Fermenter

Definition of a fermenter

A fermenter (or fermenter) is a vessel for the growth of microorganisms which, (while not permitting contamination), enables the provision of conditions necessary for the maximal production of the desired products. In other words, the fermenter ideally should make it possible to provide the organism growing within it with optimal pH, temperature, oxygen, and other environmental conditions.

In the chemical industry, vessels in which reactions take place are called reactors. Fermenters are therefore also known as bioreactors.

Fermenters may be liquid,(also known as submerged) or solid state, (also known as surface).

Most fermenters used in industry are of the submerged type, because the submerged fermenter saves space and is more amenable to engineering control and design.

Depending on the purpose, a fermenter can be as small as 1 liter or up to about 20 liters in laboratory-scale fermenters and range from 100,000 liters to 500,000 liters(approximately 25,000 – 125,000 gallons) for factory or production fermenters.

It should be noted that while fermenter size is measured by the total volume, only about 75% of the volume is usually utilized for actual fermentation, the rest being left for foam and exhaust gases.

Several types of fermenters are known and they may be grouped in several ways: shape or configuration, whether aerated or anaerobic and whether they are batch or continuous , liquid or solid.

The most commonly used type of fermenter is the Aerated Stirred Tank Batch Fermenter. So widely used is this type that unless specifically qualified, the word fermenter usually refers to the Aerated Stirred Tank Batch Fermenter.

The aerated stirred tank batch fermenter

is an upright closed cylindrical tank fitted with four or more baffles attached to the side of the wall, a water jacket or coil for heating and/or cooling, a device for forcible aeration (known as sparger), a mechanical agitator usually carrying a pair or more impellers, means of introducing organisms and nutrients and of taking samples, and outlets for exhaust gases.

A typical fermenter of this type (Fig. 9.1)

