

CURRENT TRENDS IN FERMENTATION TECHNOLOGY

Abstract

Fermentation technology have the wide application in production of various enzymes, compounds, energy production, material production, pharmaceutical, chemical, and food industries. Through this technology the products of short chain alcohols, diols, acids, diamines, hydroxyamines, triglycerides and polymers are produced. Moreover, using fermentation technology, the indigenous food products of kimchi, chongkukjang, doenjang, and gochujang were prepared and consumed by different kind of people in different countries. Edible cement, antifungal agents are the other important products in civil industry produced by fermentation technology from fruit and vegetable waste. The available atmospheric and lithospheric nutrients in waste based fermented products were highly utilized as manure for soil in agricultural fields.

Keywords: Fermentation Technology; Chemicals; Food products; Microorganisms

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I. INTRODUCTION

The fermentation technology defined 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, even humans are using from ancient period for the preservation, nutritional and organoleptic properties of food. Now the technology is well established in food sector for manufacturing of bread, beer, vinegar, yogurt, cheese, and wine (Singh et al., 2017).

In this technology the various microorganisms i.e., yeast, bacteria, and fungi are highly important for the conversion of various substrate into simple products. The end products of fermentation technology are generally enzymes, metabolites, biomass, recombinant product, and bio-transformed product. Among the metabolites organic acids and alcohols are the imperious products than the others (Motarjemi, 2002). However, the products of antibiotics, enzymes, growth factors and bioactive from secondary metabolites of microbes is the other industrial products.

The diverse produces from fermentation processes using distinct type of fermenter/bioreactor at industrial level. Generally, the bioreactors classified as batch, continuous, fed-batch, submerged fermenter (Inui et al., 2010).

