Enzyme reactors

1. Definitions :

Reactor :

Industrial installation where a chemical reaction takes place in the presence of a catalyst.

Bioreactor :

Compartment where bioconversions or fermentations are carried out.

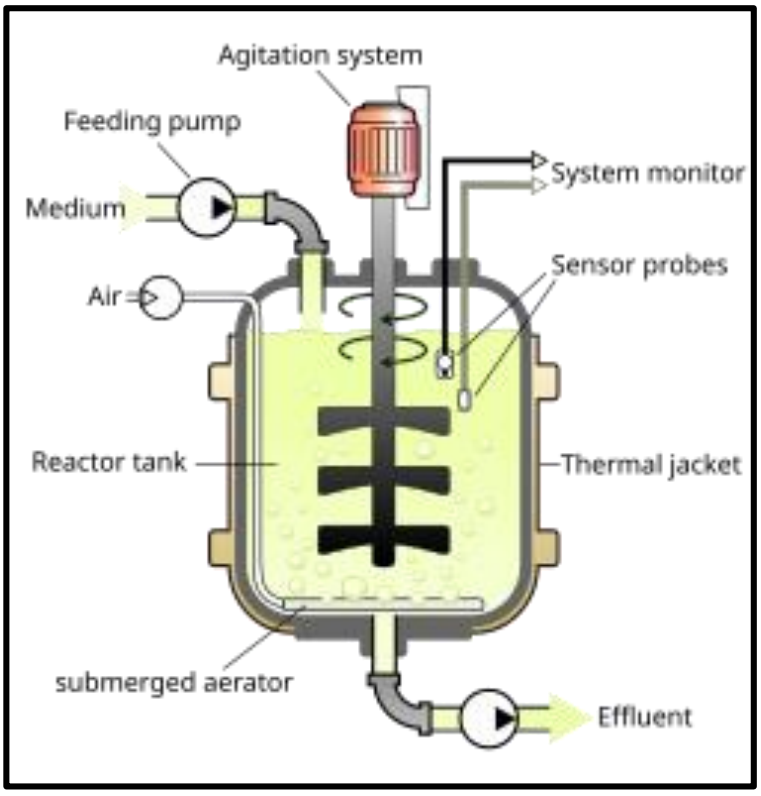
Bioconversion :

Transformation of a substance into one or more other substances, by enzymatic or fermentative means (by microorganisms).

2. Composition of a bioreactor :

A bioreactor comprises :

- ✓ A glass (for laboratory models) or stainless steel tank or chamber;
- ✓ A stopper, if necessary, to prevent air from passing between the internal and external environments;
- ✓ A syringe with a catheter for injecting a solution;
- ✓ An agitation system comprising one or more turbines, depending on their size;
- ✓ Sensors for measuring temperature (thermometer), pH (pH meter), dissolved oxygen concentration (oximetric probe), level…
- ✓ A computer-managed control system that records and controls all operating parameters.

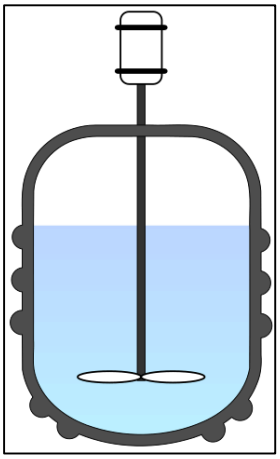


3. The different types of enzyme reactors and their operating modes :

An enzyme reactor involves devices that can be very simple or complex, involving auxiliary equipment (aeration, sterilization, etc.). The reactor is therefore designed according to the type of process that is to take place in it.

The enzymatic reaction can be produced in batch mode, fed-batch mode, or fully continuous mode (feeding and extraction).

