Modified Kinetic Model For Ethanol Fermentation From Oil Palm Trunk Sap

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Abstract. This paper extended and improved the current mathematical model for the batch fermentation process. By varying the initial cell concentration, the model predicted the profile of cell growth and ethanol production throughout the fermentation process. The kinetic models take into account the following factors which are substrate limitation, substrate inhibition, product inhibition, and cell death simultaneously for the production of ethanol from the OPT sap. The mathematical model was formulated using a set of ordinary differential equations to describe the profiles of sugar, cell and ethanol during the fermentation process. The set of equations were solved numerically by using the 4th order Runge-Kutta method. The result showed that the rate of sugar utilization and ethanol production are depended on the initial cell concentration. For low initial cell concentration, the conversion rate was increased gradually. On the other hand, for high initial cell concentration, sugar conversion to ethanol was augmented sharply and depleted after a short duration due to the access of the ethanol, which might inhibit the cell growth. The combined consideration of the substrate limitation and inhibition, growth and non-growth associated product formation, product inhibition and cell death rate increased the accuracy of the model by means of rRMSE. The proposed model has better predictive capabilities. This approach has increased our understanding of the theory behind the OPT sap fermentation.
Keywords: Kinetic model, initial cell concentration, fermentation, bio-ethanol, oil palm trunk sap

INTRODUCTION

Ethanol is an alternative fuel which supports a sustainable economy by reducing the use of petroleum, carbon dioxide (CO2) accumulation particulate matter and nitrous/nitric oxide (NOx) emission from combustion (Srimachai et al., 2015). However, the chemical properties of biomass material and the reaction kinetics for the degradation of biomass is not well understood (Jamil & Wang, 2016). For this reason, to understand, to oper ate, to optimize and to control the ethanol fermentation process, complete knowledge of dynamic behaviour is required (Oliveira et al., 2016).

The fermentation step is an essential part of the biomass to the bio-ethanol conversion process. An appropriate kinetic model of ethanol fermentation would be a powerful instrument for increasing fermentation efficiency and process optimization (Liu & Li, 2014). The amount of the initial cell concentration is a crucial well-known process parameter in microbial fermentation (Papagianni & MooYoung, 2002; Rao et al., 2004). The impact of the initial cell concentration in ethanol formation has been very little studied and not in an easily predictable way. (Eker & Sarp, 2017) studied the analytical effects of initial sugar and biomass concentrations of H2 gas production. Some of the researchers showed that a higher level of inoculum resulted in a higher yield of ethanol (Carrau et al., 2010; Mateo et al., 2001). However, different overall behaviour was acknowledged to cell strain (Carrau et al., 2008) but the kinetic behaviour of different ratios of initial cell concentrations was not taken into account. Mathematical modelling is a cognitive tool used to describe the cellular response of microbial cells to changes in nutrient inputs and other environmental factors (Tijani et al., 2018). Currently, there exists no accurate model that simultaneously incorporates the essential factors such as substrate limitation and inhibition, growth and non-growth associated product formation, product inhibition and cell death with the combined effect of culture parameter temperature and initial cell concentration.

The fundamental model for microbial growth activities was proposed by Monod (Monod, 1949) and the kinetic model accounts only the factor of substrate limitation through an equation called as Monods equation. On the other hand, the models of Hinshelwood (1946), Hoppe and Hansford (1982) account only for ethanol inhibition. Other than those factors, Aiba and Shoda (1969) includes also product inhibition in their model. Ghaly and ElTaweel (1994) were concerned about substrate limitation, substrate inhibition, product inhibition from cheese whey by the yeast Candida pseudo-tropicalis. However, all of these models were not concerned about the effect of some culture parameters such as temperature, pH and inoculum size.

Some of the recent kinetic models in oenology (the study of wine) have been proposed by (Jin et al., 2012); (Kelkar & Dolan, 2012); (Mohamad et al., 2016) and (Oliveira et al., 2016) which are unstructured kinetic models. Specifically, Kelkar and Dolan (2012) studied the mutual effect of primary nitrogen concentration and temperature on fermentation and concluded that yeast cell growth is controlled by nitrogen and sugar concentration. Jin et al. (2012) applied the Hinshelwood model to explained the roles of preliminary reducing

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