**Current Trends in Fermentation Technology**

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**Abstract**

Fermentation technology have the wide application for the production of enzymes, compounds, energy production, material production, pharmaceutical, chemical, and food industries. Through the technology the products of short chain alcohols, diols, acids, diamines, ω-hydroxyamines, triglycerides and polymers are produced. Moreover using this technology the indigenous food products are kimchi, chongkukjang, doenjang, gochujang were also produced by different people. Fruit and vegetable wastes are converted into edible cement and other construction material and antifungal from the plant sources thus were used in civil industry. The concentration of atmospheric and lithospheric nutrients were rich in fermented products then the composed and it can be used as manure in soil and agricultural purpose.

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**1.1 Introduction**

The fermentation technology defended as production of compounds or enzymes that have the wide application in energy production, material production, pharmaceutical industries, chemical, and food industries. It occurs naturally in various food products and humans are using from ancient period for the preservation, nutritional and organoleptic properties of food. Now the technology are well established and applied in the production of bread, beer, vinegar, yogurt, cheese, and wine (Singh et al., 2017).

In this technology the various microorganisms i.e., yeast, bacteria, and fungi have crucial role from the conversion complex substrate into simple products. The products are the enzymes, metabolites, biomass, recombinant technology, and bio- transformation product on industrial scale. Organic acids and alcohols are the other main products of fermentation (Motarjemi, 2002). However, the secondary metabolites like antibiotics, enzymes, and growth factors and bioactive compounds.

The various products are produced in industrial fermentation processes using different types of fermentor or bioreactor. Generally, the bioreactor can be classified on the basis of their feeding namely batch, continuous, fed- batch fermentation, submerged fermentation and immobilization (Inui et al., 2010).

**1.2 Types of Fermentation**

**1.2.1 Solid-State Fermentation**

Solid state fermentation (SSF) are defined as the process that takes place in a solid matrix (inert support or support/substrate) in the absence of free water. Hence the substrate needs the moisture to support the growth and metabolic activity of microorganisms (Thomas et al. [2013](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5428094/#CR79)). The most important phenomenon of SSF is the resistance of microorganisms (bacterial and fungal cells) to catabolic inhibition in the presence of abundant substrates (glycerol, glucose or other carbon sources) (Lizardi-Jiménez MA, Hernández-Martínez R., 2017). The important factor is the possibility of using agro-industrial residues from industrial processes and mainly unexploited biotic substrate for metabolite production of products with low production costs.

**1.2.2 Submerged Fermentation (SmF)**

In Submerged fermentation (SmF) the decomposition of substrates under anaerobic or partially anaerobic. The SmF accomplished by using microorganisms with the presence of free water or the liquid medium (Mussatto and Teixeira, 2010). The process needs the controlled atmosphere condition for the production of quality end products and optimum productivity with yield. In industrially the process achieved through batch, fed-batch, or continuous modes. These different ways of submerged cultivation were using microorganisms in bioreactors. The various type of food industrial product has been produced with the application of continuous, batch, and fed-batch cultivation (Sudhanshu et al., 2019).

**3. Application of Fermentation Technology**

Production of high-value end products for various industry such as pharmaceuticals, chemical, food products, and agriculture are more important technology in current scenario. The impact of fermentation in these industries promising technology for reducing the high cost of products, easy way of production, minimize the energy, utilities, production temperature and special chemicals. The main relevance of fermentation technology among the chemical, food and agricultural were discussed in detail in this chapter.

**3.1 Application of fermentation in chemical production**

Chemicals produced by the chemical industry are common place in our everyday lives and make an important contribution to the standard of living we enjoy today. To ensure a sustainable future for the chemical industry and continued access to chemicals and materials that are essential for our high standard of living. In a circular economy, the consumption of non-renewable resources, such as fossil fuels, for the production of chemicals and materials is eliminated and replaced by the use of renewable resources. The most direct way to produce chemicals and materials from renewable resources, is to convert them into new chemicals and materials at their end-of-life by reuse or (mechanical or chemical) recycling. A loss of material will always occur as collection and recycling processes will not reach 100% efficiency (Brouwer et al., 2020). The chemical industry's demand for starting materials will exceed the amount of material that can be generated by recycling or reuse alone and other sources of renewable starting materials, in particular sources of organic carbon, will be required. One prominent example of a renewable carbon source is carbon from biomass, which can be replenished within a matter of years to decades using only carbon dioxide and sunlight required for photosynthesis. Therefore, the development of biobased chemicals and materials, and the biorefinery and conversion technologies required to manufacture them has been a topic of extensive research in recent decades (Sheldon. 2014).