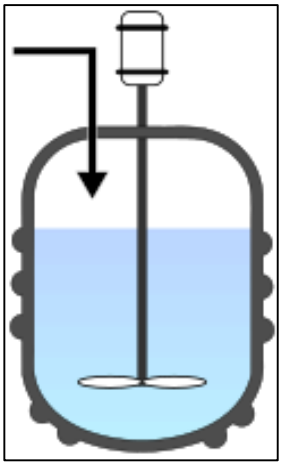
3.1. Batch reactor :



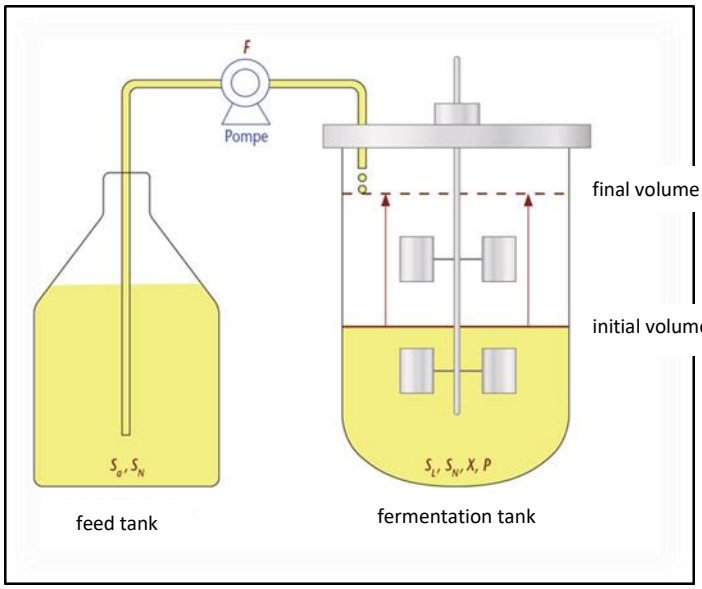
3.1.1. Tank reactor « batch » :

~ The reaction is conducted in batches;
~ This reaction mode is recommended for small volumes (laboratory scale) or when quality control requires a lot number (such as in the pharmaceutical industry);
~ After placing the substrate and enzyme (which may be in solution or immobilized), water if necessary, and after reaching the set values for the various parameters (temperature, pH), the system is closed during the reaction time;
~ A small amount of additive may be added to the system in the case of pH regulation, but no substrate or enzyme is added to the system.
~ The volume remains the same and agitation can be carried out uniformly throughout the reaction.
~ Enzymatic hydrolysis often causes the hydrolyzed products to liquefy, making agitation easier.
~ Batch reactors have lower productivity due to interruptions.
~ Product recovery is usually achieved by filtration, centrifugation, or precipitation.

3.1.2. Feed tank reactor « fed batch » :

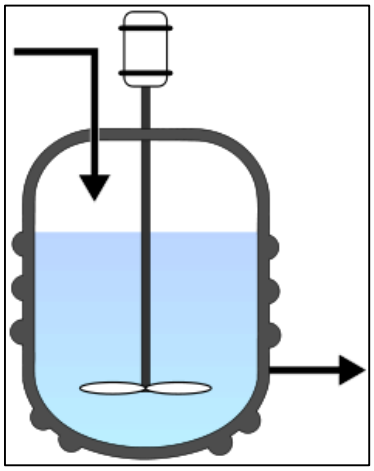


~ The reaction in this case is handled differently.
~ It starts with a small volume of substrate;
~ The amount of enzyme present is therefore in a higher concentration than in a batch system, and the reaction starts more quickly;
~ The substrate is fed continuously into the reactor;
~ The total volume increases constantly;
~ This technique, widely used in microbial fermentation, is not very common in enzymatic hydrolysis, where batch hydrolysis is generally preferred.



3.2. Continuous reactor :

3.2.1. Perfectly agitated reactor :



~ In this type of reactor, the vessel is continuously fed and drained ;