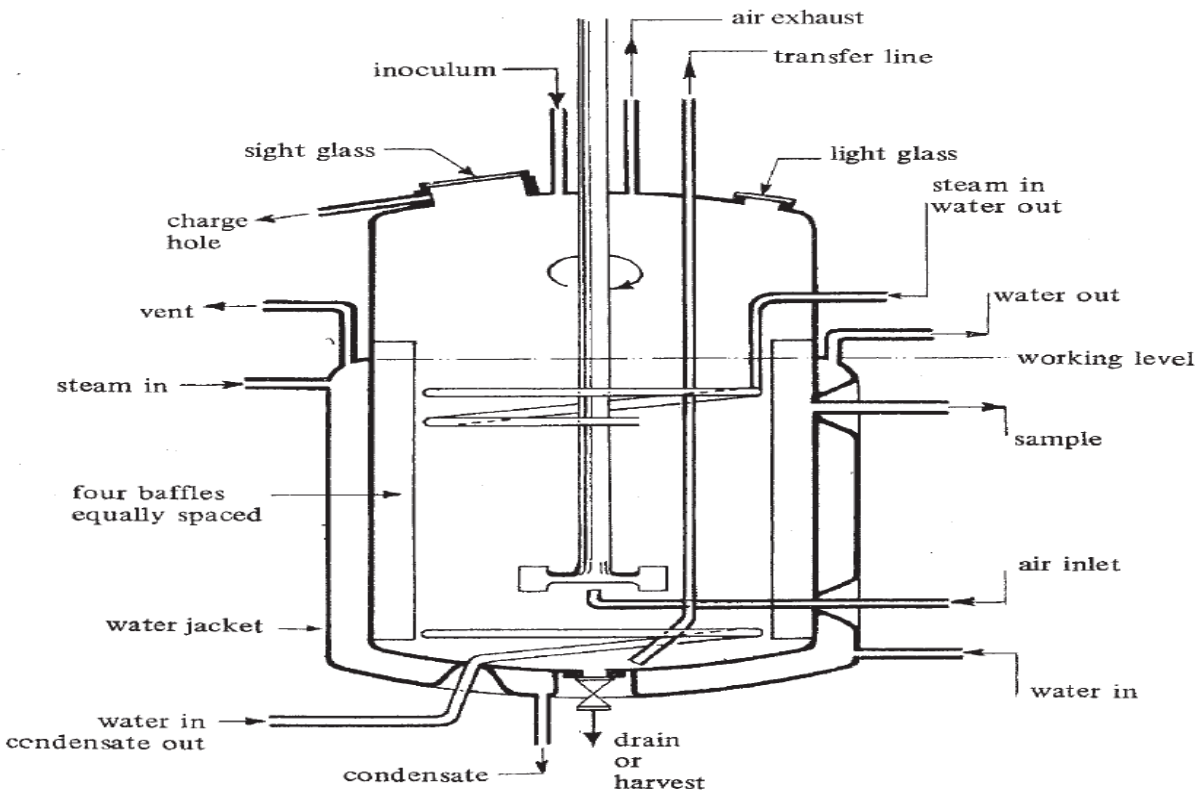


Fig. 9.1 Structure of a Typical Fermentor (Stirred Tank Batch Bioreactor)

Modern fermenters are highly automated and usually have means of continuously monitoring, controlling or recording pH, oxidation-reduction potential, dissolved oxygen, effluent O_2 and CO_2, and chemical components of the fermentation broth (or fermentation beer as the broth is called before it is extracted).

Nevertheless the fermenter need not have all these gadgets and many automated activities can also be prosecuted manually.

Fermenter configurations

Based on the nomenclature of the chemical engineering industry fermenters have been grouped into four:

(1) Batch fermenters (Stirred Tank Batch fermenters): (designated BF in Fig. 9.6) and Fig. 9.1. The other three are continuous fermenters and these are described below.

(2) Continuous stirred tank fermenters: (CSTF in Fig. 9.6) The tank used in this system is essentially similar to that of the batch fermenter. It differs only in so far as there is provision for the inlet of medium and the outlet of broth. The system has been described under continuous cultivation.

(3) Tubular fermenters: (TF in Fig. 9.6) The tubular fermenter was originally so named because it resembled a tube. In general tubular fermenters are continuous unstirred fermenters in which the reactants move in a general direction. Reactants enter at one end and leave from the other and no attempt is made to mix them. Due to the absence of mixing, there is a gradual fall in the substrate concentration between the entry point and the outlet while there is an increase in the product in the same direction.

(4) The fluidized bed fermenter: This is essentially similar to the tubular fermenter. In both the continuous stirred fermenter and the tubular fermenter there is a real danger of the organisms being washed out (Fig. 9.10). The fluidized bed reactor is an answer to this problem because it is intermediate in nature between the stirred tank and the tubular fermenter.

The microorganisms which are in a fluidized bed fermenter are kept in suspension by a medium flow rate whose force just balances the gravitational force. If the flow were lower, the bed would remain ‘fixed’ and if the flow rate was at a force higher than the weight of the cells then ‘elutriation’ would occur with the particles being washed away from the tube. The tower fermenter for the brewing of beer and production of vinegar is an example of a fluidized bed fermenter.