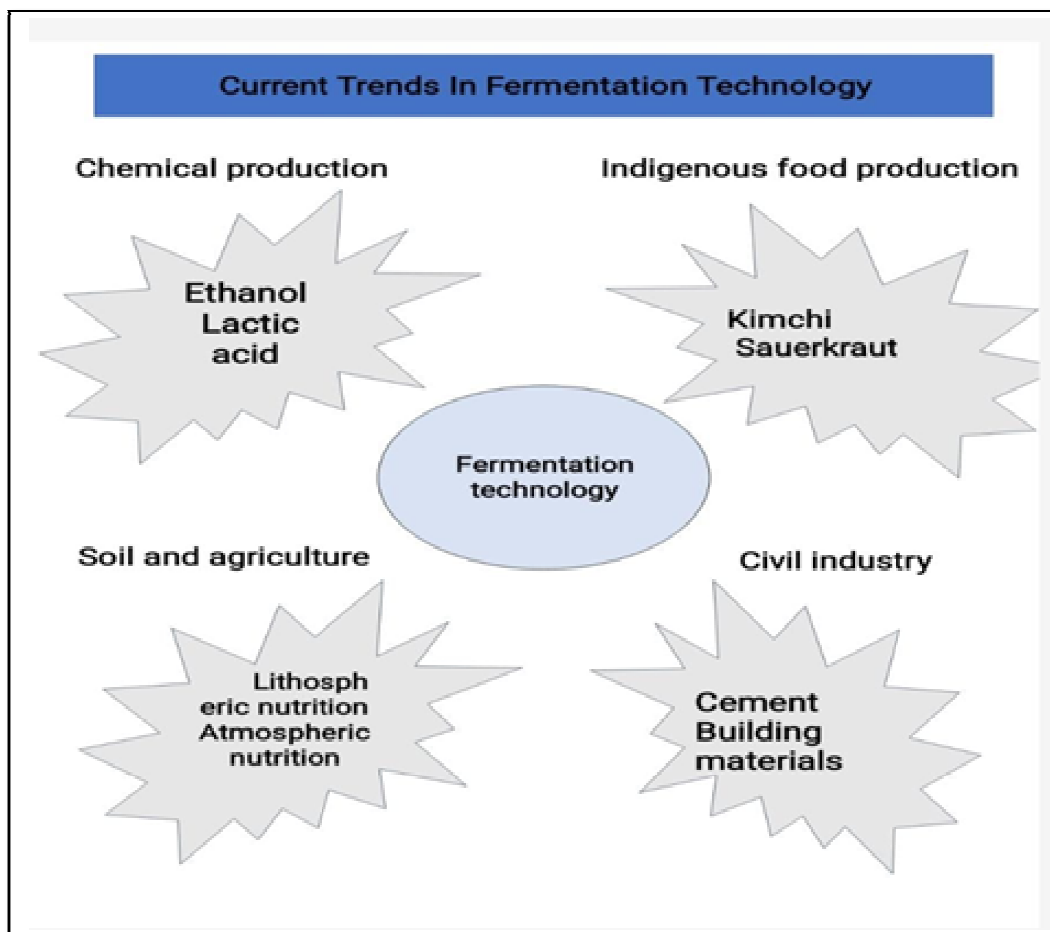
II. TYPES OF FERMENTATION

- 1. Solid-State Fermentation:** Solid state fermentation (SSF) are stated as the fermentation that occurs in the solid matrix i.e., inert support/substrate without the presence of water. Hence the substrate needs the moisture to support the growth and metabolic activity of microorganisms (Thomas et al. 2013). The most important phenomenon of SSF is the resistance of microorganisms (bacterial and fungal cells) to catabolic inhibition in the presence of abundant substrates such as glycerol, glucose or other carbon sources (Lizardi-Jiménez MA, Hernández-Martínez R., 2017). The usage of low cost agro-industrial residues from the industrial processes for the production metabolite products are other important factor.
- 2. Submerged Fermentation (SmF):** In Submerged fermentation (SmF) the decomposition of substrates under anaerobic or partially anaerobic condition. The SmF accomplished by microorganisms in the liquid medium (Mussatto and Teixeira, 2010). The process needs the controlled atmosphere condition for producing the quality end products with the optimum productivity and yield. In industrially the process achieved through batch, fed-batch, or continuous modes. These different ways of submerged cultivation were using microorganisms in bioreactors. By using continuous, batch, and fed-batch cultivation various industrial food products are produced by this method. (Panda, S. K., & Saranraj., 2019).

III. APPLICATION OF FERMENTATION TECHNOLOGY

Production of high-value end products for various industry such as pharmaceuticals, chemical, food products, and agriculture are more important in current scenario. The impact of fermentation in these industries is promising tool 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.



1. Application of Fermentation in Chemical Production: Chemicals have a larger role in our daily lives and numerous chemical products are generated from industry, which contributes significant role in our daily life. To ensure a sustainable production, continued access of chemical industry the essential chemicals and materials are assured from renewable resources. The consumption of non-renewable resources, such as fossil fuels, for the production of chemicals need to replace by using renewable resources. Industry can quickly transform renewable resources into new chemicals and materials, and they can also be recycled or reused. Hence the loss of material in collection and recycling processes does not reach 100% efficiency (Brouwer et al., 2014). In the chemical production, the demand of raw material costs typically outweighs than the amount of material produced. Therefore, recycling or reuse alone and other sources of renewable starting materials, in particularly the sources of organic carbon, are required for sustainable production. Finally, the sustainable production or conversion technologies needs extensive research in current decades to manufacture the chemicals (Sheldon. 2014).

- Biobased Feedstock 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 compounds. The compounds are carbohydrates, proteins, oils and fats, and lignin. Carbohydrates are the most often used feedstocks for fermentation-based biobased chemical synthesis. Once a suitable feedstock has been obtained from biomass, fermentation technology can quickly transform into a desired biobased chemical. First generation biomass feedstocks are sourced from sucrose, which 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 uses sugars from non-edible lignocellulosic biomass residues, such as corn stover, sugarcane bagasse, non-food crops such as silver grass (*Miscanthus*) or forest residues e.g. bark or wood chips (Sigoillot et al., 2016).
- Chemical Products by Fermentation:** As the demand for bio-based products is increasing, and several attempts are prepared to replace more traditional chemical processes with faster, cheaper, and better enzymatic or fermentation methods. Substantial progress is needed for the 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 (Saha, B. C.2003). Cellulose, ethanol, lactic acid, and acetic acid are a few examples of compounds produced by microbial fermentation. The manufactured chemical products via fermentation were listed in Table 1. For the manufacturing of bulk chemicals and medicinal products, enhanced downstream processing and suitable fermentation technology are more important.

