Bioreactors / Fermenters and fermentation processes.

Solid state fermentation :-

Solid-state fermentation (SSF) or solid substrate fermentation is the fermentation process occuring in the absence or near absence of free water.

Substrates used in SSF :-

1. Sugar cane Bagasse.
2. Tea waste.
3. Wheat Bran.
4. Saw Dust.
5. Apple Pomace.
6. Coconut oil cake.

Advantages of Solid State Fermentation :-

1. Process is simple.
2. Cost Effective.
3. Less Effluent release, reduces pollution
4. High Titers, (High product yield.)
5. Aeration Process is easy
6. Resembles the natural habitate of some fungi and bacteria.
7. Easier downstream processing

Factors influencing SSF:

1. Selection of micro-organisms. - bacteria, yeast and filamentous fungi
2. Substrate.
3. Process optimization.

Application of SSF

1. Agro - Food Industry
2. Agriculture Industry
3. Industrial ~~Formation~~ Fermentation.

Liquid state fermentations:-

Submerged fermentation is a process ~~is~~ involving the development of microorganisms in a liquid broth

O_2 → Fermenter { Microorganisms. [bacteria, fungi, etc.] + Liquid broth [fruit juice, veg-juice, Sugars] + Products [enzyme, antibiotics, alcohols, et + CO_2.

Primary metabolites ⟶ Secondary metabolites.

⟶ Liquid ~~as~~ fermentation [free flowing liquids]

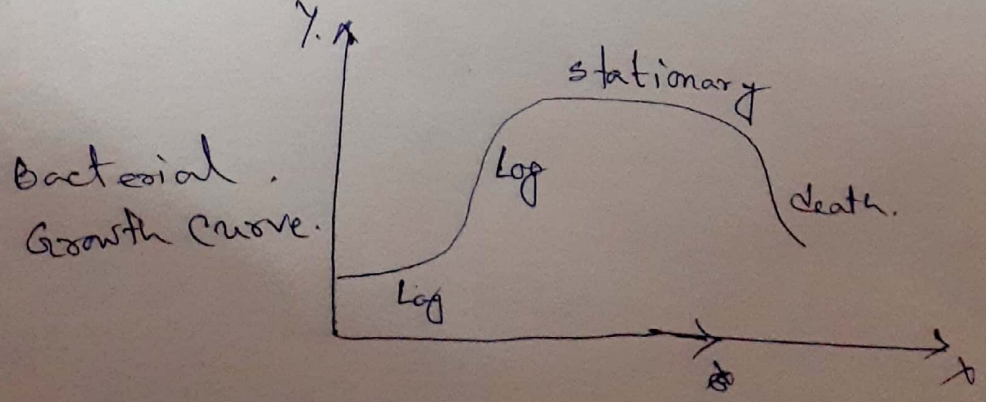
⟶ Industrial manufacturing.

① Batch - Fed Fermentation
② Continuous Fermentation.

① Batch - Fed Fermentation :—

The process in which the nutrients will be added to the fermenter intermittently to control the metabolic activity of the cells.

- Generates high cell densities.



Continuous fermentation :—

The liquid nutrients are slowly and continuosly added to the bioreactor such that the metabolism of microorganisms will be done in steady rate.

→ Certain variables.

Temp. pH, O_2.

→ Substrates.

Soluble sugar, Liquid media, fruit & vegjuices.

Types of Bioreactor :—

① Stirred tank Bio reactor.
② Bubble colum bio reactor.
③ Airlift bioreactor.
④ Fluaidized bed bioreactor.
⑤ Packed bed. "
⑥ Photo bioreactor.

Fermentation :-

Any of a group of chemical ~~reactor~~ reactions induced by microorganisms or enzymes that split complex organic compounds into relatively simple substances, especially the anaerobic conversion of sugar to carbon dioxide and ~~alch~~ alcohol.