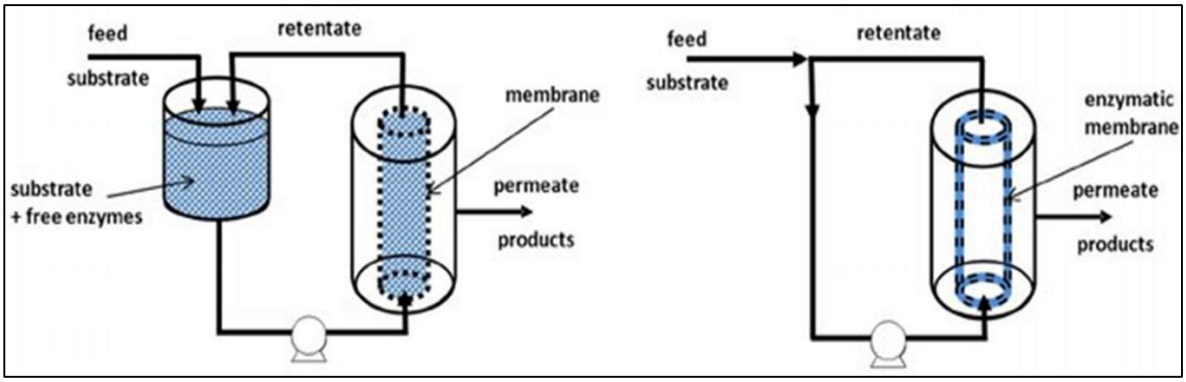
~ The tank containment is different from the other two in that selective drainage is carried out so that only the product leaves the containment ;

~ To recover only these products, the reactor could, for example, be combined with an ultrafiltration (UF) system. Such a system would make it possible to control the size of the products generated ;

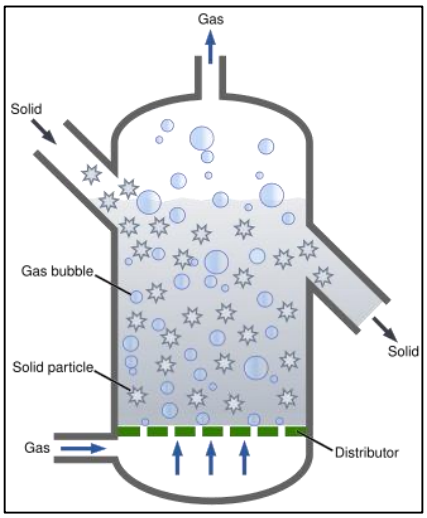
~ Enzymes are immobilized on an inert support so that they do not pass through the membrane ;

~ One of the major problems with this type of process is the clogging of the membranes by various substances resulting from the reaction.

~ The inlet flow rate is equal to the outlet flow rate, and the concentrations are the same in the reactor and at the outlet.



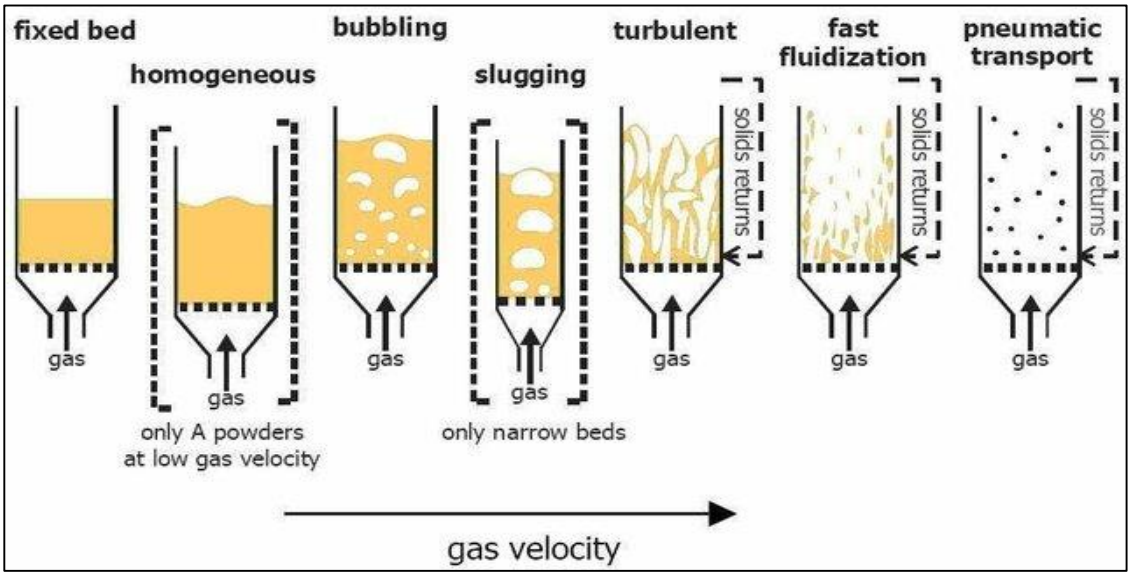
Fluidized bed reactor :



