

EVALUATION OF INDUSTRIAL FOOD FERMENTATION TECHNOLOGY

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I. INTRODUCTION

Fermented foods are staples of the human diet and have been produced and used up since the development of human civilizations. The process whereby microorganisms and their enzymes bring about these required changes in food materials is known as fermentation. Food fermentation methods can be categorized by the primary metabolites and microorganisms elaborated. Lactic acid bacteria (LAB) belonging to genera such as *Leuconostoc*, *Lactobacillus*, and *Streptococcus*. Fermentations can also be defined based on the food substrates, which include meats and fish, dairy, soybeans and other legumes, cereals, and grapes. Raw materials that contain more concentrations of monosaccharides and disaccharides, or in some cases starch, are fermented through lactic acid bacteria. Lactic acid bacteria (LAB) are a cluster of gram-positive, non-sporulating, anaerobic or facultative aerobic cocci or rods, fastidious on artificial media, but they grow gladly in most food substrates and lower the pH rapidly to a point where competing organisms are no longer able to grow, and it is one of the main fermentation products of the carbohydrates metabolism.

II. HISTORY OF FERMENTATION ART AND SCIENCE

Ancient Egyptians were the first to ferment alcohol and vinegar from malt grains and fruits juices during the 1700s. However, they had no understanding of contamination in the fermentation process and the role of microorganisms in fermentation, and the use of specific equipment for production was not yet established (Gaden, 1982).

In the mid-eighteenth century, Louis Pasteur established the role of yeast in wine fermentation, and from then on a pure culture was used for quality wine, beer, and vinegar. During the same time, Carlsberg tried isolating single pure yeast cells for quality alcohol production. In the late eighteenth century and the early nineteenth century, use of an aerator for vinegar production was started. Vinegar fermentation also included a known volume of pasteurized, previously fermented vinegar as an initial substrate to prevent contamination and to serve as an inoculum. Hence, the process control of fermentation was initiated (Brinberg, 1953; Herrero, 1969). The importance of fermentation and production of different products gained attention in the beginning of the nineteenth century and continued through the middle of the nineteenth century. Several products were produced via fermentation, namely, glycerol, baker's yeast, lactic acid, and acetone butanol. Production of secondary metabolites via fermentation (such as antibiotics, amino acids, and vitamins) flourished during the late nineteenth century due to the need to treat soldiers fighting in World War I. Submerged fermentation with larger volumes under aerobic conditions with moderate process control was established during this period. In subsequent years, the fermentation industry has seen constant improvement with leaps and bounds on the production of high-value metabolites, including various antibiotics and growth hormones, using sophisticated bioreactors (Chiao and Sun, 2007; Formenti et al., 2014; Humer and Schedle, 2016; Li et al., 2015; Liu et al., 2013; Motarjemi and Nout, 1996).

III. HISTORY OF FERMENTATION

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IV. FERMENTATION TECHNOLOGY

Micro-organisms, grown on a large scale, to produce valuable commercial products or to carry out important chemical transformations

V. FERMENTATION

Pasteur's "life without air", Latin word *fervere, to boil*

Table 1: Some Important Fermentation Products

Product	Organism	Use
Ethanol	<i>Saccharomyces cerevisiae</i>	Industrial solvents, beverages
Glycerol	<i>Saccharomyces cerevisiae</i>	Production of explosives
Lactic acid	<i>Lactobacillus bulgaricus</i>	Food and pharmaceutical
Acetone and butanol	<i>Clostridium acetobutylicum</i>	Solvents
α -amylase	<i>Bacillus subtilis</i>	Starch hydrolysis

VI. THE ROLE OF FERMENTATION TO FOOD

1. Flavor Enhancement

- Fermentation makes the food palatable by enhancing its aroma and flavor.
- These organoleptic properties make fermented food further popular than the unfermented one in terms of consumer acceptance.

2. Nutritional Quality

- A number of foods especially cereals are poor in nutritional value, and they constitute the main staple diet of the low-income populations. However, Lactic acid bacteria (LAB) fermentation has been shown to improve the nutritional value and digestibility of these foods. The acidic nature of the fermentation products enhances the activity of microbial enzymes at a temperature range of 22-25°C.
- The enzymes, which include amylases, proteases, phytases and lipases, modify the primary food products through hydrolysis of polysaccharides, proteins, phytates and lipids respectively. Thus, in addition to enhancing the activity of enzymes, Lactic acid bacteria (LAB) fermentation also reduces the levels of anti-nutrients such as phytic acid and tannins in food leading to improved bioavailability of minerals such as iron, protein and simple sugars. The number of vitamins is also increased in the ferment.

3. Preservative Properties

- The preservative activity of Lactic acid bacteria (LAB) has been observed in some fermented products such as cereals, and yogurt.
- The lowering the pH to below 4 through acid production, inhibits the growth of pathogenic microorganisms which can cause food spoilage, food poisoning and disease. For example, Lactic acid bacteria (LAB) has antifungal activities. By doing this, the shelf life of fermented food is extended.

