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Pretreatment of Lignocellulose on Palm Oil Stems for Bioethanol Production

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ABSTRACT

The second generation bioethanol production (G2) is made from cellulose and hemicellulose. This research aim was to determine the concentration of 1-3% NaOH solution and the best immersion time in the pre-treatment process in the manufacture of bioethanol from lignocellulose raw materials of palm oil stems. NaOH concentration (1%, 2% and 3%) and immersion time of oil palm lignocellulose stem had no significant effect on bioethanol levels. The bioethanol levels produced were still very good. The best treatment was X4.

Introduction

World energy from fossil materials has decreased in line with population growth and economic growth. The availability of world energy from fossils is getting fewer hence fossil fuels are increasingly scarce, and the price has increased significantly. On the other hand, the increasing development of fossil fuel industries causes environmental impacts and global warming because it produces CO_2 gas emissions. The solution to the fossil energy crisis is to look for new and renewable alternative energy materials such as bioethanol. Apart from being renewable, bioethanol can also reduce emissions due to the disposal of greenhouse gases hence it can reduce the impact of global warming [1].

The Second generation (G2) bioethanol production is made from matters containing cellulose and hemicellulose. Currently, bioethanol production is sourced from G1 originating from food; the development of bioethanol from foods can cause problems in the future. Therefore, it is necessary to develop bioethanol from non-food ingredients, namely from the Second Generation in the form of lignocellulose. Lignocellulose is biomass derived from plants with the main components of cellulose, hemicellulose and lignin. All three have complex bonds which are the basic ingredients for building plant cell walls [2]

The source of lignocellulose in Indonesia comes from agricultural, livestock and plantations biomass. Palm oil biomass; in the form of oil palm empty fruit bunches, shells, midribs and stems which are originating from plantations are having great potential because considering the area of oil palm plantations according to data from the Directorate General of Plantation, it is around 10.5 million hectares. Oil palm stem contains cellulose, hemicellulose and lignin, which has the potential to be used as a raw material for making bioethanol

Oil palm stem has cellulose content of 50.78 grams/100 grams, hemicellulose of 30.36 grams/100 grams and lignin of 17.87 grams/100 grams. Bioethanol manufacture from lignocellulose can be done by stages namely pre-treatment, hydrolysis, fermentation and purification. The pretreatment process aim was for delignification. The hydrolysis process can use dilute acids such as sulfuric acid, whereas fermentation is generally carried out using bread yeast (*Saccharomyces cerevisiae*), and purification processes aim was to purify the bioethanol produced [4]

This research aim was to determine the concentration of 1-3% Na OH solution and the best immersion time in the pre-treatment process in the manufacture of bioethanol from lignocellulose raw materials of palm oil stems.

Materials and Methods

1. Time and Place

The research was carried out at the Laboratory of Quality STIPER-Agrobisnis Perkebunan and the Laboratory of Organic Chemistry Faculty of Mathematics and Sciences, University of Sumatera Utara, Indonesia from May to August 2017.

2. Research Design

The research used Completely Randomized Factorial Designs, consisting of 2 factors, namely the concentration of NaOH solution and the immersion time of oil palm trunks.The combination of treatments was as follows: X1 (1% NaOH, 3 Hours), X2 (1% NaOH, 5 Hours, X3 (1% NaOH, 8 Hours), X4 (2% NaOH, 3 Hours), X5 (2% NaOH, 5 Hours), X6 (2% NaOH, 8 Hours), X7 (3% NaOH, 3 Hours), X8 (3% NaOH, 5 Hours), X9 (3% NaOH, 8 Hours), each treatment has three replications.

3. Materials and Equipment

The material used in this research was palm oil stem, 1%, 2% and 3% NaOH solution, aquades, HCl, Urea and yeast.The tools used were 150, 180 and 250 sieve, water bath, analytic balance, oven, thermometer, hammer mill and supporting equipment in the laboratory.