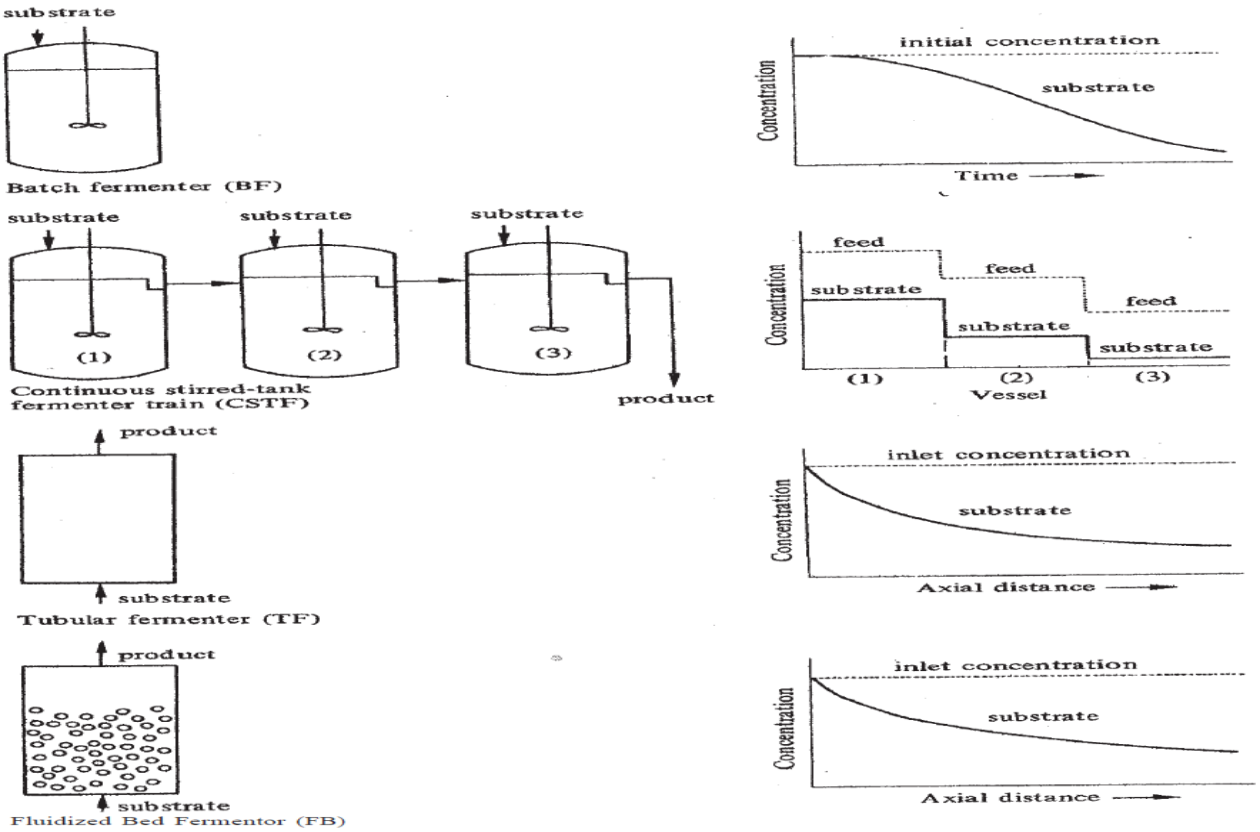


Fig. 9.6 Different Fermentor Configurations (Left) and Graphs Depicting Substrate Usage in the Various Configurations (Left) (see also Fig. 9.7)