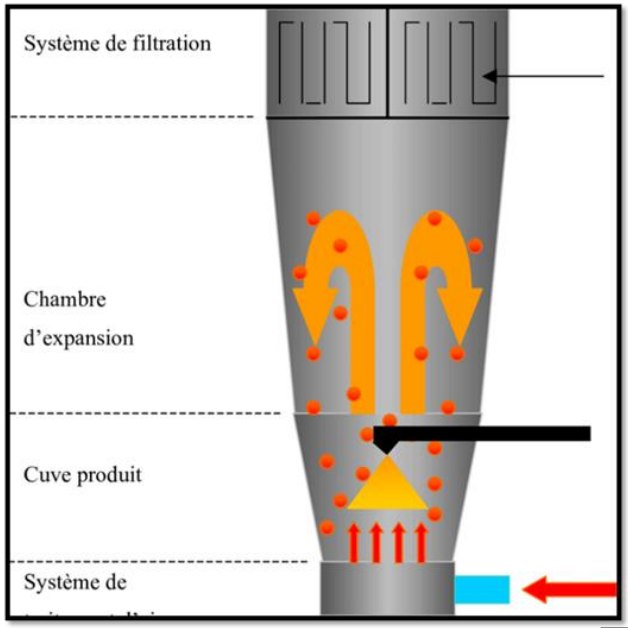
The carrier particles with their attached cells (or enzymes) are in movement, fluidized by a flow stream.

It consists of a circular tube filled with active solid particles, but placed vertically and with only one end closed by a grid or perforated plate.

The activity is carried out by bacteria or enzymes that are attached to a mobile support, fine and porous granular particles such as sand or activated carbon.



The liquid phase flows through the reactor from bottom to top, and since the solid particles are not confined, as soon as the surface velocity of the liquid exceeds the minimum fluidization value, the bed expands and the solid particles move freely within the liquid-solid suspension.