4. Stages of Research

a. Preparation of raw materials

The raw material used in this research was palm oil stem, ± 4 years old plant life, taken from the plantations of Matapao with the type of tenera. The part of the plant which was taken

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was the stem, about 2 meters from the stump. The stump was grated using grated coconut, squeezed to reduce the moisture content of the material, then dried under the sun for 5 days. After drying, the raw material was further mashed and sifted.

b. Pre-treatment

Oil palm stems which have become powder were filtered using a filter then the filtered powder was weighed as much as 50 grams per sample.The sample was put into 500 ml Erlenmeyer, 1%, 2% and 3% NaOH solution were added according to the treatment accompanied by hot plate heating with a temperature of 80°C, 90^{o}C and 100^{o}C, with 3 hours, 5 hours and 8 hours heating time.The sample was filtered using gauze, the results were in the form of thick powder and water, the thick powder was rinsed with distilled water (aquades) until pH 7, the pH is measured using pH paper.

c. Hydrolysis

The neutral sample then added with 12% of HCl to reach pH 5, furthermore, the hydrolysis solution was filtered, and the filtrate was taken for the fermentation process.

d. Fermentation

The filtrate from hydrolysis was put into a container and was added bread yeast and urea as much as 0.2 gram to accelerate the fermentation process. Fermentation was carried out for 7 days then distillation was carried out.

e. Distillation

Distillation is a method of separating chemicals based on differences in speed or ease of evaporation (volatility) materials.In distillation, the mixture of substances is boiled so that it evaporates, and this vapor is then cooled back into liquid form.The distillation results were inserted into 2 neck-flask which was heated on top of the hotplate at a temperature of 78 - 80^{o}C to produce alcohol obtained from the of oil palm stem

Result and Discussion

1. Characterization of bioethanol

Table 1.Characterization of bioethanol.

Treatment	T	Area [pA*]	V	BC	A
	Min		L	%	%
X_1	2.413	102.0839	1	67.29	71.12
	2.278	859.5872	1	68.49	
	2.235	819.6341	1	77.59	
X_2	2.350	100.0873	1	70.45	70.20
	2.325	849.4827	1	70.14	
	2.412	829.3476	1	70.10	
X_3	2.342	104.4567	1	69.87	65.85
	2.253	101.8975	1	67.23	
	2.397	987.7586	1	60.45	
X_4	2.397	102.0839	1	77.59	77.25
	2.321	102.0132	1	77.11	
	2.315	102.0131	1	77.04	
X_5	2.412	796.8552	1	72.45	71.83
	2.523	796.2462	1	71.31	
	2.621	796.3448	1	71.72	
X_6	2.413	793.4659	1	70.50	70.56
	2.415	793.5659	1	70.62	
	2.437	793.5352	1	70.56	
X_7	2.413	102.0839	1	77.59	77.18
	2.301	102.7148	1	77.00	
	2.221	102.70551	1	76.95	
X_8	2.412	796.8552	1	76.60	74.26
	2.312	778.7430	1	76.01	
	2.001	690.5662	1	70.17	
X_9	2.412	793.4659	1	70.01	69.31
	2.245	699.7653	1	69.23	
	2.413	102.0839	1	77.59	

Note:T=time references; V=volume distillate; BC=bioethanol content ; A = the average of bioethanol content

Bioethanol characteristics produced through the immersion treatment of oil palm stems with NaOH with different immersion time were presented in Table 1.

Bioethanol content in all treatments were very good and the best bioethanol content was shown in the X4 treatment (2% NaOH, 3 Hours), i.e. 77.25%, the yeast's maximum ethanol yield was 0.51 g ethanol / g glucose or 51% which is calculated through a stoichiometric reaction [5]. In anaerobic conditions, yeast metabolizes by overhauling glucose into ethanol through the Embden-Meyerhof (EMP) pathway. The overall fermentation reaction involves the production of each 2 moles of ethanol, but the results achieved in practical fermentation usually do not exceed 90-95% of the yield theory [6].

