, A., Federici, S. and Bontempi, E. 2018. A sustainable bioplastic obtained from rice straw. *J. Clean Prod.*, **200**: 357–368.
- Bingol, E.B., Ciftcioglu, G., Yilmaz Eker, F., Yardibi, H., Yesil, O., Bayrakal, G. and Demirel, G. 2014. Effect of starter cultures combinations on lipolytic activity and ripening of dry fermented sausages. *Ital. J. Anim. Sci.* <https://doi.org/10.4081/ijas.2014.3422>
- Bintsis, T. and Papademas, P. 2022. The evolution of fermented milks, from artisanal to industrial products: a critical review. *Fermentation*, **8**(12): 679.
- Biscola, V., Choiset, Y., Rabesona, H., Chobert, J.M., Haertlé, T. and Franco, B.D.G.M. 2018. Brazilian artisanal ripened cheeses as sources of proteolytic lactic.
- Biscola, V., Tulini, F.L., Choiset, Y., Rabesona, H., Ivanova, I., Chobert, J-M., Todorov, S.D., Haertlé, T. and Franco, B.D.G.M. 2016. Proteolytic activity of *Enterococcus faecalis* VB63F for reduction of allergenicity of bovine milk proteins. *J. Dairy Sci.*, **99**(7): 5144–5154.
- Chai, K.F., Chang, L.S., Adzahan, N.M., Karim, R., Rukayadi, Y. and Ghazali, H.M. 2019. Physico-chemical properties and toxicity of cocoa powder-like product from roasted seeds of fermented rambutan (*Nephelium lappaceum* L.) fruit. *Food Chem.*, **271**: 298 – 308.
- Chai, K.F., Voo, A.Y.H. and Chen, W.N. 2020. Bioactive peptides from food fermentation: a comprehensive review of their sources, bioactivities, applications, and future development. *Comp. Rev. Food Sci. Food Saf.*, **19**: 3825 – 3885.

- <https://study.com/academy/lesson/alcohol-fermentation-definition-equation-process.html>!;ÿÿ
- <https://www.ncbi.nlm.nih.gov/books/NBK234703/>
- <https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/acetic-acid-bacteria#:~:text=The%20acetic%20acid%20fermentation%20is,part%20is%20transformed%20into%20acetoin.>
- Jung, J.Y., Lee, S.H. and Jeon, C.O. 2014. Kimchi microflora: history, current status, and perspectives for industrial kimchi production. *Appl. Microbiol. Biotechnol.*, **98**: 2385 – 2393.
- Lee, J.J.L. and Chen, W.N. 2018. Analysis of improved nutritional composition of potential functional food (okara) after probiotic solidstate fermentation. *J. Agricult. Food Chem.*, **66**: 5373 – 5381
- Lee, J.J.L., Chen, L., Cao, B. and Chen, W.N. 2016. Engineering *Rhodospiridium toruloides* with a membrane transporter facilitates production and separation of carotenoids and lipids in a bi-phasic culture. *Appl. Microbiol. Biotechnol.*, **100**: 869 – 877
- Leroy, F. and De Vuyst, L. 2014. Fermented food in the context of a healthy diet: how to produce novel functional foods? *Curr. Opin. Clin. Nutr. Metab. Care*, **17**: 574 – 581.
- Linder, T. 2019. Making the case for edible microorganisms as an integral part of a more sustainable and resilient food production system. *Food Security*, **11**: 265 – 278
- Mok, W.K., Tan, Y.X., Lee, J., Kim, J. and Chen, W.N. 2019. A metabolomic approach to understand the solid-state fermentation of okara using *Bacillus subtilis* WX-17 for enhanced nutritional profile. *AMB Express*, **9**: 60.
- Nam, Y.D., Lee, S.Y. and Lim, S.I. 2012. Microbial community analysis of Korean soybean pastes by next-generation sequencing. *Int. J. Food Microbiol.*, **2**: 36 – 42.
- Park, Y.-K., Nicaud, J.-M. and Ledesma-Amaro, R. 2018. The engineering potential of *Rhodospiridium toruloides* as a workhorse for environmental impact and health aspects. *World J. Microbiol. Biotechnol.*, **35**: 147.
- Tan, Y.X., Mok, W.K., Lee, J., Kim, J. and Chen, W.N. 2019. Solid state fermentation of brewers' spent grains for improved nutritional profile using *Bacillus subtilis* WX-17. *Fermentation*, **5**.
- Zhang, L., Liao, W., Huang, Y., Wen, Y., Chu, Y. and Zhao, C. 2022. Global seaweed farming and processing in the past 20 years. *Food Prod Process Nutr.*, **4**: 23.
- Zhao, C.J., Schieber, A. and Gänzle, M.G. 2016. Formation of taste-active amino acids, amino acid derivatives and peptides in food fermentations—a review. *Food Res. Int.*, **89**: 39–47.
- Zhao, Y., Kumar, M., Caspers, M.P.M., Nierop Groot, M.N., van der Vossen, J.M.B.M. and Abee, T. 2018. Short communication: growth of dairy isolates of *Geobacillus thermoglucosidans* in skim milk depends on lactose degradation products supplied by *Anoxybacillus favithermus* as secondary species. *J. Dairy Sci.*, **101**(2): 1013–1019.
- Zhong, H., Abdullah, Zhao, M., Tang, J., Deng, L. and Feng, F. 2021. Probiotics fermented blueberry juices as potential antidiabetic product: antioxidant, antimicrobial and antidiabetic potentials. *J. Sci. Food Agric.*, **101**(10): 4420–4427.