Fermenter :-

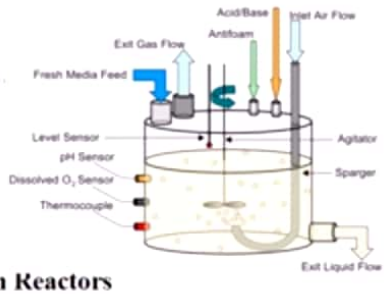
A specially designed vessel in which large quantity fermentation media is added with fermentation microorganisms which provides best possible environment control and process control for the biosynthesis of fermentation products.

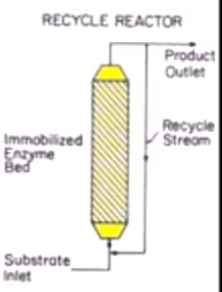
Components of a typical bioreactor :-

1. Drive motor.
2. pH probe.
3. pO_2 probe.
4. Head plate.
5. Filter.
6. Water jacket
7. Rotameter.
8. Glass vessel.
9. Control panel.
10. Exit gas cooler.
11. Condenser.
12. Inlet filter connected to sparger.
13. Reagent bottle (Anti foam).
14. Reagent.
15. Sterilized syringe.
16. Syringe.

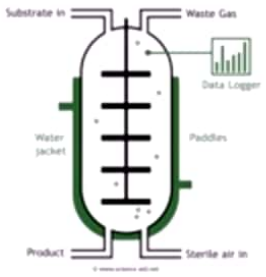
Types of bioreactors

BATCH FERMENTERS,
CONTINUOUS FERMENTERS
RECYCLE REACTORS.



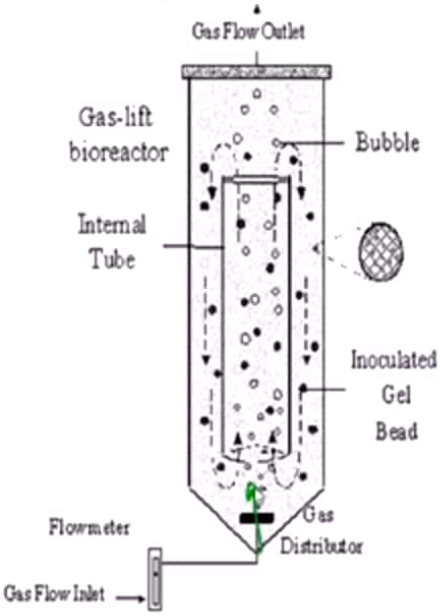


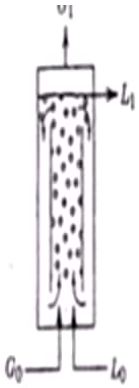
1. **Airlift bioreactors (ALB)**
2. **Tower Fermenter**
   - **---Bubble Column Reactors**
   - **---Bubble cap reactor**
3. **Plug flow reactors (PFB)**
4. **Packed bed bioreactors (PBB)**
5. **Fluidized bed Bioreactors (FBB)**
6. **Stirred tank bioreactors (STB)**



1. Airlift bioreactors (ALB)

Air-lift bioreactors are similar to bubble column reactors, but differ by the fact that they contain a draft tube. The draft tube is always an inner tube (this kind of air-lift bioreactor is called "air-lift bioreactor with an internal loop) or an external tube (this kind of air-lift bioreactor is called "air-lift bioreactor with an external loop) which improves circulation and oxygen transfer and equalizes shear forces in the reactor.