Table1: Chemical Products Produced By Fermentation Technology

Chemical Produced	Major Application	Producing Organism	Suitable Feedstock
Ethanol	Ethylene production	<i>Saccharomyces cerevisiae</i>	Sugarcane juice or molasses, corn starch
n-Butanol	Butene, butadiene production	<i>Clostridium acetobutylicum</i> , <i>Clostridium beijerinckii</i>	(Corn) starch, molasses
Isobutanol	Isobutylene production	Engineered yeasts	Corn starch
1,3-Propanediol	Polytrimethylene terephthalate production	Engineered <i>E.coli</i> Likely bacteria (e.g. <i>Klebsiella</i> sp.)	Corn starch
1,4-Butanediol	Polybutylene succinate, polybutylene terephthalate, (poly)tetrahydrofuran production	Engineered <i>Escherichia coli</i>	Glycerol

Lactic acid	Polylactic acid production	Lactic acid bacteria	Sugarcane/sugar beet derived sugars, starches
Succinic acid	Polybutylene succinate production, 1,4-butanediol production	<i>Basfia succiniciproducens</i> , engineered yeasts, engineered <i>Escherichia coli</i>	Starch-derived sugars
Dodecanedioic acid	Polyamide and polyester production	Bacterial strain	Fatty acids, likely from tropical oils
Itaconic acid	Production of polyacrylates	<i>Aspergillus terreus</i>	Fatty acids, likely from tropical oils
Citric acid	Production of itaconic acid	<i>Aspergillus niger</i> , <i>Aspergillus wentii</i>	Molasses, starch-derived sugars
1,5-Pentanediamine	Production of polyamides	Likely engineered <i>Escherichia coli</i>	Sugars from starch, molasses + ammonium salt
L-Glutamic acid	To be developed	<i>Corynebacterium glutamicum</i>	Sugars from starch, molasses + ammonium salt
L-Lysine	Production of polyamide building blocks	(Modified) <i>Corynebacterium glutamicum</i> or <i>Escherichia coli</i>	Sugars from starch, molasses + ammonium salt
β -Farnesene	Polymer production, lubricants	Engineered <i>Saccharomyces cerevisiae</i>	Sugarcane-derived sugars

2. Application of Fermentation in Indigenous Food Products

- Current state of Indigenous Foods:** Indigenous foods serve a variety of functions in society, but perhaps their most significant contribution is to the diversification of our diets and improved nutritional security. However, the benefits and value of indigenous foods in Asian context have not fully understood. Asians fermented foods are greatly beneficial system than the African food system, which has recently received attention. The existing literatures relating the underutilized indigenous foods in Africa and their four main contributions of these foods i.e., nutritional, environmental, economic, and social-cultural. The benefits of indigenous foods have just come to the public's attention. Moreover, the last of communication from one generation to another generation, reduce the implications of indigenous foods. Now the people are recognizing the benefits of indigenous foods and their key role for ensuring healthy food systems.
- Indigenous Fermented Foods of Asia:** The most popular native cuisine items among South Asians are those made from vegetables including turnips, carrots, radishes, and cucumbers. People prepare these varied items foods for long-term preservation to offer dietary advantages (Joshi and Sharma 2009; 2012) and it described in Table 2. A

number of fermented vegetables that are taken regularly made prepared using traditional methods (Karkri, 1986). Among the various processing methods, the fermentation is the effective tool to develop new vegetable-based products. The best result is produced when vegetables like carrots, cucumbers, and radishes are naturally fermented with lactic acid bacteria at a temperature of 26°C while also adding salt at a concentration of 2.5% and mustard at a concentration of 2.0% (Joshi et al., 2003).

- **Indigenous Fermented Foods among Tribes:** The tribal people of India and the state of Sikkim ferment and preserve various crops. Additionally, the prepared foods are comparable to atchara (Philippines), suan cai (China), tsukemono (Japan), kimchi (South Korea), oncom (Indonesia), and sauerkraut (Europe) (Lee, 2009). The north east Indian tribes of Ao Naga makes the fermented cake of anishi produced from the leaves of the Colocasia plant. This anishi preparation the Colocasia leaves were covered in banana leaves or gunny (natural fiber) sacks for a period of around 3-4 days until they became yellow. Following that, the leaves are ground into pastes and made into cakes. These cakes are wrapped in banana leaves and let out in the sun to dry completely harden (Jamir and Deb, 2014).
- **Factors Affecting Fermentation:** There are a lot of elements that have an impact on the vegetables that are preserved via lactic acid fermentation. In particular, the presence of microorganisms, temperature, salt content, chemical additions, the amount of fermentable carbohydrates in the vegetables, and the availability of minerals in the brine (Sharma, 2012). Other influencing elements are temperature, salt content, and sequential culture. For the production of fermented vegetables with higher quality characteristics, similar to the natural fermentation, sequential culture fermentation is a potential approach. Compared to regulated fermentation, natural fermentation has more nutritional advantages.
- **Microorganisms:** One of the crucial microorganisms in food fermentation is lactic acid bacteria (LAB), which has been demonstrated by serological methods and 16S ribosomal RNA sequencing to be phylogenetically linked and have a number of similar traits (Adams and Moss, 1996). Lactic acid is the main byproduct of the fermentation of carbohydrates produced by the LAB (Battcock and Azmi-ali, 1998). This group of bacteria includes *Lactobacillus brevis*, *Lactobacillus plantarum*, *Leuconostoc mesenteroides*, *Streptococcus faecalis*, and *Pediococcus cerevisiae*, and they belong to the genera *Lactobacillus*, *Streptococcus*, *Pediococcus*, and *Leuconostoc* (Gibbs, 1987). The LAB found in raw foods like vegetables or those generated from a starting culture causes lactic fermentation as a natural process (Sagarika and Pradeepa, 2003). *Leuconostoc mesenteroides*, a heterofermentative LAB, starts it off, followed by homolactic bacteria like *Lactobacillus brevis* completed the fermentation.
- **Yeast:** Yeast is a component of the microflora in many native foods, including fermented foods. The fermented foods are mainly made up of microflora of bacteria, yeasts, and occasionally fungus. The mix of these organisms enhances the specific texture, aroma, and flavor in food in addition to causing it to ferment. Numerous yeasts in addition to bacteria have been found in a wide sample of fermented foods from India. The identified microflora of yeast with fermented foods is similar in some

