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Upgraded Seawater-Alkaline Pre-Treatment of Lignocellulosic Biomass for Bio-Methane Production

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Abstract

The presence of lignin in lignocellulosic biomass leads to a protective barrier that prevents plant cell destruction by fungi and bacteria for conversion to bio-methane gas. Therefore, the aim of this study was to evaluate the effects of upgraded seawater with NaOH, $NaCO_2$ and palm kernel ash (PKA) to produce the best alkaline solution in order to convert lignin and increase the fermentable sugars content in oil palm empty fruit bunch (OPEFB). In this study, alkaline pretreatment of EFB is carried out at room temperature using different concentration of alkaline solution which are 5%, 10%, 15% and 20% w/v of chemical (NaOH, Na_2CO_3 and PKA) and seawater for 48 hours. OPEFB in a size of 0.5 – 1.0 mm was soaked into the NaOH and Na_2CO_3 solution for 48 hours at room temperature. The surface morphology analysis of lignocellulosic biomass after pre-treatment were done by using scanning electron microscopic (SEM). Analysis of delignification using Kappa Number showed that the highest percentage of delignification were 86.6%, 69.8% and 58.8% by using concentration of 5% NaOH, 15% Na_2CO_3 and 20% PKSA, respectively. Morphological change on OPEFB was found when silica was cracks and creating a pore during pre-treatment. This significant increase in reducing sugar yields due to removal of silica and lignin. The results of FTIR showed lignocellulose were removed effectively from EFB fiber. This observation also supported FTIR and SEM analysis that showed significant changes in lignin structure throughout the pre-treatment process. Interestingly, with respect to all factors, upgraded seawater with NaOH demonstrated the highest delignification and fermentable sugar production.

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Keywords: Alkaline pretreatment; Delignification; Fermentable sugar; Lignocellulosic biomass

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1. Introduction

Recently, the demand for renewable fuel sources continues to grow due to diminishing supply of fossil fuel and growing concerns about environmental issues. Burning of fossil fuels such as coal and oil release carbon dioxide (CO_2) which is a major cause of global warming. The utilization of biomass as an energy source offers a way to reduce both consumption of crude oil and environmental pollution. Biomass refers to non-fossilized and biodegradable organic material that originating from plants, animals or microorganisms [1].

Oil palm wastes are one of the examples of high-potential biomass energy resources available in Malaysia as the country is the second largest palm oil producer and exporter, currently lead by Indonesia. Milling process of palm oil extraction generates a large amount of solid waste in the form of empty fruit bunch fiber (EPFB). Therefore, EPFB as lignocellulose has been identified as a new alternative for conversion into renewable energy or value-added products [2, 3].

EFB fiber contains a relatively high percentage of hemicellulose and lignin per gram of biomass. The crystallize structure of cellulose, its accessible surface area and protection by lignin and hemicellulose, degree of cellulose polymerization, and degree of acetylation of hemicelluloses are the main factors considered as affecting delignification [4].

Alkaline pretreatment has potential advantage compared to other pretreatment process including low operation cost. Besides, this pretreatment was favored since lower temperatures and pressures could be employed compared to other pretreatment technologies. It can be carried out at ambient conditions and is generally more effective on agricultural residues and herbaceous crops [5]. Therefore, the chemical methods using alkaline solution could degrade the lignocellulosic structures and disassemble the polymers chains, synergistically increase the accessible surface area of EFB to optimize production of important chemicals that rich in hydrocarbons. Chemical that is commonly used is sodium hydroxide (NaOH), hydrogen peroxide (H_2O_2) and calcium hydroxide. This research will introduce the usage of sodium carbonate (Na_2CO_3) and palm kernel shell ash (PKSA) as an alternative chemicals for EFB delignification beside NaOH. According to Chang *et. al.* [6], the carbonate can then be converted to lime using established lime kiln technology.

Sodium carbonate is also used as a relatively strong base in various settings. It acts as an alkali because when dissolved in water, it dissociates into the weak acid: carbonic acid and the strong alkali; sodium hydroxide. This gives sodium carbonate in solution the ability to attack metals such as aluminum with the release of hydrogen gas [7]. Palm kernel shell ash was the residual waste remain after the burning of palm kernel shell. The PKS was used to powered up the boiler and provide heat energy for the continuous process at the palm oil mill. Consist of multiple components such as silicate, aluminum trioxide, and ferum (III) oxide, it is composed of base compound and the properties could be benefits to produce weak alkaline solution.

The objective of this study is to investigate different concentration of chemicals in delignification of EFB. The degree of delignification is monitored based on the amount of lignin after the pretreatment and also by the increasing the accessible surface area.

2. Material and methods

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