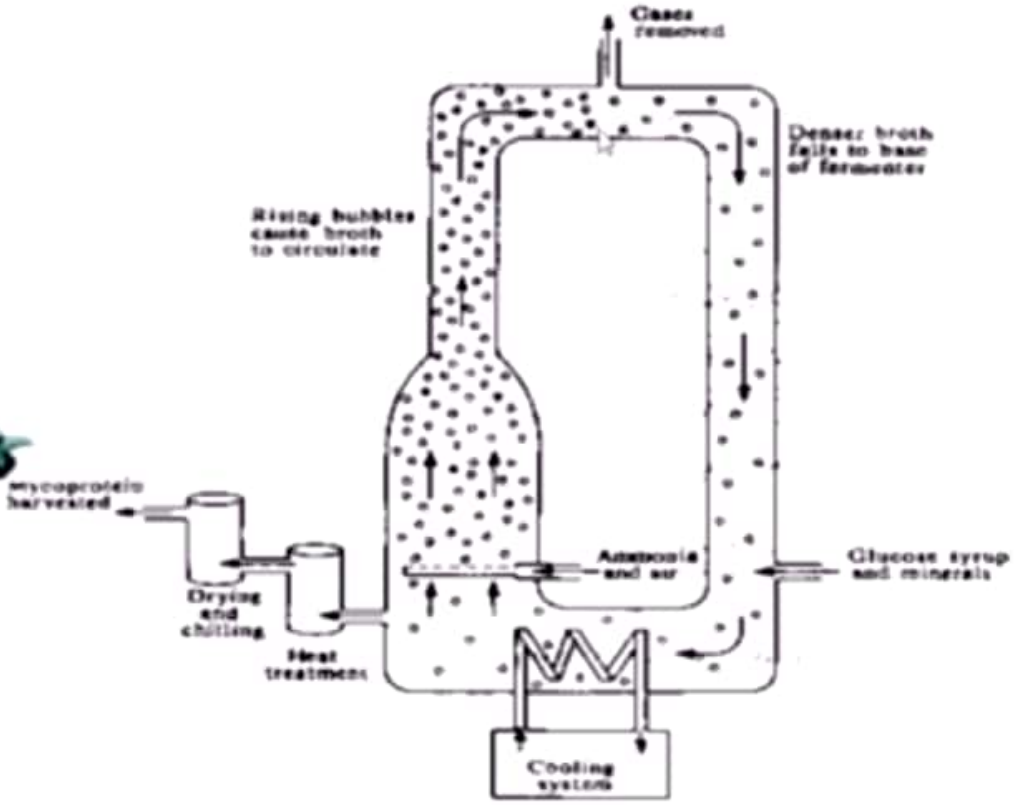


- Airlift bioreactors (ALB) are generally classified as **pneumatic reactors** without any mechanical stirring arrangements for mixing.
- The turbulence caused by the fluid flow **ensures adequate mixing** of the liquid.
- The draft tube is provided in the central section of the reactor. The introduction of the fluid (air/liquid) causes upward motion and results in **circulatory flow in the entire reactor**.
- The air/liquid velocities will be low and hence the **energy consumption is also low**.

Advantages

- ALBs can be used for both **free and immobilized cells**.
- There are very few reports on ALBs for metabolite production.
- The advantages of Airlift reactors are the **elimination of attrition effects** generally encountered in mechanical agitated reactors.
- It is ideally suited for aerobic cultures since **oxygen mass transfer coefficient are quite high** in comparison to stirred tank reactors.
- These bioreactors can be of external or internal loop bioreactor type.
- Advantageous for **cell culture**.
- The world's largest industrial fermenter is still the ICI's air lift system first operated at the Billingham, U.K. plant for making single-cell protein in 1979.

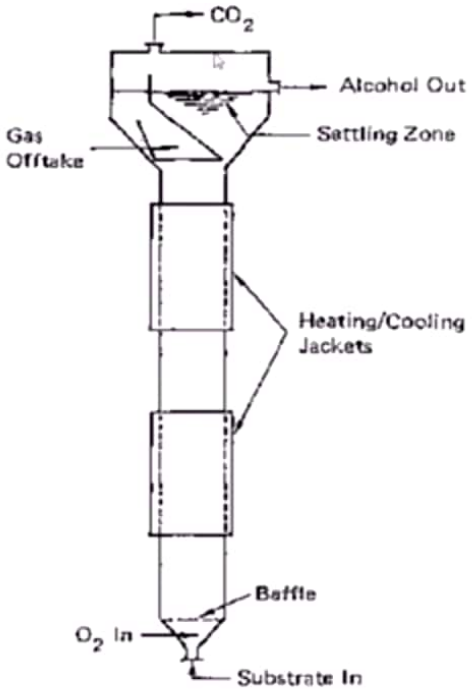
Airlift bioreactors (ALB)(lab scale)



Airlift (loop) bioreactors (ALB)