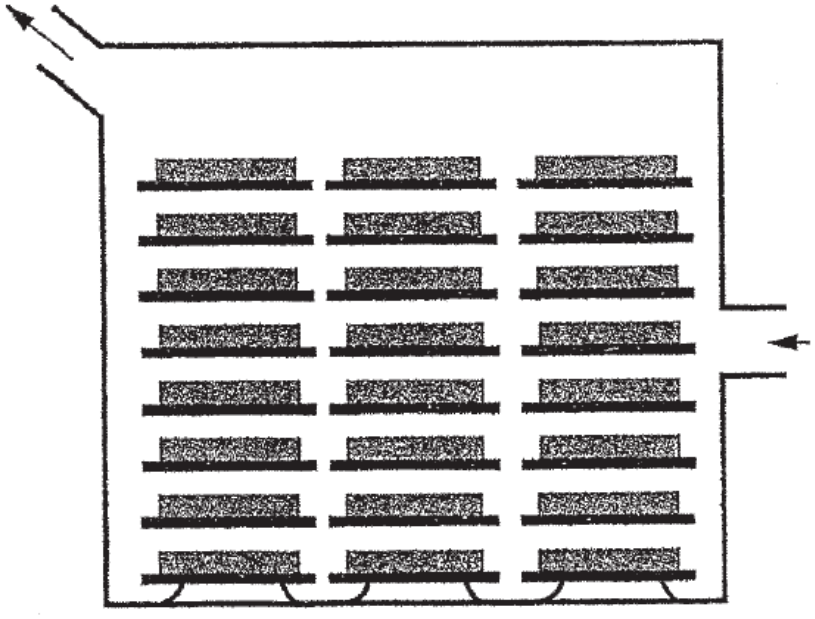
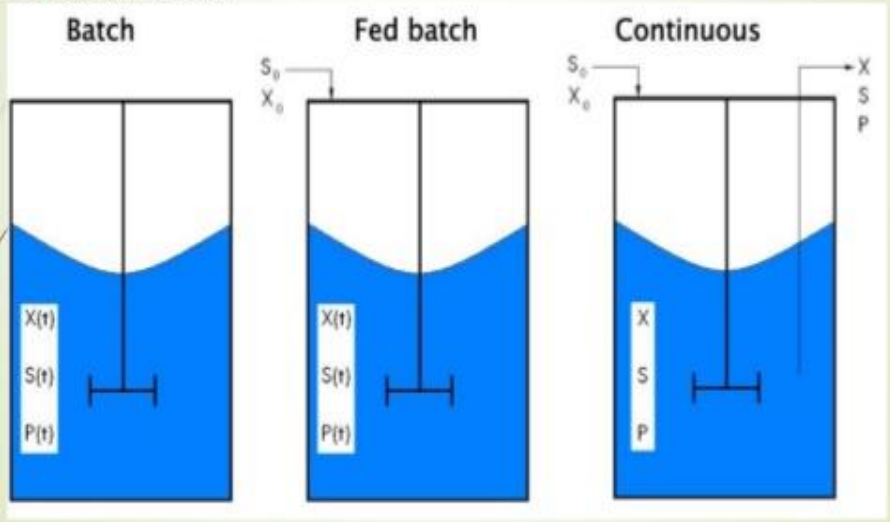


Fig. 9.10 Diagram of a Solid-state (Surface)Tray Fermentor Humid Cooled, Sometimes Filtered, Air is let into the Fermentor; the Exhaust Air is also Filtered (see text)

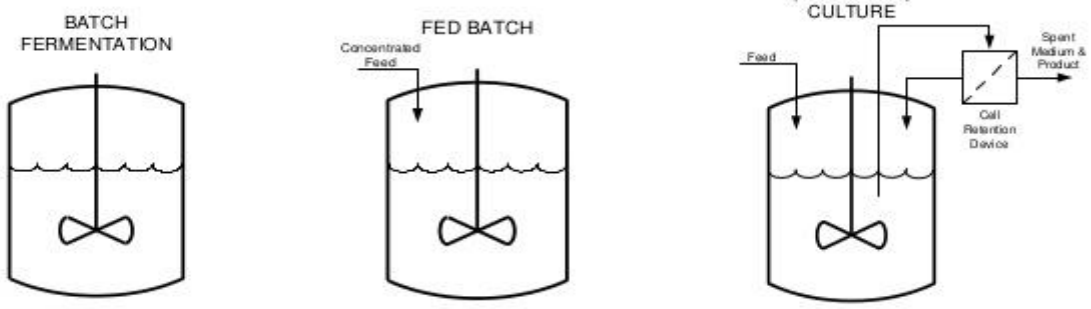
TYPES OF FERMENTATION

- Batch fermentation
- Continuous fermentation
- Fed-batch fermentation



Process Methodologies
Batch and Continuous Cell Culture

* Batch
  * Add materials at the beginning, production yield is nominally **1x**
* Fed-Batch (Semi-Batch)
  * Media addition to increase production yield up to **2x to 3x.**
* Continuous
  * Perfusion culture to increase production yield up to **10x.**



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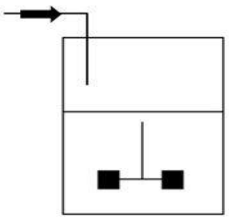
I. Batch Fermentation Process

