Mini Review

Pharmaceutical BIOPROCESSING

Solid State Fermentation Technology using Bioreactors Design, Applications, and Technical Considerations

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Abstract

Due to its many advantages over submerged fermentation, solid-state fermentation (SSF) technology has gained significant acceptance in recent years (SMF). The complete potential of SSF technology has not yet been fully utilised at an industrial scale, despite its huge advantages. The fundamental cause of this is still the absence of logical, scalable bioreactor designs supported by automated control systems and mathematical models that could effectively handle heat and mass heterogeneity and function aseptically. Because of this, there is still a huge opportunity for SSF bioreactor research and development to support a wide range of biotechnological applications. The current paper analyses current SSF technology with a focus on bioreactors used for bioprocess applications, particularly enzyme production. Bioreactors are broken down into four categories based on how they operate, with a focus on design elements, how operating conditions affect productivity, applications, and restrictions. In order to address the restrictions, some modelling studies that have been generated throughout the years have been reworked and presented in a problem-specific way. We go into greater detail on a few intriguing designs, some of which have recently been suggested and/or used in pilot and commercial settings [1-3].

Keywords: Bioreactor design • Heat and mass transfer • Mathematical models • Microorganism • Solid-state fermentation • Substrate-support

Introduction

Any manufactured system or device that supports a biologically active environment is referred to as a bioreactor. In one instance, a bioreactor is a container used for chemical reactions involving living things or substances produced from them that are biochemically active. There are two types of this process: aerobic and anaerobic. These cylinder-shaped bioreactors, which can range in size from litres to cubic metres, are frequently composed of stainless steel. In the context of cell culture, it may also refer to a device or system made to grow cells or tissues. These tools are being created for use in biochemical and biological process engineering as well as tissue engineering.

A bioreactor can be characterised as batch, fed batch, or continuous depending on how it operates (e.g. a continuous stirred-tank reactor model). The chemostat is a type of continuous bioreactor. Since the organisms won't be washed away with the reactor effluent, immobilisation is advantageous for continuously operating processes, but its application is scale-limited because the bacteria are only found on the vessel's surfaces.

Design

The field of biochemical/bioprocess engineering studies the comparatively difficult engineering task of bioreactor design. The microorganisms or cells can carry out their intended job with little impurity formation when the conditions are ideal. The temperature, nutrient concentrations, pH, and dissolved gases (particularly oxygen for aerobic fermentations) inside the bioreactor all have an impact on the growth and productivity of the organisms. A cooling jacket, coils, or both are used to keep the temperature of the fermenting medium constant. The use of external heat exchangers may be necessary for fermentations that are particularly exothermic. In a fed-batch system, nutrients can either be charged into the reactor at the start of fermentation or added constantly

to the fermenter. Depending on the kind of fermentation, the pH of the medium is assessed and slightly acidic or basic adjustments are made. Reactant gases, particularly oxygen, must be introduced to the fermentation for aerobic (and some anaerobic) fermentations. Since water (the primary component of almost all fermentation media) is relatively insoluble in oxygen, air (or pure oxygen) must be continuously introduced. In addition to mixing the fermentation medium, the action of the rising bubbles "strips" away waste gases like carbon dioxide. Bioreactors are frequently pressured in practise, which improves the solubility of oxygen in water. The best oxygen transfer is occasionally the rate-limiting phase in an aerobic process. In heated fermentation broths, oxygen is considerably less soluble in water and is relatively rare in air (20.95%). Agitation, which is required to combine nutrients and maintain the homogeneity of the fermentation, typically aids oxygen transmission. Air bubbles are dispersed throughout the vessel using agitators that disperse gas [4-6].

Bioreactor classification

Based on how they operate, the bioreactors have been divided into the four groups listed below.

- Tray bioreactor
- Packed bed bioreactor
- Air pressure pulsation bioreactor
- Intermittent or continuously mixed SSF bioreactors

Discussion

The recent increase in demand for single cell proteins, enzymes, industrial chemicals, biofuel, food, phenolics, feed, and pharmaceutical products (antibiotics, bacterial toxins, immune drugs, and alkaloids) has made SSF technology an essential alternative production method to submerged fermentation (SmF). SSF is becoming more and more popular as a waste management method, with potential uses in bioremediation, detoxification, bioleaching, and biopulping, in addition to the creation of bio-active products of commercial interest. As a result of the technique's widespread use and operational advantage over SmF, significant research contributions have been made that will eventually improve reactor design, operation, and scale-up strategies. Despite advancements, the greatest obstacle to the industrialisation of the SSF process is still the lack of straightforward, effective, and easily scalable bioreactors that could efficiently address heat build-up, heterogeneity (heat and mass), and function with the highest degree of sterility. This is most likely caused by the absence of three things: an effective bioreactor design, mathematical models that accurately describe the transport and kinetic processes at micro- and macro-scales, and strategies for online process monitoring and control. There have been reports of a few bioreactor systems in recent years that have at least partially addressed these difficulties for a particular application, but there is still a great deal of room for improvement to address a wide range of biotechnological applications [7-10].

SSF bioreactors have been divided into four types in this review based on how they operate. With an emphasis on enzyme production, the description under each category starts with an introduction of the reactor type and highlights of recent case studies. The case studies offer a comprehensive look at reactor layout, how operating conditions affect process productivity, and advantages and disadvantages. Mathematical models are effective tools that can help with bioprocess optimization, offer recommendations for scale-up, and ease control and automation of bioreactors. For instance, models might be included into control strategies (such as model predictive control or PID control), and the resulting control algorithms would enable automation and control, so greatly enhancing the performance of the bioreactor. To address constraints, talk about scale-up options, and encourage more collaboration between biologists and engineers, a few modelling works have been revisited and quoted at the end of each category. Model assumptions and solution methods, however, are not covered in detail and are instead covered in the publications cited above. Table 2 provides examples of SSF bioreactors that have recently been used to produce enzymes, while Table 3 lists instances of SSF bioreactors that have recently been used to produce spores, antibiotics, pigments, chemicals, and other things.

Conclusion

SSF bioreactors have undergone significant improvement and modification over time in an effort to increase productivity and the commercial viability of SSF processes. It entails the creation and investigation of novel procedures that make use of various engineering instruments to produce the desired results. SSF can advance in industrial standardisation by making continuous improvements and applying logical engineering techniques. the bioreactors discussed earlier.

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