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Bio-production of Ethanol in Packed Bioreactor

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Abstract

A lab-scale packed Biofilm reactor was used for ethanol production by fermentation of sugar solution using a local isolated yeast saccharomyces cerevisia and glutaraldehyde on gelating as a covalent bounding agent. In this study four types of packing in the reactor were used. They are; polypropylene mesh, glass rashig rings, ceramic rashig rings and glass beads. Glucose solutions were used as substrate with four concentrations; (5, 10, 15, 20 g/l). Results show that the ethanol productivity was increase with increasing sugar concentration. Also it was found that polypropylene mesh packing give the highest productivity while glass beads gives the lowest productivity. The experiments were conducted at three temperatures; 30, 35, 40 °C. Highest value of productivity was obtained at 35°C. Finally results show that ethanol productivity increased with increasing the feed ratio of yeast / sugar.

Keywords: Bioreactor, Ethanol, Packed bed, Fermentation

Introduction

From the 18th century to the beginning of this century, major discoveries about the biology and chemistry of fermentation and distillation made it possible to produce cheaper ethanol from variety of organic materials [1, 2].

Production of alcohol in a packed bed bioreactor represents a very promising and challenging opportunity to the engineers and scientist. The continuous process gives a potential and renewable source of energy, due to the abundance of raw materials, in other words, instead of refining petroleum to make hydrocarbon derivatives such as fuels, liberates and chemicals, we can refines biomass (wood ,municipal and industrial wastewater ,agriculture and paper wastes) into fuel[3]. The sugars are raw materials that can be used for making many products such as bioplastics, ethanol, citric acid, and other chemicals [1]. In recent years the demand for energy has increased, resulting in high oil prices. As prices rise, biomass derived products increasingly have economic and environmental advantage over product from fossil fuels [3].

In the last decade bioalcohol has become more and more important as an alternative energy source and chemical fuel stock. This caused an increasing attention to the development of new bioprocess such as "vacuum fermentation "or ethanol production with immobilized microorganisms [4, 5]. The use of cell immobilization has been a common laboratory practice within the last few years as a method to improve the performance and the economics of most fermentation processes [4]. Immobilization offers several potential advantages to fermentation system from the stand point of process engineering; these include ease of handling and cell separation; as well as the obvious potential benefits of increasing cell concentration, which allows continuous bioprocess to be run at high diluting rates.

Many fermentation processes involve microorganisms attached to solid particles (packing). In these systems, the rate of reaction depends on the rate of mass transfer outside or within solid catalyst [6]. The reaction rate depends on the kinetics parameters of the cell or enzyme .packed bed bioreactors are characterized by excellent intimate contact of reacting species. Air and liquid feeds are introduced in a co-current fashion at the lower part of the column. Yeast particles can be added to the reactor through feeding parts at the top of the reactor. Uniform

distribution of the feed liquid and air stream is accomplished through the use of packing in the column. These main characteristics made the use of packed bed configuration extremely suitable for conducting biochemical reactions [7].

The main aim of this research is to analyze and study the process of glucose conversion into ethanol by yeast particles as a function of major operating parameters in a packed bed bioreactor. This process is described by the global reaction:

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2C_2H_5OH + 2CO_2$$

Experimental Work

Reactor system

Fig.(1) shows a schematic diagram of the packed bed reactor ,which is constructed of 10" polyethylene cylinder of 25 cm diameter and 150cm high. The reactor is fitted with a sampling point. Feed streams into the reactor are air and sugar solution .the air stream is uniformly bubbled in the liquid phase via perforated tube, while the feed sugar solution is pumped to the top part of the reactor and distributed through the packing. as a result, gas bubbles coals and escape through the top of the bed, while the liquid flows toward the bottom of the reactor .after several circulating of liquid product through the reactor, the liquid exit from the bottom of the reactor through aside port. The feed sugar solution is kept in a metal tank fitted with an immersion heater to maintain constant temperature through the experiment. Also another immersion heater is positioned in the reactor top to ensure temperature uniformity. During experiments both heaters are set to the same temperature reading .flow rate of liquid through the reactor is achieved by the use of a variable speed Watson marlo pump.

