**Types of Fermenters**

Conical flasks are used for carrying out laboratory scale submerged fermentations while large scale fermentations are usually carried out in glass or stainless steel tank fermenters. The requirements of a good fermentation vessel are thatit should: be inexpensive, prevent contamination, be non-toxic to the microorganism used for the process, and be easy to operate andsterilize, and be tough,reliableand leak proof. Further, it should also allow visual monitoring of the fermentation process as well ashave sampling ports.

**Batch Fermenter/Stirred Tank Fermenter (STR)**

They are one of the most commonly used fermenter types because of their flexibility;they are cylindrical vessels with a motor driven central shaft with impellers/ agitator to stir the contents in the tank(Figure. 5). The shaft supports 3-4 impellers placed about 1 impeller diameter apart. The fermenter has an working aspect (height: width) ratio ranging from 2:1 to 6:1. There are four equally spaced vertical baffles that extend from near the walls into the vessel to avoid vortex formation and improve mixing.



**Figure 5:** Schematic diagram of a stirred tank fermenter.

Source: http://commons.wikimedia.org/wiki/Category:Agitated\_vessels (cc)

**Continuous Culture Unit/ Continuous Stirred-tank Fermenter**

This fermenter unit is based on continuous fermentation (Figure. 6). It is similar to the batch fermenter, except that there is provision for an inlet and an outlet for the entry of fresh medium and flow of the excess medium and cells, respectively. It can use the techniques of chemostat or turbidostat to maintain cells in logarithmic phase continuously, which facilitatehigher production in some cases due to faster rates of substrate utilization.



**Figure 6:** A schematic diagram of a continous stirred tank fermenter.

**Airlift/ Lift-tube Fermenter**

They areagain similar to batch fermenters except that theydo not have mechanical agitation systems (motor, shaft, impeller blades). Instead, the contents are shaken up by injecting air from the bottom and the cell suspension circulates around the column as a result of the gradient of air bubbles in different parts of the reactor(Figure. 7). Thus, the medium is divided into two interconnected zones by means of a draft tube. Only one of these zones is sparged with air/ gas. The sparged zone is known as riser and the zone that receives no gas is down-comer. Airlift fermenters are available in two designs: the internal-loop and external-loop. In the internal loop type, the aerated riser and the non-aerated downcomer are contained in the same casing, while in the external loop design, the riser and the down-comer are different tubes joined near the top and the bottom. This system is suitable for cultivation of filamentous fungi (which can get damaged by mechanical agitators)and for immobilized cells.

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**Figure 7:**Schematic diagram depicting an air-lift fermenter with **A)**internal loop designand **B)** external loop design.

Source: Author An airlift fermenter varies from bubble column bioreactors due to the presence of a draft tube which offers better mass and heat transfer efficiencies and lower shear conditions. The major disadvantages of air-lift fermenters include its higher capital cost, higher energy requirements, extensive foaming and damage to cellsdue to bursting ofbubble.

**Bubble Column Reactor**

A bubble column reactor is essentially a cylindrical vessel with a gas distribution system at the bottom, whereby the gas is sparged/ introduced in the form of bubbles into either a liquid phase or a solid–liquidsuspension, thus bringing about the mixing(Figure. 8). Bubble column reactors have a number of advantages as compared to other reactors like an excellent heat and mass transfer characteristics, less maintenance and lower operating costs due to non-requirement of mechanical mixing parts. They have been used extensively to produce industrially valuable products such as enzymes, antibiotics,proteins as well as in biological wastewater treatment.

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**Figure 8:** A bubble column reactor.

**Fluidized Bed Reactor**

These are also similar to bubble column reactors but in this case, air is replaced with fresh or recirculated liquid, which is continuously pumped into the bottom of the vessel at a rate that is adequate to fluidize the solids or maintain them in suspension(Figure. 9). In these bioreactors, mixing is brought about by the action of a pump and the cells or enzymes are immobilised in and/or on the surface of light particles, while a pump situated at the base of the reactorcauses the immobilized catalysts to move with the liquid. The upward force of the pump is balanced by the downward movement of the particles due to gravity,thereby, preventing washing out of immobilized catalysts from the bioreactor. Sparging may bedone to improve oxygen transfer rates for aerobic microbial systems. Fluidized bed bioreactors are a method of maintaining high biomass concentrations and simultaneously good mass transfer rates in continuous cultures.

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**Figure9:**A schematic diagram of a fluidized bed reactor.

**Fixed Bed Reactor**

In this kind of bioreactors, the cells are immobilized on some surfaces or form biofilms, thus they are fixed in place and cannot move(Figure. 10). The medium containing the substrate flows past the catalytic cells, which carry out the reaction and the end-product flows out through the other end.

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**Tower Fermenter** Tower fermenters are modified stirred tank reactors that do not require agitation, therefore, they lack shafts, impellers and blades.They consist of a long cylindrical vessel (with a working aspect ratio of six or more) with an inlet at the bottom, an exhaust at the top, and a jacket to control temperature (Figure 11). Consequently, tower fermenters are uncomplicated in design and easy to construct. Tower fermenters have found applications in continuous fermentation of beer, yeast and SCP.

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**Figure 11**. Schematic Diagram of Tower Fermenter.

