CHAPTER I

INTRODUCTION

Biofuel has emerged as one of the most attractive and promising alternative energy carriers to fossil fuels. Ethanol is an ideal fuel because it is positive environmental impact due to lower toxic and greenhouse gas emission. The production of ethanol by fermentation has received special attention as a consequence of the world energy crisis, which enhanced the interest in renewable energy sources. There is growing interest to find alternate bioresources apart from sugar cane/beet molasses and starchy crops like sweet sorghum, cassava and sweet potato for production of ethanol [1].

Ethanol fermentation by conventional batch suffers from various constrains such as low cell density, nutritional limitation and rather time consuming. Although continuous uses of suspended yeast cells can be used to speed up the process and enhance the cell population, it is more difficult to operate and maintain it free of microbial contamination. Immobilizing yeast cells on suitable support has been suggested as an effective mean for improve production and operational stability. The main advantages in the use of immobilized cells in comparison with suspended cells are the retention in the reactor of higher concentrations of microorganisms, protection of cells against toxic substances and elimination of costly processes of cell recovery and cell recycle. Among the different cell immobilization techniques, entrapment in calcium alginate gel has been one of the most used matrices for whole cell entrapment due to its simplicity and non-toxic character [2]. However, one of the major problems of immobilization by entrapment in calcium alginate gel is diffusion limitations of nutrients and metabolites and gel degradation [2, 3]. Alumina (Al_2O_3) has been reported as good promoters of ethanol fermentation because the electrostatic attraction between Al_2O_3 particles and yeast cells [4, 5]. In our previous study, γ- Al_2O_3 doped alginate gel carrier for *Saccharomyces cerevisiae* M30 were developed and test for batch and repeated batch ethanol fermentation. In repeated batch fermentation, this carrier demonstrates a good potential of

reusability and ethanol production was more stable than suspension cell culture. These result indicated that γ- Al_2O_3 doped alginate gel can be used as a new carrier for the scale up in packed bed reactor for improve productivity and yield [6].

The aim of this work was to study the effect of the carrier characteristics on the ethanol fermentation and investigate the performance of ethanol production using Al_2O_3 doped alginate gel in packed bed reactor. Molasses, by product of sugar industries, is used as a carbon source of the fermentation. The effect of bead diameter, Al_2O_3 concentration and Na-alginate concentration on ethanol fermentation is examined in batch shaking flasks. Subsequently, the suitable procedure from batch was carried out in a vertical packed bed reactor and the results were compared to the batch system.

1.1 Objectives

1. To develop Al_2O_3 doped alginate gel as a carrier for ethanol fermentation.
2. To investigate ethanol fermentation by immobilized cell in Al_2O_3 doped alginate gel carriers in packed bed reactor.

1.2 Expected benefits

1. Invention of high performance immobilization carrier for large scale commercial ethanol fermentation in packed bed reactor.
2. Useful information for a better understanding of immobilized cell technology and performance in packed bed reactor.

1.3 Working scopes

In this study, the immobilized cell system by Al_2O_3 entrapment with alginate gel for ethanol production is carried out in batch and packed bed system. The fermentation systems of *Saccharomyces cerevisiae* M30 for ethanol production are used for the performance evaluation of the carrier system of Al_2O_3 doped alginate gel. The performance index is included productivity, product concentration, production yield and

stability. The optimum condition for ethanol production from our previous study is applied for this study. The working scopes are as follows:

1.3.1 Batch system

- Flocculating yeast strain, *S. cerevisiae* M30 is used as ethanol producer.
- Palm sugar and sugar cane molasses are utilized as carbon and energy source.
- Al_2O_3 and alginate are applied as materials for constructing immobilized cell carriers and the immobilization method are the cell adsorption onto the surface of Al_2O_3 powder and the entrapment of Al_2O_3-cells in alginate matrix.
- The fermentation is carried out in shake flasks culture system at shaking frequency of 150 rpm, temperature of 33 °C and initial sugar concentration of 220 g/l.
- The operating condition is as follows:
  - Bead diameter: 2, 4 and 6 mm
  - Na-alginate concentration: 1.5%, 2.0%, 2.5% and 3.0% w/v
  - Al_2O_3 concentration: 3.3%, 5.0%, 6.7% and 8.3% w/v of alginate

1.3.2 Packed bed system

- Flocculating yeast strain, *S. cerevisiae* M30 is used as ethanol producer.
- Palm sugar and sugar cane molasses are utilized as carbon and energy source.
- The optimum condition for ethanol production from batch system is applied for packed bed reactor.
- The fermentation is carried out in packed bed reactor system with the working volume around 1 liter (Ø = 6 cm and 35 cm height) at temperature of 32 ± 1 °C and initial sugar concentration 220 g/l.
- The operating condition is as follows:
  - Dilution rates: 0.09, 0.16, 0.22 and 0.28 h^{-1}
  - Stability test at the dilution rate of 0.09 h^{-1}