**3.1.1 Biobased feedstocks for fermentation**

Production of biobased chemicals and materials starts from a biomass-derived feedstock. Biomass feedstocks are typically complex, heterogeneous materials, containing a diverse range of molecules such as carbohydrates, proteins, oils and fats, and lignin. The most commonly used feedstocks for the production of biobased chemicals by fermentation are carbohydrates. Once a suitable feedstock has been obtained from biomass, it can be converted to the desired biobased chemical by fermentation. First generation biomass feedstocks-Common sources of sucrose include sugarcane and sugar beet, while common sources of starch are, for example, corn, cassava and sorghum (Bertrand, et al., 2016). Second generation biomass feedstocks - The use of sugars from non-edible lignocellulosic biomass residues, such as corn stover, sugarcane bagasse, non-food crops such as silvergrass (Miscanthus) or forestry residues (e.g. bark or wood chips) (Sigoillot et al., 2016).

**3.1.2 Chemical Products by fermentation**

As the demand for bio-based products is increasing, attempts have been made to replace more and more traditional chemical processes with faster, cheaper, and better enzymatic or fermentation methods. Significant progress has been made for fermentative production of numerous compounds such as ethanol, organic acids, calcium magnesium acetate, butanol, amino acids, exopolysaccharides, surfactants, biodegradable polymers, antibiotics, vitamins, carotenoids, industrial enzymes, biopesticides, and biopharmaceuticals (Badal. 2003).Some more examples of chemicals obtained by microbial fermentation include cellulose, ethanol, lactic acid and acetic acid. Table 1 lists production of some other commodity chemicals by fermentation. Fermentation biotechnology, along with improved downstream processing, has played a great role in the production of bulk chemicals as well as high value pharmaceuticals.

**Table1: Chemical Products produced by fermentation technology**

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemical produced** | **Major application** | **Producing organism** | **Suitable feedstock** |
| Ethanol | Ethylene production | Saccharomyces cerevisiae | Sugarcane juice or molasses, corn starch |
| n-Butanol | Butene, butadiene production | Clostridium acetobutylicum, Clostridium beijerinckii | (Corn) starch, molasses |
| Isobutanol | Isobutylene production | Engineered yeasts | Corn starch |
| 1,3-Propanediol | Polytrimethylene terephthalate production | Engineered E.coli Likely bacteria (e.g. Klebsiella sp.) | Corn starch |
| 1,4-Butanediol | Polybutylene succinate, polybutylene terephthalate, (poly)tetrahydrofuran production | Engineered Escherichia coli | Glycerol |
| Lactic acid | Polylactic acid production | Lactic acid bacteria | Sugarcane/sugar beet derived sugars, starches |
| Succinic acid | Polybutylene succinate production, 1,4-butanediol production | Basfia succiniciproducens, engineered yeasts, engineered Escherichia coli | Starch-derived sugars |
| Dodecanedioic acid | Polyamide and polyester production | Bacterial strain | Fatty acids, likely from tropical oils |
| Itaconic acid | Production of polyacrylates | Aspergillus terreus | Fatty acids, likely from tropical oils |
| Citric acid | Production of itaconic acid | Aspergillus niger, Aspergillus wentii | Molasses, starch-derived sugars |
| 1,5-Pentanediamine | Production of polyamides | Likely engineered Escherichia coli | Sugars from starch, molasses + ammonium salt |
| L-Glutamic acid | To be developed | Corynebacterium glutamicum | Sugars from starch, molasses + ammonium salt |
| L-Lysine | Production of polyamide building blocks | (Modified) Corynebacterium glutamicum or Escherichia coli | Sugars from starch, molasses + ammonium salt |
| β-Farnesene | Polymer production, lubricants | Engineered Saccharomyces cerevisiae | Sugarcane-derived sugars |

**3.2 Application of Fermentation in Indigenous Food Products**

**3.2.1 Indigenous and Traditional Food Crops (ITFCS)**

ITFCs have multiple uses within society, and most notably have an important role to play in the attempt to diversify the food in order to enhance nutrition security. However, research suggests that the benefits and value of indigenous foods within the South African and the African context have not been fully understood and synthesized. Their potential value to the African food system could be enhanced if their benefits were explored more comprehensively. This synthesis presents a literature review relating to underutilized indigenous crop species and foods in Africa. It organizes the findings into four main contributions, nutritional, environmental, economic, and social-cultural, in line with key themes of a sustainable food system framework. It also goes on to unpack the benefits and challenges associated with ITFCs under these themes. A major obstacle is that people are not valuing indigenous foods and the potential benefit. Furthermore, knowledge is being lost from one generation to the next, with potentially dire implications for long-term sustainable food security. The results show the need to recognize and enable indigenous foods as a key resource in ensuring healthy food systems in the African continent.