regions of Asia and Africa. The most popular fermented vegetable product on the market in Europe is table olives. It involves the interaction of yeasts and the microflora of lactic acid bacteria. *Candida*, *Pichia*, and *Saccharomyces* are the three most prevalent yeasts. The fermented food industry and the chocolate industry are only two examples of where yeast is used. As the indigenous fermented food industry develops and becomes organized, there is a growing need to standardize the starter cultures, which involve a variety of organisms to obtain the best texture and flavor. For instance, *Candida rugosa* plays a role in the processing of the pectin, reducing the bitterness of the product.

- **Temperature:** All microbial cells are influenced by temperature, and its need a optimum temperature for their growth. Microorganisms are destroyed at high temperatures, whereas their activity is reduced or halted at low temperatures. In accordance with this, they are divided into three groups: psychrophiles, mesophiles, and thermophiles. According to Battcock and Azmi-ali (1998), LAB are mesophilic and perform best in a temperature range of 18 to 22°C. Temperature impacts the rate of acidity in vegetable fermentation and encourages the growth of a particular microbial species, giving it a competitive advantage over other species, both of which are essential for generating high-quality product (Sharma and Joshi, 2007).
- **Salt Concentration:** According to Pederson (1971), salt is typically applied to fermented products using one of three methods: high-salt brine salting, low-salt brine salting, or dry salting. Cucumbers, radishes, and carrots are pickled using dry salting (Mcfeters et al., 1989). According to Cheigha et al. (1994), the salt concentration in fermented vegetables can range from 20 to 80 g/L during fermentation and up to 160 g/L in some vegetables that have been kept. High salt concentrations promote anaerobiosis in the medium while inhibiting the growth of undesirable microbes. Anaerobiosis is more effective in the final chopped and shredded plant material, though.
- **Other Additives:** Many ingredients apart from salt can be used in the preparation of lactic acid-fermented fruits and vegetables. They serve three primary purposes: they provide nutrients (sugars, mineral salts, and vitamins) for the microorganisms that cause fermentation; they aid in limiting the growth of undesirable bacteria (either by regulating the pH level or by producing inhibitory substances); and, in the case of spices, they contribute to the final flavor of the fermented vegetables Montet et al., 1999).

Table 2: Indigenous Fermented Food Products from Fermentation Technology

Name of the Indigenous Product	Microorganisms	Reference
Kimchi	<i>Ln. mesenteroides</i> , <i>Ln. citreum</i> , and <i>Lb. plantarum</i>	Patra, et al., 2016
Chongkukjang	<i>Bacillus subtilis</i>	Su et al., 2007
Doenjang	<i>B. subtilis</i> and <i>B. licheniformis</i>	Hyun Am. et al., 2009
Gochujang	<i>Bacillus velezensis</i>	Seo-Jung Jang. 2011
Ganjang	<i>Staphylococcus</i> , <i>Debaryomyces</i>	Han D.M. et al., 2020
Oncom	<i>Rhizopus oligosporus</i>	Sastraatmadja, D.D;et al (2002)
Sauerkraut	<i>Lactobacillus spp</i> , <i>Lactococcus lactis</i> and <i>Pediococcus spp</i>	E. Penas and J. Frias.2017

- 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.
- 4. Application of Fermentation in Civil Industry:** Typically, waste from fruits and vegetables is turned into cement and building materials. 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 (Olubajo. et al., 2019).

IV. CONCLUSION

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

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