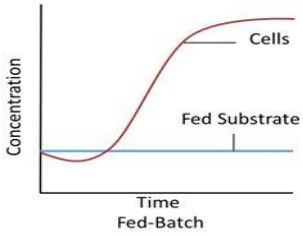
A tank of fermenter is filled with the prepared mash of raw materials(media) to be fermented. The temperature and pH for microbial fermentation is properly adjusted, and occasionally nutritive supplements are added to the prepared mash. The mash is steam sterilized in a pure culture process.
The inoculums of a pure culture is added to the fermenter, from a separate pure culture vessel.
Fermentation proceeds, and after the proper time the contents of the fermenter, are taken out for further processing.
The fermenter is cleaned and the process is repeated.
Growth of microorganisms during batch fermentation confirms to the characteristic growth curve, with a lag phase followed by a logarithmic phase.
This, in turn, is terminated by progressive decrements in the rate of growth until the stationary phase is reached. This is because of limitation of one or more of the essential nutrients .

II. Fed-Batch fermentation

In fed-batch fermentation, fresh growth medium is added continuously during fermentation, and no growth medium is removed until the end of the process.



Batch



(1) The continuous addition of medium prolongs both the log and stationary phases, thereby increasing the biomass and the amount of metabolites.

(2) However, microorganisms in stationary phase often produce proteolytic enzymes (proteases) to degrade proteins.

(3) A fed-batch fermentation strategy can increase the yield from 25% to more than 1,000% compared with batch fermentation.

Continous Fermentation Process

In continuous fermentation, the substrate is added to the fermenter continuously at a fixed rate. This maintains the organisms in the logarithmic growth phase (steady state). The fermentation products are taken out continuously. The design and arrangements for continuous fermentation, are some what complex.

The flow of culture media into the fermenter is related with the size of the fermenter ,this relation is known as the Dilution rate.
The steady state could be done through the flow of the culture media into the fermenter at a certain speed and this speed depend upon the size of the fermenter .

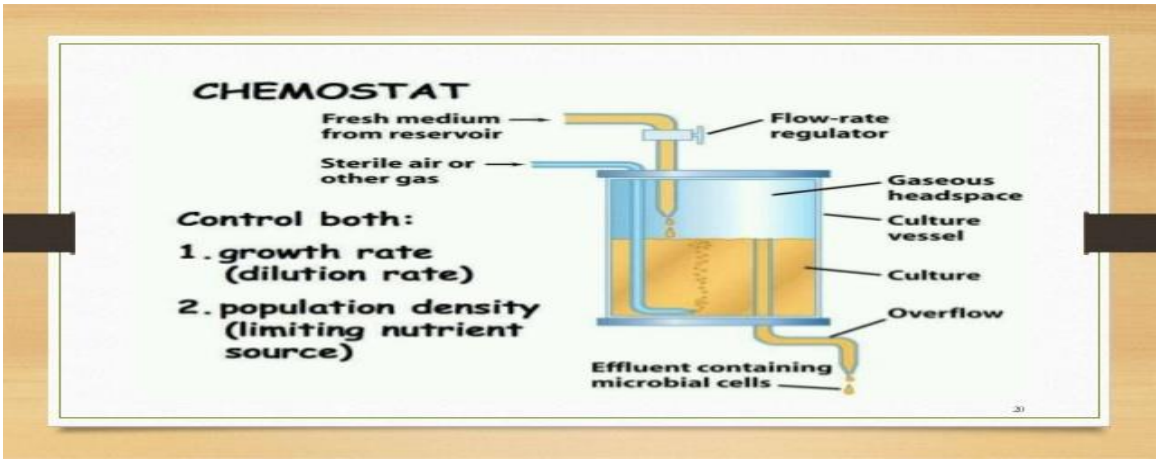
Controll of continous process

Continuous processes could be controlled through the followings;-

Chemoststst Culture

Device for maintaining a bacterial population in the exponential growth phase by controlling nutrient input and cell removal .

Growth rate of microorganisms in culture media is controlled through the control of the concentration of a certain nutrient which is critical for growth or through the control of the addition of one of the essential nutrient for growth at a fixed rate .