**3.2.2 Indigenous fermented food of South Asia**

In south Aisa the Indigenous food products from vegetables such as carrots, radishes, cucumbers, and turnips are the popular items. In order to preserve and provide dietary variety in the form of diversified products (Joshi and Sharma 2009; 2012; Sharma et al., 2012; Bhushan et al., 2013). Methods for producing several vegetables based products have been standardized and the products are prepared and consumed as a routine diet (Karkri, 1986; Montet et al., 1999; Joshi and Thakur, 2000; Pandya et al., 2006; Joshi, 2015). Fermentation is one of the tools used to develop new, fermented, vegetable-based products after the natural or inoculated fermentation of vegetables. The LAB fermentation of carrots (Asiatic type), cucumber and radishes (Chinese pink) with a salt concentration of 2.5%, mustard of 2.0%, at the temperature of 26°C, and a sequential culture was found to provide the best product (Joshi et al., 2003, 2008).

**3.2.3 Indigenous fermented food of tribes**

Many different forms of vegetables are fermented and preserved by the tribal people of the Indian state of Sikkim. These products are similar to sauerkraut (Europe), kimchi (Korea), oncom (Indonesia), tsukemono (Japan), suan cai (China), and atchara (Philippines) (Pederson and Albury, 1969; Mikky, 1971; Banwart, 1981; Kumari et al., 1993; Lee, 2009)

Anishi This is a fermented cake made from the leaves of the Colocasia plant exclusively by the Ao Naga tribe of northeast India. Its preparation involves the packing of the Colocasia leaves in gunny (natural fiber) bags, or, alternatively, wrapped in banana leaves for about 3–4 days or until they become yellow. Then, the leaves are pounded into pastes and made into cakes. These cakes are then, wrapped in banana leaves and kept under the ash near the fireplace or exposed to the sunlight until they are completely dried and become hard (Jamir and Deb, 2014).

**3.2.4 Factors affecting fermentation of fruit and vegetables**

To preserve a vegetable with lactic acid fermentation, the choice of technique is determined by a number of factors. Specifically, microorganisms, salt concentration, temperature, chemical additives, the amount of fermentable carbohydrates in the vegetables, and the availability of nutrients in the brine are all known to affect the lactic acid fermentation (Pederson, 1971; Joshi et al., 1993; Joshi and Sharma, 2012), and several of these factors are discussed in the subsequent sections. S alt concentration of 3.0%, mustard of 2.0%, a temperature of 32 °C, and a sequential culture produced products of the highest quality. Thus, sequential culture fermentation is considered to hold promise for the production of fermented vegetables with better quality attributes, similar to the natural fermentation. It also has the advantage over natural fermentation with respect to controlled fermentation.

**3.2.5 Microorganisms**

The microorganisms of lactic acid bacteria (LAB) are one of the important microorganisms in food fermentation, and have been shown by serological techniques and 16S ribosomal RNA cataloguing to be phylogenetically related and to share a number of common features(Adams and Moss, 1996). The LAB produce lactic acid as the major end product of the fermentation of carbohydrates (Battcock and Azmi-ali, 1998). These bacteria are within the genera of *Lactobacillus*, *Streptococcus*, *Pediococcus*, and *Leuconostoc*, and include *Lactobacillus brevis*, *Lactobacillus plantarum*, *Leuconostoc mesenteroides*, *Streptococcus faecalis*, and *Pediococcus cerevisiae* (Gibbs, 1987). Lactic fermentation is a natural process brought about by the LAB present in the raw food, such as vegetables, or those derived from a starter culture (Pederson, 1971;Motarjemi and Nout, 1996; Sagarika and Pradeepa, 2003). It is initiated by heterofermentative LAB-namely, *Leuconostoc mesenteroides* followed by homolactic bacteria, such as *Lactobacillus brevis*.

**3.2.6 yeast**

Yeast in fermented foods and other are part of the microflora of many indigenous foods. In most cases, the microflora consists of bacteria and yeasts , and in some cases fungi. In addition to the fermentation of foods, the combination of these organisms adds to the distinctive texture, aroma, flavour. An analysis of a large number of fermented foods in India has revealed the presence of several yeasts in addition to bacteria. A similar situation occur with the fermented foods found in their parts of Asia and Africa. In Europe, table olives, which are the most widely fermented vegetables product in the market. It involves an interplay of microflora of lactic acid bacteria with the yeasts. The most common yeast are S*accharomyces* , *Pichia* , and *Candida*. The use of yeast is not restricted to the fermented food sector and chocolate industry.

For example, candida rugosa plays a role in the processing of the pectin reducing the bitterness, as the indigenous fermented food industry grows and becomes organized, there is an increasing need to standardize the starter cultures that involve a mix of organisms to obtain the most suitable texture and flavour, while also ensuring minimal spoilage.