Source: Author & ILLL (

**Solid-state Fermenter**

They are simple fermenters used for solid-state fermentation i.e. fermentation on moistened solid or particulate substrates without the addition of excess water. Hence, microbes grow on the surface of the substrate. Provisions for control of temperature and aeration as well as occasional turning/ mixing are there(Figure. 12).

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**Pilot scale Fermentor:**

A **pilot plant** is a pre-commercial production system that employs new production technology and/or produces small volumes of new technology-based products, mainly for the purpose of learning about the new technology. The knowledge obtained is then used for [design](https://en.wikipedia.org/wiki/Design) of full-scale production systems and commercial products, as well as for identification of further research objectives and support of investment decisions. Other (non-technical) purposes include gaining public support for new technologies and questioning government regulations. Pilot plant is a relative term in the sense that pilot plants are typically smaller than full-scale production plants, but are built in a range of sizes. Also, as pilot plants are intended for learning, they typically are more flexible, possibly at the expense of economy. Some pilot plants are built in [laboratories](https://en.wikipedia.org/wiki/Laboratory) using stock lab equipment, while others require substantial engineering efforts, cost millions of dollars, and are custom-assembled and fabricated from process equipment, instrumentation and piping. They can also be used to train personnel for a full-scale plant. Pilot plants tend to be smaller compared to demonstration plants.

**Horton sphere**

Initially, Hortonspheres were constructed by riveting together separate wrought iron or steel plates, but from the 1940s, were of welded construction. The plates are formed in roller plants and cut to patterns.

 Chicago Bridge & Iron Company CBI accounts for a large proportion of spherical pressure vessels in the world. They are used extensively for LPG, as well as for other volatile gasses. CBI identifies the following uses: gasoline, anhydrous ammonia, vinyl chloride monomer (VCM), naphtha, propane, propylene, ethane, butane, NGL and butadien. Cryogenic storage is also possible for LNG, methane, ethylene, hydrogen and oxygen. Gases that may be stored include hydrogen, nitrogen, oxygen, helium and argon. Other uses have been applied to the Horton sphere including space chambers, hyperbaric chambers, environmental chambers, vacuum vessels, process vessels, test vessels, containment vessels and surge vessels.

**Computer Applications in Fermentation Technology**

The use of computers for for modelling fermentation processes started in 1960s. Initially the use of computers was restricted because of the cost factor but reductions in the cost and the availability of the cheaper small computers has widened interest in their possible applications. The availability of efficient small computers has led their use for pilot plants and laboratory systems because the financial costs for the online computer systems counts the insignificant part of the whole system. There are three distinct systems areas of computer function postulated by Nyiri in 1972:

a) Logging of Process Data: This is performed by the data acquisition which has both hardware  and software components. there is  an interface between the sensors and the computer. the software should include the computer program for sequential; scanning of the sensor signals and the procedure of data storage.

b) Data Analysis: Data reduction is performed by the data analysis systems which is  acomputer program based on a series of mathematical equations. the analysed information may be put on a print out, fed into data bank or utilized for process control.

c) process control: is also performed by a computer program. signals from the computer are fed tio the pumps, valves or switches via the interface. in addition to this computer program may contain instructions to display devices or teletypes to indicate alrms.

Components of Computer Linked system:

When a computer is linked to a fermenter to operate as a control and recording system, a number of factors must be considered to ensure taht all the components interact  and function satisfactorily for the control a d data logging.An example is DDC (Direct Digital Control) system to explain the computer controlled addition  of a liquid from a resrvoir to a fermenter.

A simple outline of the main components is as follows:



Sensor S in fermenter produces a signal which may need to be simplified and conditioned in the correct analogue form. at this stage it is necessary to convert the signal to a digital form which can be  subsequently transmitte dto the computer. An interface is placed in the circuit  at this point. The interface serves as  the junction point for the inputs  from the fermenter  sensors to the computers and output signals  from the computer to the fermenter controls such as  a pump T attached to an additive reservoir.

A sensor will generate  a small voltage proportional to the parameter it is going to measure. for example a temperature probe might generate 1V at 10oC and 5V at 50oC. But this signal cannot be understood by the computer  and must be converted  from an analogue to digital converter ( ADC) into digital form.

The accuracy will depend upon the number of bits  it sends to the computer. AN 8-bit converter will work in the range of 0-255 and it is tehrefore  able to divide  a signal voltage into  256 steps. This will give  amaximum accuracy of 100/256, which is pproximately  0.4%. However a 10- bit converter  can give 1024 steps with a n accuracy of 100/1024, which is pproximately 0.1%. therefore when a parameter is to be monitored  very accurately  a converter of the appropraite degree of accuracy will be required. the time taken for an ADC to convert voltage signals to a digital output will vary with accuracy, but improved accuracy will lead to slower conversion  and hence slower control responses. The small computers is often used for one or more fermenters. it is coupled  to a real time clock, which determines how frequently  readings from teh sensor should be taken and possibly recorded. Ancillary equipments  include  a VDU, a data store , a teletype, a graphic display unit, a print out, alarms and barometer.

It is also possible to develop online programs so that online instruments can be checked regularly and recalibrated when necessary.