4. Detoxification

- Detoxification of mycotoxins in food through Lactic acid bacteria (LAB) fermentation has been demonstrated over the years.
- Using Lactic acid bacteria (LAB) fermentation for detoxification is more advantageous in that it is a minor method which preserves the nutritive value and flavor of purified food. In addition to this, Lactic acid bacteria (LAB) fermentation irreversibly degrades mycotoxins without leaving any toxic residues. The detoxifying effect is believed to be through toxin binding effect.

5. Antibiotic Activities

- Lactic acid bacteria (LAB) is applied as a hurdle against non-acid tolerant bacteria, which are ecologically eradicated from the medium due to their sensitivity to acidic environment.
- Also, fermentation has been demonstrated to be further effective in the removal of gram negative than the gram-positive bacteria, which are more resistant to fermentation processing.
- As such, fermented food can control diarrheal diseases in children. Moreover, Lactic acid bacteria (LAB) is also known to produce protein antimicrobial agents such as bacteriocins. Bacteriocins are peptides that elicit antimicrobial activity against food spoilage organisms and food borne pathogens but do not affect the producing

organisms. Lactic acid bacteria (LAB) also synthesizes other anti-microbial compounds such as, hydrogen peroxide, reuterin, and reutericyclin.

- Other applications of Lactic acid bacteria (LAB) include their use as probiotics that restore the gut flora in patients suffering from diarrhea, following the usage of antibiotics that destroy the normal flora.

VII. FERMENTATION TECHNIQUES

1. **Surface (solid state) techniques:** Microorganisms cultivated on the surface of a liquid or solid substrate. Complicated and rarely used in industry.

Mushroom, bread, cocoa, tempeh

2. **Submersion techniques:** Microorganisms are grown in a liquid medium.

Biomass, protein, antibiotics carried out by submersion processes.

VIII. REQUIREMENTS

1. **Pure culture:** organism, quantity, physiological state
2. **Sterilized medium:** for microorganism growth
3. **Seed fermenter:** inoculums to initiate process
4. **Production fermenter:** large model
5. **Equipment**
 - Drawing the culture medium
 - Cell separation
 - Collection of cell
 - product purification
 - Effluent treatment

IX. TYPES ON THE BASIS OF CULTURE

1. **Batch fermentation:** Sterile nutrient substrate, inoculated, grow until no more of the product is being made, "harvested" and cleaned out for another run.
 - **lag phase**(adapt to their surroundings)
 - **exponential growth**(grow in numbers)
 - **stationary phase**(stop growing)
 - **death phase**

X. CONTINUOUS FERMENTATION

Substrate is added continuously to the fermenter, and biomass or products are continuously removed at the same rate. Under these conditions the cells remain in the Logarithmic phase of growth

XI. FED-BATCH FERMENTATION

Substrate increments as the fermentation progresses. Started as batch wise with a minor substrate concentration. Initial substrate is consumed, addition of fermentation medium

Table 2: Range of fermentation Technology

Microbial cell (Biomass)	Yeast
Microbial enzymes	Glucose isomerase
Microbial metabolites	Penicillin
Food products	Cheese, yoghurt, vinegar
Vitamins	B12, riboflavin

Table 3: Examples of Foods and Food Additive Manufactured Using Industrial Fermentation Processes in Developing Countries.

FOODS	FOOD ADDITIVE MANUFACTURED
Alcoholic beverages	Wines, beer
Milk and milk products	Cultured milks, yogurts, cheeses
Flavors	Monosodium glutamate, nucleotides
Organic acids	Lactic acid, citric acid, acetic acid
Amino acids	Lysine, glutamic acid
Vitamins	Vitamins A, C and B ₁₂ , riboflavin
Enzymes	Amylases, proteases, invertases

XII. FROM DESHPANDE AND SALUNKHE (2000).

Advantages

- Preserves and enriches food, improves digestibility, and enhances the taste and flavor of foods.
- Potential of enhancing food safety by governing the growth and multiplication of amount of pathogens in foods.
- Important contribution to human nutrition particularly in developing countries, where economic problems pose a major barrier to ensuring food safety.
- Low energy consumption due to the minor operating conditions relatively low capital and operating costs relatively simple technologies.
- They cause extremely specific and controlled changes to foods by using enzymes.
- Preservation and detoxification of the food.
- Waste treatment.
- Health associated product.

Table 4: Major Categories And Examples Of Fermented Milk Products

Category	Typical examples
I. Lactic fermentations	
a. Mesophilic	Butter milk, Cultured buttermilk, Langofil, Tetmjolk, Ymer
b. Thermophilic	Yogurt, laban, zabadi, labneh, skyr, Bulgarian buttermilk
c. Therapeutic	Biogarde, Bifighurt, Acidophilus milk, yakult, Cultura-AB
II. Yeast – lactic fermentations	Kefir, koumiss, acidophilus – yeast milk
III. Mold – lactic fermentation	Viili

Source : Table 4 p. 58. In B. A. Law, editor, 1997. *Microbiology and Biochemistry of cheese and fermented milk*, New York: Chapman and Hall.

Disadvantages

- Hazardous microbial contamination always exist in fermented food.
- The irregular distribution of salt in lactic acid fermented fish products and contamination of *Aspergillus flavus* in traditional starter cultures for rice wine and soybean sauce result in severe food poisoning occurrences.

• Health (obesity, cancer)

C.H. LEE, 1989

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