2. Tower Fermenter:

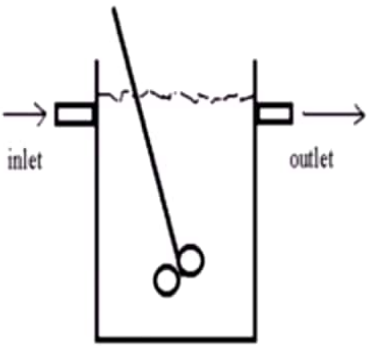
Elongated **non-mechanically stirred** fermenter with an **aspect ratio** (height:diameter) of 6:1 through which there is an unidirectional flow of gases.
Used for **continuous production of alcoholic beverages** (lager & ale beer).



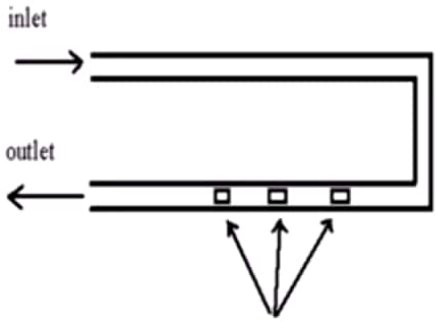
Tower Fermenter

3. Plug flow reactors (PFB)

Well Mixed Reactor



Plug Flow Reactor



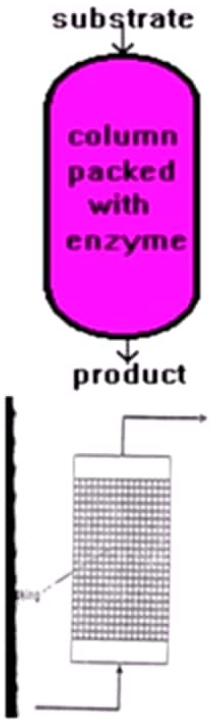
No mixing between flowing "plugs"

➢A very important characteristic of the CSTR is that the **concentration of the reactants in the outlet is equal to the concentration of the reactants in the vessel** regardless of the concentration of the reactants in the inlet.

➢Plug flow reactors can be modeled as a pipe where the reactants move as a plug along the pipe. **The concentrations of the reactants will vary along the pipe** and there is **no mixing** between the beginning and the end of the system.

4. Packed bed bioreactors (PBB)

- Packed bed or fixed bed bioreactors are commonly used with **attached biofilms** especially in **wastewater engineering**.
- The packed bed reactors are widely used with **immobilized cells.**
- The immobilized biocatalyst is packed in the column and fed with nutrients either from top or from bottom.
- One of the **disadvantages** of packed beds is the changed flow characteristic due to **alterations in the bed porosity** during operation.
- The **bed compaction** which generally occurs during fermentation results in high pressure drop across the bed.
- In addition **channeling** may occur due to turbulence in the bed.
- Though packed beds belong to the class of plug flow reactors in which back mixing is absent, *in many of the packed beds slight amount of back mixing occurs which changes the characteristics of fermentation.*