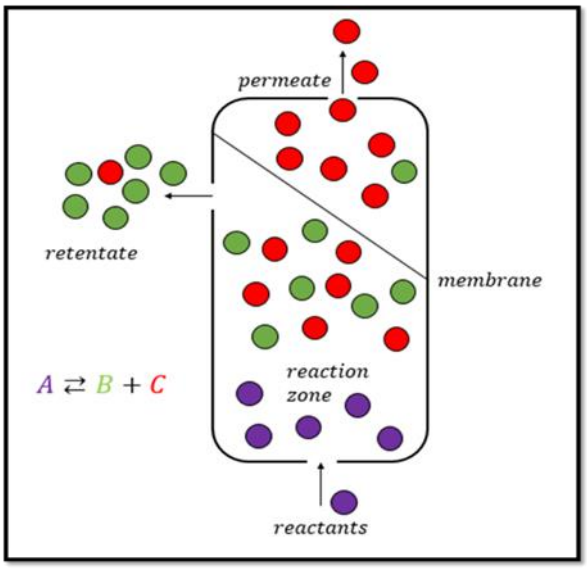


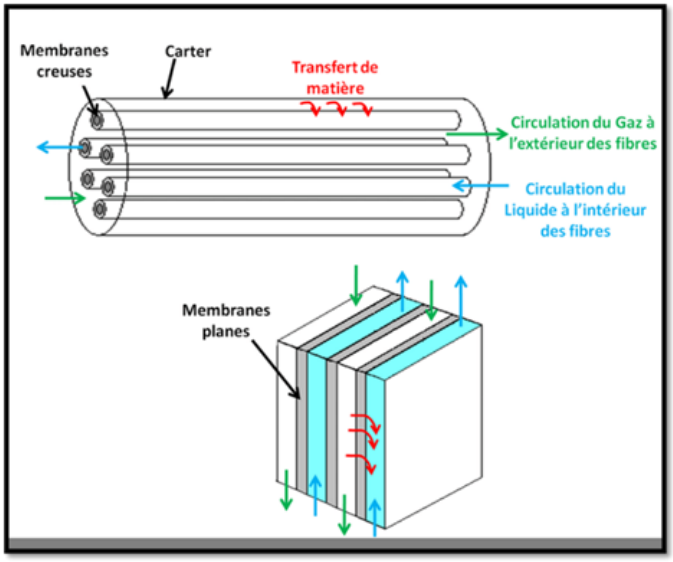
The bed is then said to be fluidized; the solid particles are set in movement by the rapid and regular upward flow of the effluent, which ensures that they are mixed together.

This system minimizes the phenomena of column clogging and gas entrapment. It ensures better mass and heat transfer.

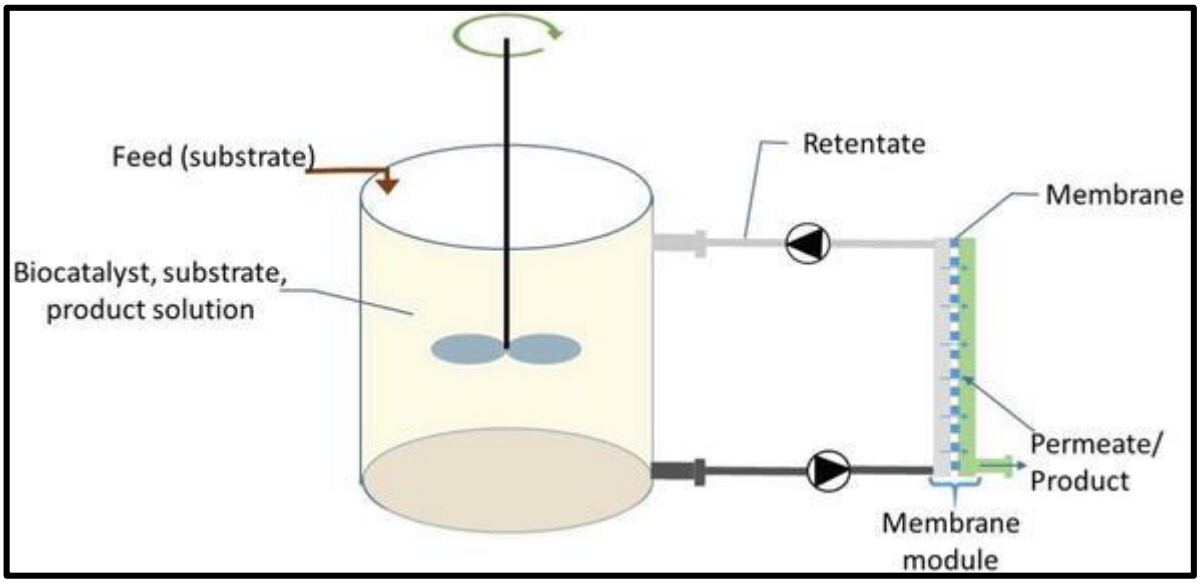
3.2.2. Membrane reactor :

Membrane bioreactors are involved in the transformation of various food compounds with a view to developing continuous, high-productivity processes.



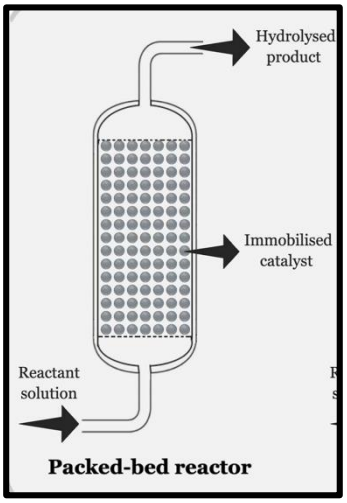


Their application concerns both the bioconversion of macromolecules (proteins, polysaccharides) and low molecular weight molecules (amino acids, oligosaccharides).

