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Design of a batch stirred fermenter for ethanol production

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Abstract

This paper addresses the batch stirred bioreactor design for ethanol production with yeasts Saccharomyces cerevisiae under anaerobic conditions carried out to improve the performance of the fermentation process. A large, appropriate – sized fermenter is supposed 70 m^3. The operating volume is 52,5 m^3. Batch fermentation was perform with 200 g/l glucose concentration. Fermentation time, is 11,4 hours with ethanol stripping 69,1 $g.l^{-1}$ and 12 hours 75,9 $g.l^{-1}$ without stripping. Computing is stopped when glucose alteration obtain 97 percent. The kinetic constants (K_s, K_p, μ_{max}) of batch fermentation were 2,0 $kg.m^{-3}$, 97,9 $kg.m^{-3}$, 0,476 h^{-1} respectively. Output per a batch is 3 623 kg and a single fermenter can produce 514 batches per year. From it follows that the year vintage is close to the actual 1 862 222 kg. Therefore, the number of 70 m^3 fermenters required 4 bioreactor. Whole heat exchange and heat surface area estimated 338437 J/s and 40 m^2 respectively. The maximum yield of biomass on substrate ($Y_{X/S}$) and the maximum yield of product on substrate ($Y_{P/S}$) in batch fermentation were 82 % and 35,5 % respectively. The present research has shown that high sugar concentration (200 g/l) in the batch stirred bioreactor was successfully converted to ethanol. The achieved results in batch stirred bioreactor with high substrate concentration are promising for scale up operation. The proposed model can be used to design a larger scale batch stirred bioreactor for production of high ethanol concentration.

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Keywords: batch stirred bioreactor design; metabolic processes; bioreactor scale-up

1. Introduction

Biochemical engineering is concerned with conducting biological processes on an industrial scale. This area links biological sciences (genetics, microbiology, animal cell culture, molecular biology, biochemistry, embryology, cell biology, enzyme technology) and engineering sciences such as chemical and reaction engineering. The role of biochemical engineering has become more important in recent years due to the dramatic developments of biotechnology. Biotechnology can be defined as “Commercial techniques that use living organisms, or substances from those organisms, to make or modify a product, including techniques used for the improvement of the characteristics of economically important plants and animals and for the development of microorganisms to act on the environment [1]. The numerous applications of the biotechnology are mainly in areas of pharmaceuticals (antibiotics, antigens, etc.), animal and plant agriculture (higher – yielding food animals, herbicides, insecticides, etc), specialty chemicals (amino acids, enzymes, vitamins, etc.), environmental applications (mineral leaching, toxic waste degradation, etc.), commodity chemicals (acetic acid, ethanol, citric acid, etc.) and bioelectronics (biosensors, biochips). Biological processes have advantages and disadvantages over the traditional chemical processes. The major advantages are mild reaction condition (typically room temperature, atmospheric pressure, fairly neutral medium pH, etc.) specificity (enzyme – highly specific catalyst), effectiveness (enzyme-catalyzed reaction is usually much faster than non-biological catalysts and

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selectively produced the desired product), renewable resources (biomass provides both carbon skeletons and energy required for synthesis), recombinant DNA technology (promises enormous possibilities to improve biological processes). On the other hand disadvantages are as follows: complex product mixtures (cell mass, metabolic products, no conversed original nutrients), dilute aqueous environments (product separation is very expensive), contamination and variability (cells tend to mutate due to the changing environment and may lose some characteristics vital for the success of process). The main biotechnological nodes are pre-treatment processes (e.g. solubilization and hydrolysation of raw materials, sterilization), bio reaction section (bioreactor – the most important and main equipment) and separation section (removal of insoluble, product isolation, purification and polishing). The crown of successful solution of each chemical process is a large scale production at the best economic efficiency.

The submitted diploma work is concentrated on the Design of a batch stirred fermenter for ethanol production and is divided into several parts. Firstly ethanol properties, applications, production and recovery are briefly mentioned. Then the industrial scale batch stirred fermenter design for ethanol production with cells Saccharomyces cerevisiaeis the matter of our concern. Only engineering aspects are taken into account in order to properly model the bioreactor and allow scale-up [2]. Engineering aspects are a combination of metabolic processes that involve stoichiometry, thermodynamics, microbial kinetics and physical processes such as mixing, power consumption, heat transport and mass transport. Finally conclusion summarizes results gained through bioreactor design for ethanol production.

2. Properties, Applications and Microbial Production of Ethanol

2.1. Properties

Ethanol (ethyl alcohol) is a clear colorless liquid with a characteristic agreeable odor. In dilute aqueous solution it has a somewhat sweet flavor but in more concentrated solutions it has a burning taste. Ethanol, CH_3CH_2OH is an alcohol a group of chemical compounds whose molecules contain a hydroxyl group – OH bonded to a carbon atom. Its low freezing point has made it useful as the fluid in thermometers for temperatures below –40°C the freezing point of mercury and for other low-temperature purposes such as for antifreeze in automobile radiators. Ethanol is an alternative energy source. It is an alcohol made by fermenting corn or other similar biomass material. There are three primary ways that ethanol can be used as a transportation fuel [3].

2.2. Ethanol Production Process

There are two basic types of ethanol production plants already alluded to. One is the “wet mill” and the other is the “dry mill”. The wet mill process will soak the grain (corn is the most common so we will use it in our discussion here) until the corn is able to be broken down into its components [4]. At the present time, this product is commercially manufactured via large scale aerobic fed-batch fermentation of selected strains of Saccharomyces cerevisiae [5].

Production of ethanol from biomass requires even more extensive processing to release the polymeric sugars in cellulose and hemicellulose that account for 23 % – 53 % and 20 % – 35 % of plant material, respectively. Cellulose is a beta-linked glucose polymer, whereas hemicellulose is a highly branched chain of xylose and arabinose that also contains glucose, mannose and galactose [6]. Hydrolysis of these carbohydrate polymers is usually accomplished by exposure to acid (contributed either by the biomass or added externally) and by enzymes.

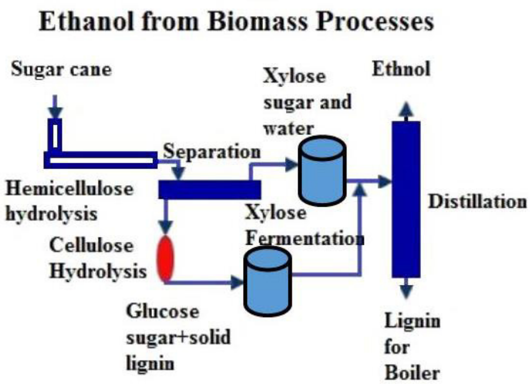

Fig. 1. From biomass process flow sheet for ethanol production [7]