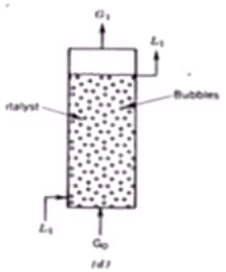


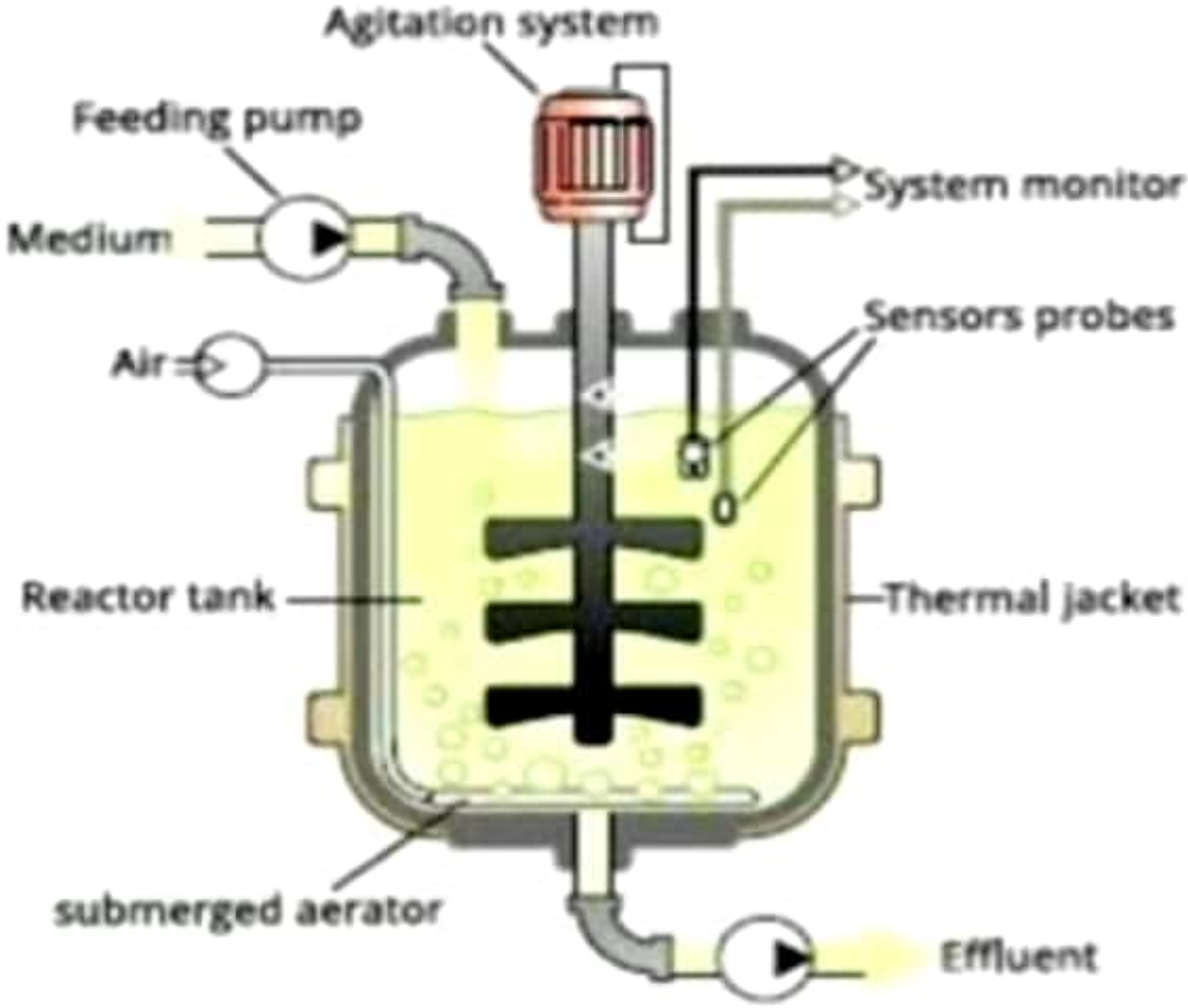
5. Fluidized bed Bioreactors (FBB)

- Fluidized bed bioreactors (FBB) are developed for biological systems involving cells as biocatalysts are **three phase systems (solid, liquid & gas).**
- The FBBs are generally **operated in co-current upflow with liquid as continuous phase.**
- Basically the particles used in FBBs can be of three different types: (i) inert core on which the biomass is created by cell attachment. (ii) Porous particles in which the biocatalyst is entrapped.(iii) Cell aggregates/ flocs (self-immobilization).
- In comparison to conventional mechanically stirred reactors, **FBBs provide a much lower attrition of solid particles.**

Advantages

- In comparison to packed bed reactors FBBs can be operated with smaller size particles without the drawbacks of clogging, high liquid pressure drop, channeling and bed compaction.
- The smaller particle size facilitates higher mass transfer rates and better mixing.
- The volumetric productivity attained in FBBs is usually higher than in stirred tank and packed bed bioreactors.





General structure of a continuous stirred-tank type bioreactor