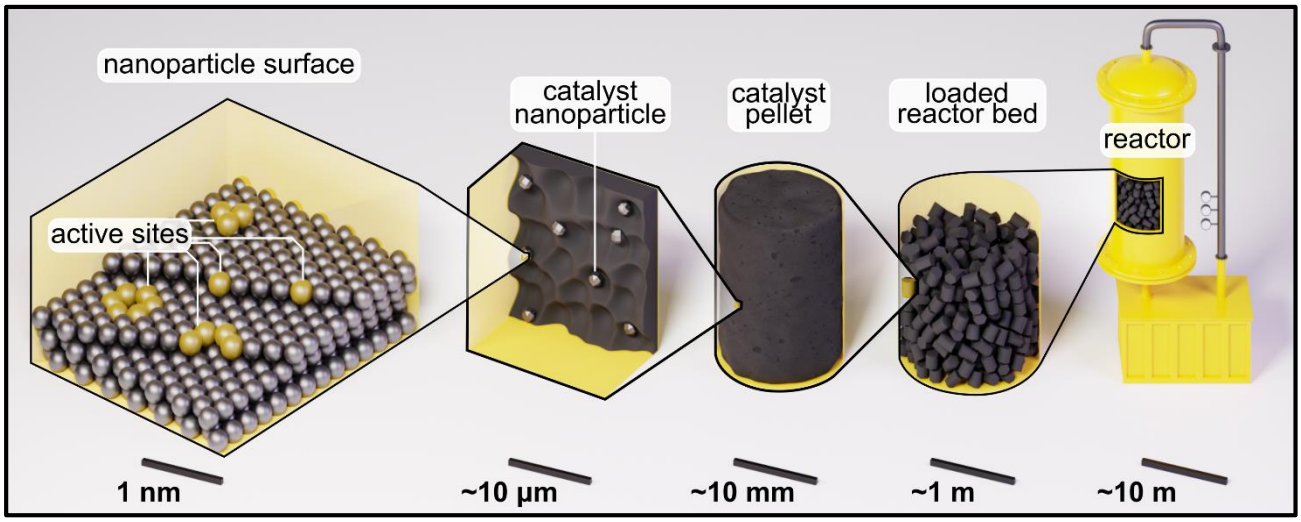


Various immobilization techniques can be used, such as attachment to a surface by adsorption or covalent bonding, encapsulation, or inclusion in a matrix. In addition to the variety of membrane shapes and types (such as hollow fiber membranes).

3.2.3. Fixed bed reactor « packed bed » :



- ~ Enzymes are immobilized on solid supports, which are particles or beads.
- ~ The immobilized enzyme at the start of the reactor is present in high substrate concentrations and therefore operates at high speed ;
- ~ Towards the end of the reactor, the substrate concentration decreases and it is only in this region that the enzyme works at a slower speed ;
- ~ There is therefore potential for better use of the enzyme ;
- ~ The limitations of this type of reactor are :
  - The nature of the substrate (gaseous or poorly soluble substrates) and substrate-induced inhibition phenomena.
  - A significant loss of load
  - Risque de colmatage du lit ;
  - Significant diffusion limitations, which reduce reactor performance.



4. The different reactor models :

- ~ Reactors can be more or less sophisticated in their design and have more or less accessory equipment ;
- ~ Most reactors are cylindrical or parallelepiped, but they can also be cylindroconical to allow work on small volumes, providing better separation ;
- ~ The temperature is regulated either by means of a double jacket with continuous circulation or by adding an immersion heater directly into the system ;
- ~ Reactors generally have several inlets to allow accessories to be added or to enable intervention in the reaction medium. These inlets allow physical measurement sensors (temperature probe, pH electrode, pressure probe, etc.), distribution probes (liquid, gas, etc.), etc. to be introduced into the system ;

- ~ Enzyme reactors are used on a laboratory scale (0.1-15 liters) and on an industrial scale (over 1000m^3) or employed for testing with a view to industrial production ("pilot reactors") (20-1000m^3) ;
- ~ The reactors can be combined with a computer-managed control system that records and controls all operating parameters.