Kinetic Study of Gluconic Acid Batch Fermentation by *Aspergillus niger*

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***Abstract*—** Gluconic acid is one of interesting chemical products in industries such as detergents, leather, photographic, textile, and especially in food and pharmaceutical industries. Fermentation is an advantageous process to produce gluconic acid. Mathematical modeling is important in the design and operation of fermentation process. In fact, kinetic data must be available for modeling. The kinetic parameters of gluconic acid production by *Aspergillus niger* in batch culture was studied in this research at initial substrate concentration of 150, 200 and 250 g/l. The kinetic models used were logistic equation for growth, Luedeking-Piret equation for gluconic acid formation, and Luedeking-Piret-like equation for glucose consumption. The Kinetic parameters in the model were obtained by minimizing non linear least squares curve fitting.

***Keywords*—** Aspergillus niger, fermentation, gluconic acid, kinetic

I. Introduction

Gluconic acid, a mild organic acid, is an interesting material widely used in pharmaceutical, food, feed, detergent, textile, leather, photographic and concrete industries. There are several methods to produce gluconic acid including chemical, electrochemical, biochemical and bioelectrochemical [1]. Fermentation process has many advantages for producing organic acids including its low cost, mild reaction conditions, and use of renewable resources for the raw material. Microbial species such as *Aspergillus niger*, and *Gluconobacter oxydans* have been utilized in many researches of gluconic acid fermentation [1],[2],[3],[5],[6].

Gluconic acid production by *Aspergillus niger* is an aerobic fermentation with a high oxygen demand. The overall mechanism to describe the process in the gluconic acid fermentation is as follow [3]:

Cell growth: $C_6H_{12}O_6 + O_2 + \text{biomass} \rightarrow \text{Biomass}$

Glucose oxidation : $C_6H_{12}O_6 + O_2 \xrightarrow{GOD} C_6H_{10}O_6 + H_2O_2$

Gluconolactone hydrolysis: $C_6H_{10}O_6 + H_2O \rightarrow C_6H_{12}O_7$ (Gluconic Acid)

H_2O_2 decomposition: $H_2O_2 \xrightarrow{catalase} 2H_2O + O_2$

Firstly, glucose is oxidized into glucono-δ-lactone in the presence of enzyme glucose oxidase (GOD) produced by *Aspergillus niger*. Gluconic acid is formed from the hydrolysis of glucono-δ-lactone. The hydrogen peroxide produced from glucose oxidation is decomposed into water and oxygen by the presence of catalase enzyme produced by *Aspergillus niger*. In the production of gluconic acid, oxygen is used for bioconversion of glucose into gluconic acid, as well as mycelial respiration. Hence oxygen is one of the main direct substrate of the bioconversion.

The design and operation of a fermenter, in which biochemical transformation occurs in a controlled condition, needs the understanding complex biological reactions. This requires mathematical modeling to describe the process more simply but still represent the process quite well. Fermentation kinetic data are absolutely needed in developing the mathematical model. The purpose of this research is to obtain the kinetic parameters of gluconic acid production from glucose by *Aspergillus niger* FNCC 6098. The benefit of this research is that the kinetic parameters obtained can be used in the fermenter modeling which is eventually useful in the fermenter design and optimization.

This paper is organized as follows. Section 2 presents kinetic models for batch fermentation of glucose by *Aspergillus niger* to produce gluconic acid. Section 3 presents material and method to obtain batch fermentation data. Section 4 discuss the fermentation result and provide the calculated kinetic parameters. Finally, some conclusions are given in Section 5.

II. Kinetic Model

Fermentation models consist of two classes: structured models, which consider intracellular metabolic pathway, and unstructured models, which assume biomass as one variable. Unstructured models are much easier to use and therefore, it is used in this research. The cell growth model used in this research is logistic equation which can be written as follow:

$$\frac{dX}{dt} = \mu_m X\left(1 - \frac{X}{Xm}\right) \quad (1)$$

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