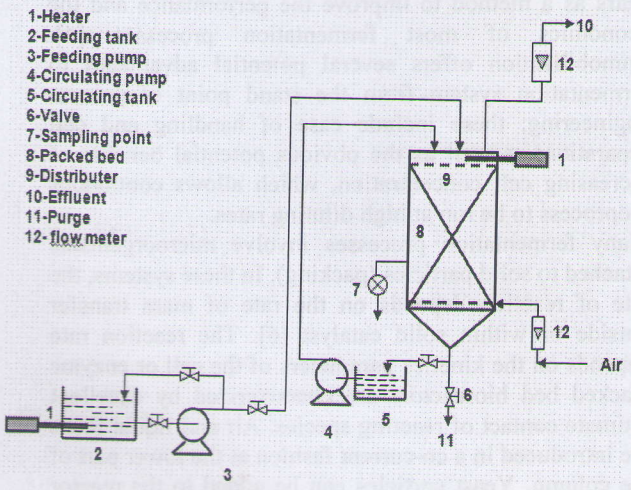

Fig.1 Schematic diagram of the packed bed bioreactor.

Material and Analytical Instruments

Operating of packed bed required preparation of the glucose feed solution of specific concentration. The solution was prepared and mixed in the feed tank, where part of it was pumped through the system to fill the reactor. During the initial preparation period temperatures of both immersion heaters were adjusted and kept constant to reach steady state conditions. This was followed by adjustment of the air feed flow rate .finally ,baker's yeast(saccharomyces cerevisia) solution is prepared in separate flask ,where it was dissolved in two liters of water together with a nutrients, MgCl2 0.3%, (NH4)2SO4 0.6% and NH4CL 0.2%, which necessary to sustain proper growth of the yeast cells [8].

Experimental measurement starts with addition of the yeast solution through the top of the reactor, where cell are attached to the packing by covalent bonding. A period of time (4-10 hr) is allowed for complete contact and bonding before flow of fresh medium is started [9].

After that the feed pump is operated and flow through the reactor is allowed to circulate several times and then exit the reactor via side bottom opening. Liquid samples are taken at constant time interval from the sampling point in the reactor. The samples are divided into three portions which are analyzed separately for yeast, sugar, and ethanol concentrations. The yeast concentration is measured using turbidity meter .an ultra violet spectroscopy analysis of wave length of 949 nm of the filtered solution is used to determine sugar concentration [9]. Similarly, gas chromatography analysis of the filtered solution using thermal conductivity detector is made to obtain ethanol concentration. Experiments were performed at the following conditions;

Sugar feed concentration: 5, 10, 15, 20 g/lit
Yeast initial conc.: 5, 20, 75, 200 g/lit
Air flow 90 lit /hr.
Liquid circulation rate: 4 lit/min
Temperatures: 30, 35, 40 °C
Total hold up 30 lit

Results and Discussion

The following analysis focuses on characterization of the conversion of glucose into ethanol by yeast in a packed bed reactor. To accomplish this task several experiments were performed covering different conditions. The parameters studied in this analysis are; sugar concentration, yeast to sugar feed ratio, reactor temperature and packing type.

Effect of Initial Sugar Concentration

Fig.(2) shows that the productivity of alcohol is increased as the sugar initial concentration increased. This behavior is caused by the higher consumption of sugar at high

values of concentrations. This effect is agreed with the results reported by Farag [10].

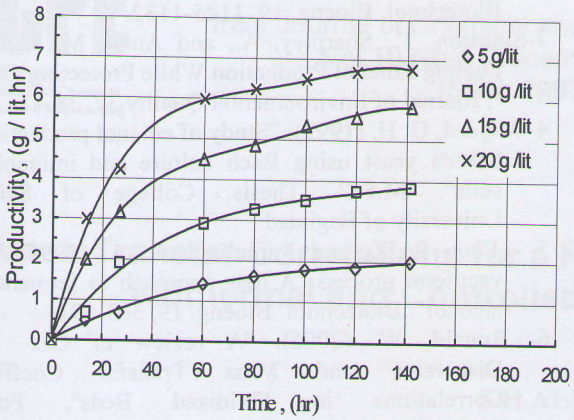

Fig. 2 Effect of sugar concentration on productivity of alcohol. (Yeast/sugar ratio=5, T=35°C, packing: polypropylene mesh)

Effect of Packing Type

Four types of packing were used in this study they are; 1- polypropylene mesh (20 mesh). 2- Ceramic rashig ring (1/4 in). 3-glass rashig ring (1/4 in). 4-glass beads (1cm). Fig.(3) shows that packing type of polypropylene mesh gives higher value of alcohol productivity about 6.1 g/lit.hr, while glass beeds gives the lowest value about 2.2 g/lit.hr . That is because the packing which provide adequate interstitial space for cell entrapment, such as mesh packing, result in faster biomass loading rates. Also the roughness of the packing is a factor as noted in the comparison of the glass and ceramic rashig rings. Although all packing surface were coated with gelatine to assure a monolayer of cells, the rough ceramic materials enable a better coating and provided spaces for subsequent layers of the cell to accumulate.

