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TYPES OF BIOREACTORS

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Types of Fermentor

- There are six types of bioreactors used in bioprocess technology.

(1)Continuous Stirred Tank
(2)Bubble Column Bioreactors
(3) Airlift Bioreactors
(4)Fluidized Bed Bioreactors
(5) Packed Bed Bioreactors
(6) Photo-Bioreactors.

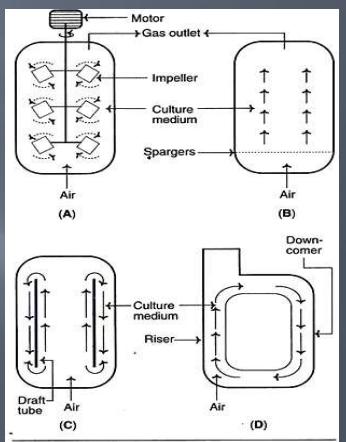

Fig. 19.1 : Types of bioreactors (A) Continuous stirred tank bioreactor (B) Bubble column bioreactor (C) Internal-loop airlift bioreactor (D) External-loop airlift bioreactor.

Type # 1: Continuous Stirred Tank

- A continuous stirred tank bioreactor consists of a cylindrical vessel with motor supports one or more agitators (impellers). The shaft is fitted at the bottom of the bioreactor.
- The number of impellers is variable and depends on the size of the bioreactor i.e., height to diameter ratio, referred to as aspect ratio of a stirred tank. However, for animal cell culture applications, the aspect ratio is less than 2.
- The diameter of the impeller is usually 1/3 rd of the vessel diameter. The distance between two impellers is approximately 1.2 impeller diameter. Different types of impellers (Rustom disc, concave bladed, marine propeller etc.) are in use.
- In stirred tank bioreactors or in short stirred tank reactors (STRs), the air is added to the culture medium under pressure through a device called sparger. The sparger may be a ring with many holes or a tube with a single orifice.
- The sparger along with impellers (agitators) enables better gas distribution system throughout the vessel. The bubbles generated by sparger are broken down to smaller ones by impellers and dispersed throughout the medium. This enables the creation of a uniform and homogeneous environment throughout the bioreactor.
- **Advantages of STRs**: These include the efficient gas transfer to growing cells, good mixing of the contents and flexible operating conditions, besides the commercial availability of the bioreactors.

Type # 2. Bubble Column Bioreactors

- In the bubble column bioreactor, the air or gas is introduced at the base of the column through perforated pipes or plates, or metal micro porous spargers (Fig. 19.1B).
- The flow rate of the air/gas influences the performance factors —O_2 transfer, mixing.
- The bubble column bioreactors may be fitted with perforated plates to improve performance.
- The vessel used for bubble column bioreactors is usually cylindrical with an aspect ratio of 4-6 (i.e., height to diameter ratio).

Type # 3. Airlift Bioreactors

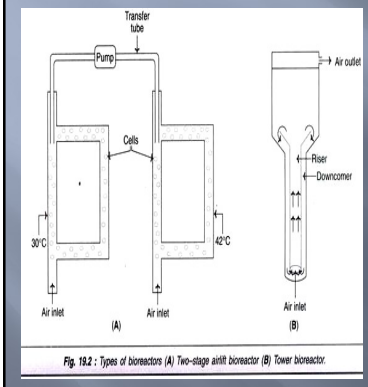

Fig. 19.2 : Types of bioreactors (A) Two-stage airlift bioreactor (B) Tower bioreactor.

- In the airlift bioreactors, the medium of the vessel is divided into two interconnected zones by means of a baffle or draft tube. In one of the two zones referred to a riser, the air/gas is pumped. The other zone that receives no gas is the down comer. The dispersion flows up the riser zone while the down flow occurs in the down comer. There are two types of airlift bioreactors.
- Internal-loop airlift bioreactor has a single container with a central draft tube that creates interior liquid circulation channels. These bioreactors are simple in design, with volume and circulation at a fixed rate for fermentation.
- External loop airlift bioreactor possesses an external loop so that the liquid circulates through separate independent channels. These reactors can be suitably modified to suit the requirements of different fermentations. In general, the airlift bioreactors are more efficient than bubble columns, particularly for more denser suspensions of microorganisms. This is mainly because in these bioreactors, the mixing of the contents is better compared to bubble columns.
- Airlift bioreactors are commonly employed for aerobic bioprocessing technology. They ensure a controlled liquid flow in a recycle system by pumping. Due to high efficiency, airlift bioreactors are sometimes preferred e.g., methanol production, waste water treatment, single-cell protein production. In general, the performance of the airlift bioreactors is dependent on the pumping (injection) of air and the liquid circulation.
- **Two-stage airlift bioreactors:**
- Two-stage airlift bioreactors are used for the temperature dependent formation of products. Growing cells from one bioreactor (maintained at temperature 30°C) are pumped into