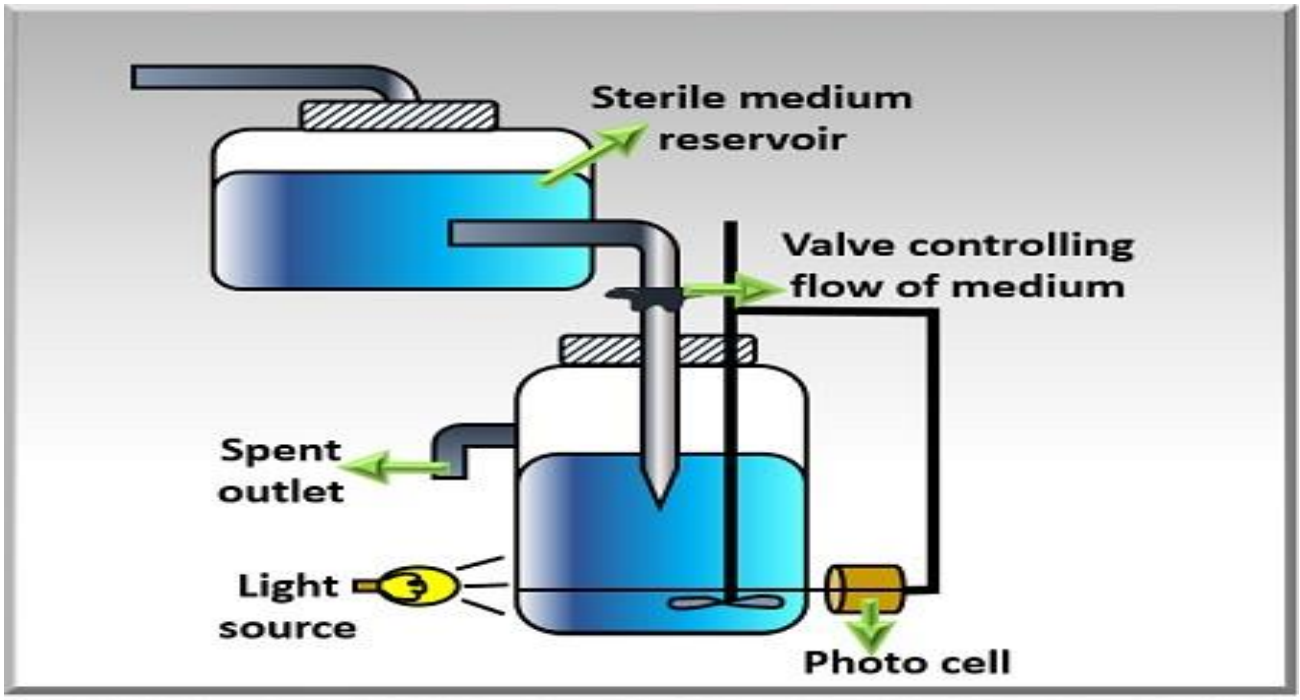


Turbdiostat culture

The continuous culture is controlled through keeping the concentration of the microorganism in the fermenter at a fixed rate ,this can be done through controlling the optical density of the culture at a certain range . In this case a photo cell is linked to the fermenter , so in the case optical density of the culture media exceeds the certain range, a signal is given to a special pump for entering a bigger quantity of the culture media and also drawn off (removal) of a quantity of the culture media in order the optical density reaches the certain range.

Biostat Culture

In this system the flow of the nutrient and drawn off the culture media is controlled through the measurement of some metabolite products such as CO_2 or O_2 consumption.



Continuous Culture By Turbidostat

Modification of continuous culture processes

In the continuous process , a lossage of the product could result since the drawn off of substance exit, contain large quantity of unutilized substrate , so modification were made :-

1.Feed back system

In this system the microorganism cell are concentrated to a high degree :-

a- Through putting filters at the points of the drawn off of the culture media ,which it makes the drawn off of the cells smaller .

b- After the drawn off the culture media , the microorganism cells will be separated through precipitation or centrifugation. And then reenter into the fermenter.

2.Multistage systems

In this system different conditions could be applied in different fermenters , and this has a benefit in the secondary metabolites production.
The first fermenter is used for growth , then the second fermenter is applied for the production of secondary metabolites, or the system could be used in the growth of microorganism cells in different sources of carbon, each in a separate fermenter.