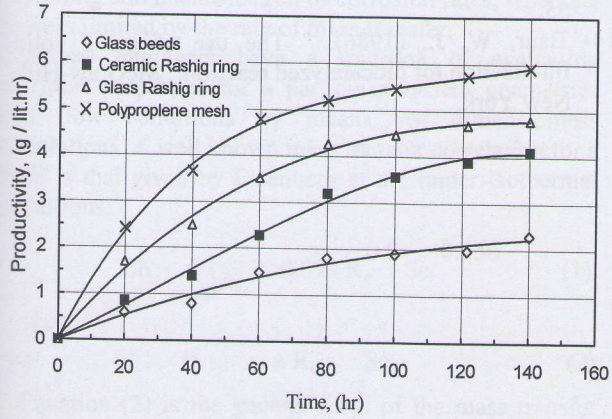

Fig. 3 Effect of packing types on productivity of alcohol.(Yeast concentration=75 g/l, sugar concentration=15 g/l. T=35°C)

Effect of feed ratio concentration of yeast / sugar

Transient profiles of alcohol productivity at different yeast to sugar ratios are shown in Fig. (4). At yeast to sugar ratio of 1.0, sugar conversion is low, where the productivity is limited to about 2 g/lit.hr. However, at higher ratio sugar conversion increases drastically and the productivity reaches 5.5 g/lit. hr at ratio of 10. This behavior is caused by the higher consumption rate of increased yeast concentration. Further increase in the ratio at yeast/ sugar from 5 to 10 will not affect the productivity level. The same observation has also been found by the work of the Del Rosario [11] and Boleckner [12]. this behavior may be due to drop in yeast concentration along the packed bed which caused by two mechanism; the first involved formation of excessive foaming at the reactor top which results in carry over of the yeast cell with air bubbles leaving the reactor. The second mechanism is due to the carry over the yeast cells in the exit stream which causes continuous depletion and in turn decreases in the yeast concentration.

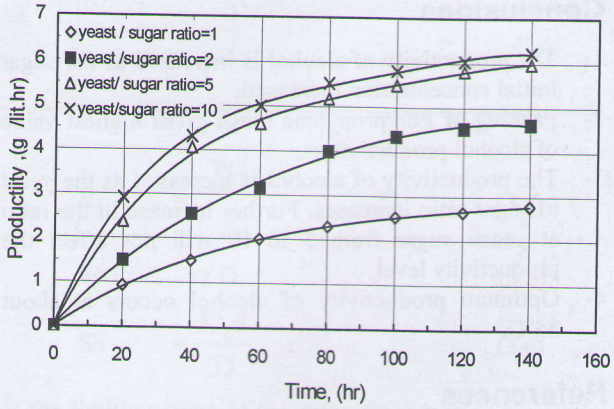

Fig. 4 Effect of yeast to sugar ratio on productivity of alcohol. (Packing: polypropylene mesh, T =35°C)

Effect of temperature

Fig. (5) Shows the effect of temperature upon the action of the yeast on the sugar conversion. the results show that the productivity increases at the temperature increase from 30°C to 35°C but it decrease when the temp increase to 40°C. This is due to the effect of temperature on the activity of the yeast and in turn the rate of glucose conversion. This result is agreed with the results reported by Heping [13] and Baur [14].

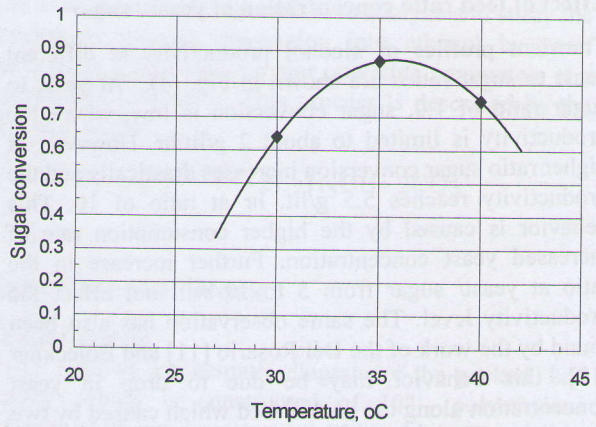

Fig. 6 Effect of Temperature upon sugar conversion. (Yeast concentration=75 g/l, packing: polypropylene mesh.)

Conclusions

1- The productivity of alcohol is increased as the sugar initial concentration increased.
2- Packing of Polypropylene mesh gives highest value of alcohol productivity.
3- The productivity of alcohol is increased as the yeast to sugar ratio increases. Further increase in the ratio at yeast/ sugar from 5 to 10 will not affect the productivity level.
4- Optimum productivity of alcohol occurs at about 35°C.

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