

Bioreactor Design for Chemical Engineers

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Fermentation processes are based on chemical engineering principles. Understand these concepts to achieve optimal bioreactor design.

Fermentation — the essence of bioprocessing — predates the discipline of chemical engineering by thousands of years. Ancient civilizations used bioprocessing to create such useful and tasty items as beer, wine, sauerkraut, kim-chi, and cheese. Until the discovery of penicillin and its commercialization in 1943, bioprocessing was not performed on an industrial scale with equipment resembling that in a chemical processing plant. Since then, the number of products made by fermentation has grown, because bioprocessing generally uses less energy than other routes, usually uses inexpensive raw materials, and sometimes makes products that cannot be made any other way. Modern products include antibiotics, amino acids, enzymes, monomers, proteins, food cultures, biopolymers, ethanol, isopropanol, isobutanol, flavorings, perfume chemicals, and many other organic chemicals.

This article will familiarize engineers who do not work in the bioprocessing industry, as well as those who are just beginning their bioprocessing careers, with the basics of bioreactor design from a chemical engineering viewpoint. Details of the biological processes are beyond the scope of this article and are not discussed.

Kinds of bioreactors

Here, the terms *fermenter* and *bioreactor* are used interchangeably. In general, there are two main classes of bioreactors: anaerobic and aerobic.

In anaerobic fermentation, the “bugs” (as chemical engineers often call microorganisms) grow and create product in the absence or near-absence of oxygen. Examples of anaerobic fermenters include most fuel processes (such as ethanol or isobutanol) and the manufacture of some organic acids.

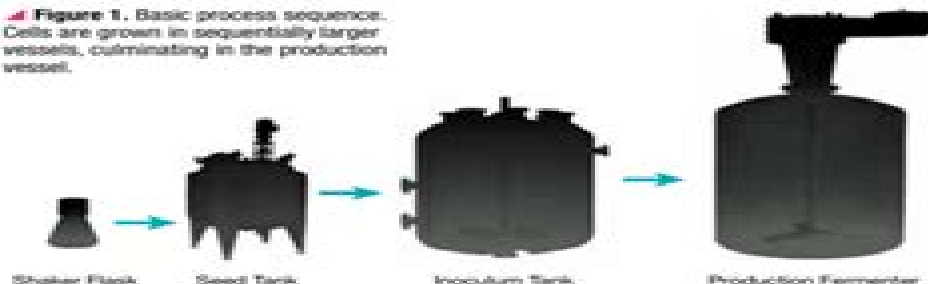
Aerobic fermentation takes place in the presence of oxygen, which the organisms consume in order to grow and/or make the desired product. Examples of aerobic processes include the production of yeast, antibiotics, enzymes, and amino acids. The amount of oxygen required varies from none (anaerobic processes) to a small amount (microaerobic) to a large amount (heavily aerobic).

The basic process

Regardless of whether the process is aerobic or anaerobic, it generally involves several steps before it reaches the production fermenter. The first step is cultivation of the organisms in the lab. This is often done in shaker flasks under the direct supervision of a microbiologist. A portion of high-cell-density broth is then transferred from the shaker flask to a seed tank, which is a small fermenter designed to increase the quantity of organisms. From there, it is usually transferred to a larger fermenter called the inoculum tank. Finally, the contents of the inoculum tank are transferred to the production fermenter (Figure 1).

The conditions in the shaker flask, seed tank, and

Figure 1. Basic process sequence. Cells are grown in sequentially larger vessels, culminating in the production vessel.



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