Fermentation by microorganisms

The term "fermentation" is borrowed from the Latin word fever which means "to boil." According to Louis Pasteur, fermentation was defined as "La vie sans l'air", i.e., life without air, and the science of fermentation is also known as zymology or zymurgy. However, fermentation is one of the oldest food storage/preservation methods throughout the world dating back to the Neolithic period (10,000 years BC).

- Fermentation is a process where the microbial, plant and animal cells are used to carry out enzyme – catalyzed transformations of organic matter.
- Fermentation is considered the first application in biotechnology.
- Fermentation Technology could be defined simply as the study of the fermentation process, techniques and its application.
- Processing (USP) and Down Stream Processing (DSP).

The reasons for using microorganisms in fermentation:

1. The ratio of surface area to volume is high, so that the nutrients in the medium consumed quickly forced the metabolic reactions.
2. Adaptation for different ecological conditions, so that it very easy to transfer M.Os. from their natural habitat to the lab. They can grow on cheap carbon and nitrogen sources to produce compounds with high economic value.
3. The ability to achieve huge chemical reactions.
4. It very easy to deal with microorganisms genetically and designing genetically modified organisms, which produced higher amounts of product.

Examples of Fermentation

Fermentation does not necessarily have to be carried out in an anaerobic environment. For example, even in the presence of abundant oxygen, yeast cells greatly prefer fermentation to aerobic respiration, as long as sugars are readily available for consumption (a phenomenon known as the Crabtree effect). Fermentation react NADH with an endogenous, organic electron acceptor. Usually this is pyruvate formed from the sugar during the glycolysis step. During fermentation, pyruvate is metabolized to various compounds through several processes:

1. Ethanol fermentation, aka alcoholic fermentation, is the production of ethanol and carbon dioxide

2. Lactic acid fermentation refers to two means of producing lactic acid:

- Homolactic fermentation is the production of lactic acid exclusively
- Heterolactic fermentation is the production of lactic acid as well as other acids and alcohols.

Sugars are the most common substrate of fermentation, and typical examples of fermentation products are ethanol, lactic acid, carbon dioxide, and hydrogen gas (H_2). However, more exotic compounds can be produced by fermentation, such as butyric acid and acetone. Yeast carries out fermentation in the production of ethanol in beers, wines, and other alcoholic drinks, along with the production of large quantities of carbon dioxide. Fermentation occurs in mammalian muscle during periods of intense exercise where oxygen supply becomes limited, resulting in the creation of lactic acid.

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Ethanol fermentation:

The chemical equation below shows the alcoholic fermentation of glucose, whose chemical formula is $C6H12O6$. One glucose molecule is converted into two ethanol molecules and two carbon dioxide molecules:

$C6H12O6 \rightarrow 2\ C2H5OH + 2\ CO2$

$C2H5OH$ is the chemical formula for ethanol.

Before fermentation takes place, one glucose molecule is broken down into two pyruvate molecules. This is known as glycolysis.

Lactic acid fermentation:

Homolactic fermentation (producing only lactic acid) is the simplest type of fermentation. The pyruvate from glycolysis undergoes a simple redox reaction, forming lactic acid. It is unique because it is one of the only respiration processes to not produce a gas as a byproduct. Overall, one molecule of glucose (or any six-carbon sugar) is converted to two molecules of lactic acid:

$C6H12O6 \rightarrow 2CH3CHOHCOOH$

It occurs in the muscles of animals when they need energy faster than the blood can supply oxygen. It also occurs in some kinds of bacteria (such as Lactobacilli) and some fungi. It is this type of bacteria that converts lactose into lactic acid in yogurt, giving it its sour taste. These lactic acid bacteria can carry out either homolactic fermentation, where the end-product is mostly lactic acid, **or**

Heterolactic fermentation, where some lactate is further metabolized and results in ethanol and carbon dioxide (via the phosphoketolase pathway), acetate, or other metabolic products, e.g.:

$C6H12O6 \rightarrow CH3CHOHCOOH + C2H5OH + CO2$

If lactose is fermented (as in yogurts and cheeses), it is first converted into glucose and galactose (both six-carbon sugars with the same atomic formula):

$C_{12}H_{22}O_{11} + H_2O \rightarrow 2\ C_6H_{12}O_6$

Heterolactic fermentation is in a sense intermediate between lactic acid fermentation, and other types, e.g. alcoholic fermentation.

Requirements of fermentation:

1- Specific strain or microbial enzymes.

2- Raw material substrate (Fermentation medium).

3- Controlled favorable environment.

Specific strain or microbial enzymes

Microorganisms hold the key to the success or failure of a fermentation process. It is therefore important to select the most suitable microorganisms to carry out the desired industrial process. The most important factor for the success of any fermentation industry is a production strain. The M.Os. that isolated from the nature have low production efficiency, therefore; there are two ways for enhance the productivity; ecological ways and genetic ways.

Fermentation medium (raw material)

- The growth medium (liquid or solid) in which microbes grow and multiply is called fermentation medium.
- The selected microbe should be able to utilize and grow on cheap sources of carbon and nitrogen. Usually these sources are waste products of industrial process e.g. molasses, whey, corn steepliquor etc. Care is taken to avoid the use of such microbes which require expensive nutrients for their growth.
- Fermentation media must satisfy all the nutritional requirements of the microorganism and fulfill the technical objectives of the process.

All microorganisms require water, sources of energy, carbon, nitrogen, mineral elements and possibly vitamins plus oxygen if aerobic. The nutrients should be formulated to promote the synthesis of the target product, either cell biomass or a specific metabolite.

The main factors that affect the final choice of individual raw materials are as follows:

1. Cost and availability: ideally, materials should be inexpensive and of consistent quality and year round availability.
2. Ease of handling in solid or liquid forms, along with associated transport and storage costs, e.g., requirements for temperature control.
3. Sterilization requirements and any potential denaturation problems.
4. Formulation, mixing, complexity and viscosity characteristics that may influence agitation, aeration and foaming during fermentation and downstream processing stages.
5. The concentration of target product to be attained, its rate of formation and yield per gram of substrate utilized.
6. The levels and range of impurities and the potential for generating further undesired products during the process.
7. Overall health and safety implications.

Controlled favorable environment

For production of a desired microbial product, it is of utmost importance to optimize physical (temperature, aeration etc.) and chemical (carbon, nitrogen, mineral sources etc.) composition of the fermentation medium. To maintain these stringent conditions, microbes are grown in containers called as ferment- ers/ors or bioreactors. The capacity of bioreactors may vary from 10 liters to 100,000 liters depending on the product.

Fermentor is known as the heart of fermentation process.