Type # 4. Fluidized Bed Bioreactors

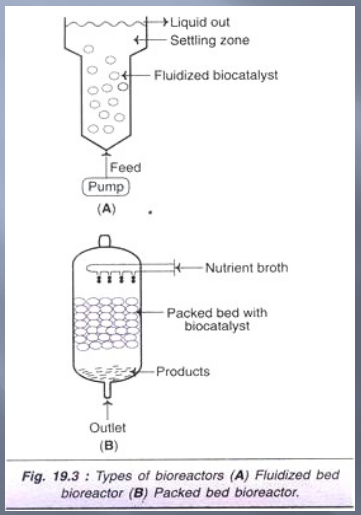

Fig. 19.3 : Types of bioreactors (A) Fluidized bed bioreactor (B) Packed bed bioreactor.

- Fluidized bed bioreactor is comparable to bubble column bioreactor except the top position is expanded to reduce the velocity of the fluid.
- The design of the fluidized bioreactors (expanded top and narrow reaction column) is such that the solids are retained in the reactor while the liquid flows out (Fig. 19.3A).
- These bioreactors are suitable for use to carry out reactions involving fluid suspended biocatalysts such as immobilized enzymes, immobilized cells, and microbial flocs.
- For an efficient operation of fluidized beds, gas is spared to create a suitable gas-liquid-solid fluid bed.
- It is also necessary to ensure that the suspended solid particles are not too light or too dense (too light ones may float whereas to dense ones may settle at the bottom), and they are in a good suspended state.
- Recycling of the liquid is important to maintain continuous contact between the reaction contents and biocatalysts. This enable good efficiency of bioprocessing.

Type # 5. Packed Bed Bioreactors

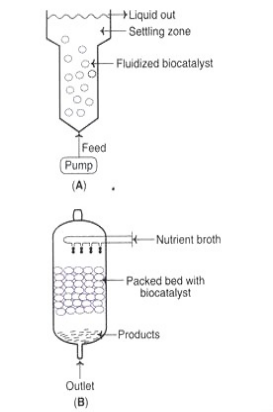

Fig. 19.3 : Types of bioreactors (A) Fluidized bed bioreactor (B) Packed bed bioreactor.

- A bed of solid particles, with biocatalysts on or within the matrix of solids, packed in a column constitutes a packed bed bioreactor (Fig. 19.3B).
- The solids used may be porous or non-porous gels, and they may be compressible or rigid in nature.
- A nutrient broth flows continuously over the immobilised biocatalyst.
- The products obtained in the packed bed bioreactor are released into the fluid and removed. While the flow of the fluid can be upward or downward, down flow under gravity is preferred.
- The concentration of the nutrients (and therefore the products formed) can be increased by increasing the flow rate of the nutrient broth.
- Because of poor mixing, it is rather difficult to control the pH of packed bed bioreactors by the addition of acid or alkali.
- However, these bioreactors are preferred for bioprocessing technology involving product-inhibited reactions.
- The packed bed bioreactors do not allow accumulation of the products to any significant extent.

Type # 6. Photo-Bioreactors

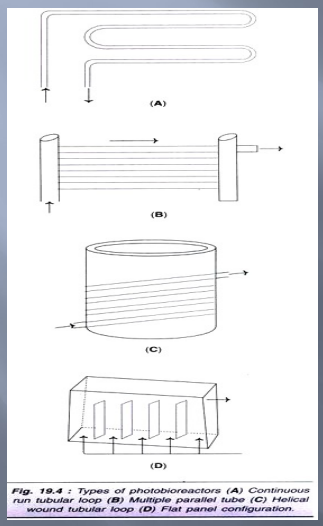

Fig. 19.4 : Types of photobioreactors (A) Continuous run tubular loop (B) Multiple parallel tube (C) Helical wound tubular loop (D) Flat panel configuration.

- These are the bioreactors specialised for fermentation that can be carried out either by exposing to sunlight or artificial illumination. Since artificial illumination is expensive, only the outdoor photo-bioreactors are preferred.
- Certain important compounds are produced by employing photo-bioreactors e.g., p-carotene, asthaxanthin
- They are made up of glass or more commonly transparent plastic.
- The array of tubes or flat panels constitute light receiving systems (solar receivers). The culture can be circulated through the solar receivers by methods such as using centrifugal pumps or airlift pumps.
- It is essential that the cells are in continuous circulation without forming sediments.
- Further adequate penetration of sunlight should be maintained.
- The tubes should also be cooled to prevent rise in temperature. Photo-bioreactors are usually operated in a continuous mode at a temperature in the range of 25-40°C. Microalgae and cyanobacteria are normally used.
- The organisms grow during day light while the products are produced during night.

References and Further Readings

- https://www.researchgate.net/publication/275953938_Characteristics_and_Techniques_of_Fermentation_Systems
- https://www.researchgate.net/publication/287302702_Application_of_different_types_of_bioreactors_in_bioprocesses