**3.2.7 Temperature**

Temperature affects the growth and activity of all living cells, and microbial cells are no exception. At high temperatures, microorganisms are destroyed, while, at low temperatures, their rate of activity is decreased or suspended. Accordingly, they are classified into three distinct categories: psychrophiles, mesophiles, and thermophiles. LAB are mesophilic and work best in a temperature range of 18-22°C (Battcock and Azmi-ali, 1998). Temperature is a critical factor for producing high-quality fermented vegetables as it affects the acidification rate of the vegetable and promotes the growth of a single microbial species, giving it a competitive edge over other species. Influence of salt and temperature has aho been determined in radish (Sharma and Joshi, 2007).

**3.2.8 Salt concentration**

Generally salting are added by the three methods i.e., high-salt brine salting, lows salt brine salting, and dry salting in fermented products (Pederson, 1971). Dry salting is employed in pickling industry for cucumbers, radishes, and carrots (Thompson et al., 1979; Hudson and Buescher, 1985; Fleming et al., 1987; Mcfeeters et al., 1989. Salt concentration in vegetable fermentation can range from 20 to 80 g/L during fermentation, and up to 160 g/L in some stored vegetables (Cheigha et al., 1994). A high salt concentration inhibits the growth of unwanted microorganisms and induces the plasmolysis of plant cells, thus promoting anaerobiosis in the medium, which is, however, more effective in finally cut and shredded plant material.

**3.2.9 Other additives**

Many ingredients apart from salt can be used in the preparation of lactic acid-fermented fruits and vegetables. They have three main functions: as a source of nutrients (sugars, mineral salts, and vitamins) for the fermentation-causing microorganisms, to help restrict the growth of unwanted bacteria (either through a regulatory effect on the pH level or by producing inhibitory substances), and, in the case of spices, to have a final flavor-determining role in the fermented vegetables Montet et al., 1999).

**3.2.10 Fermentation Technology for production of Indigenous fermented foods**

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| **Name of the indigenous Product** | **Microorganisms** | **Reference** |
| Kimchi | *Ln. mesenteroides*, Ln. citreum, and *Lb. plantarum* | Patra, et al., 2016 |
| Chongkukjang | *Bacillus subtilis* | Su et al., 2007 |
| Doenjang | *B. subtilis* and *B. licheniformis* | Kanjang. 2009 |
| Gochujang | *Bacillus velezensis* | Seo-Jung Jang. 2011 |
| Ganjang | *Staphylococcus*, *Debaryomyces* | HM Kim, and CO Jeon. 2020 |
| Oncom | *Rhizopus oligosporus* | Sastraatmadja, D.D;et al (2002) |
| Sauerkraut | *Lactobacillus spp, Lactococcus lactis* and *Pediococcus spp* | E. Penas and J. Frias.2017 |

**3.3 Application of fermentation in Soil and Agriculture**

The natural fermentation are less ubiquitous and had the property of decomposition. This type of fermentation occurs in stomach (rumen) of ruminants such as cows. Hence the human controlled fermentation generally prevents further decomposition and post the fermentation stage. So, the fermentation and fermented products are different in decomposition. A considerable number of composts are made from fermentation are at the theoretical level. Hence the total amount of the atmospheric nutrients such as carbon, oxygen, hydrogen and nitrogen, and chemical were higher in ferment than compost. The concentration of lithospheric nutrients of phosphorus, potassium, magnesium, calcium also higher in ferment. The water content of ferment will be considerably higher than compost. The proportion of rapidly decomposable material, e.g., sugars, simple starches, proteins, will be considerably higher in ferment than compost and vice versa, the proportion of highly complex stable organic compounds, such as cellulose, lignin and humus, in compost will be much higher; Ferment is likely to have a considerably greater amount / proportion of biologically active chemicals Such as organic acids, as it is these that are in a large part responsible / and the products of fermentation. The production of compost through fermentation technology could increase the soil fertility and yield of agricultural plants.

**3.4 Application of Fermentation in civil industry**

Generally fruit and vegetable wastes are converted into cement and construction material. The waste of banana peels, cabbage leaves and orange peels were widely used in civil industry to make edible cement. Edible cement is made by grinding food waste into a fine powder, and then mixed with organic materials such as starch and cellulose. This cement can be used in variety of construction project, such as building homes and bridges. This material is strong and durable, and can stable with heavy loads and weather conditions. Orange peel are more important it sourced the antifungal, limonoids, pectin and it was widely produced by the spontaneous fermentation (Espiard,.et al 2002).

**4. Conclusion**

Through the fermentation technology various industrially valuable products can produced and utilized. The methods optimization for the respective products could provide the constant production in market at the low cost and without pollution. The products derived fermentation technology for civil and agricultural industries need to be focused in future. The application of fermentation technology in various fields are needful for day to day life. Therefore, fermentation technology replace reduces harmful methods of productions and more environmentally friendly.

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