Ethanol is produced from sugar which is the result of yeast cell fermentation activity. The pretreatment process in this research took place in the span of 3, 5 and 8 hours, with the type of yeast used was Saccharomyces cerevisiae. The zimase enzyme is a sucrose breaking enzyme into monosaccharides (glucose and fructose). Furthermore, enzyme interface converts glucose into ethanol [7]

2. Effect of Time and NaOH Concentration on Bioethanol Content

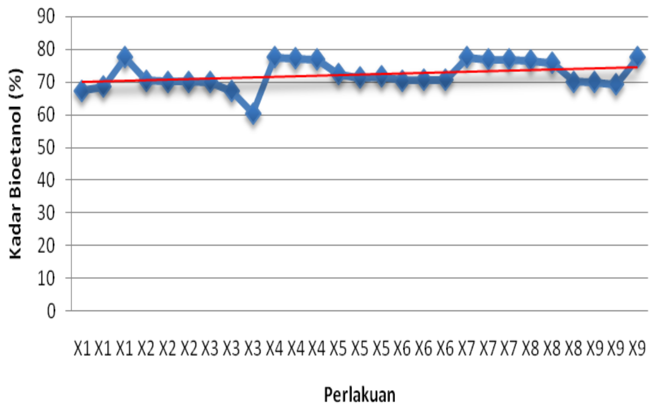
Lignocellulose structure, composed of cellulose and lignin matrix which binds through the hemicellulose chain, must be broken down so that it is more easily attacked by enzymes during the hydrolysis process. Lignocellulose of palm oil stem has three components, namely hemicellulose, lignin and cellulose. The three components are arranged in a solid and strong unit hence to get one of the three components a process must be carried out that is able to selectively separate and split each component. The process is a pretreatment which in this research uses a base method using NaOH solution [8].

The pretreatment process is needed to remove lignin and increase the porosity of cellulose in order to increase the conversion of cellulose to glucose in the hydrolysis process [8]. Immersion in NaOH solution and in a long duration was done to reduce the amount of lignin and increase cellulose porosity so that it simplifies the process of hydrolyzing cellulose into simple glucose.

To see the effect of immersion time and NaOH concentration on bioethanol content of oil palm stems can be shown in the following tables and graphs:

Table 2.Variance of Effects on Concentration and Time

Table 2. Variance of Effects on Concentration and Time					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	53.388	1	53.388	3.073	.092
Residual	434.323	25	17.373		
Total	487.711	26			



Based on Table 2, the concentration of NaOH and the immersion time of lignocellulosic oil palm stems significantly affect bioethanol content. However, in Figure 1 it can be seen that the glucose content obtained in the lignocellulose pretreatment process with varying time and NaOH concentrations generally fluctuate. The acquisition of bioethanol tends to decrease at 3% NaOH concentration with an immersion time of 8 hours (65.85%) and increases at NaOH concentration of 1% immersion time 3 hours (77.25%). The decrease in bioethanol content was also seen in the concentration of 3% NaOH with an immersion time of 8 hours (69.31%). Fluctuations and decreases in bioethanol content were seen in this research. This can be caused by the instability of operating conditions where the temperature of the hydrolysis tank is constantly changing so that the desired constant temperature is difficult to achieve every minute [9]. In addition, the decrease in bioethanol from several treatments can be caused by the bioethanol produced being converted to acetic acid because of the bioethanol oxidation reaction [10,11]

Conclusion

Na OH concentration (1%, 2% and 3%) and the time of immersion of oil palm stem lignocellulose in the pretreatment process had no significant effect on the bioethanol content obtained.All treatments showed that the bioethanol content produced were still very good.The best treatment in the process of lignocellulose oil palm stem pretreatment to produce bioethanol was X4 where 2% Na OH concentration and 3-hour immersion time, namely the average bioethanol level produced 77, 25%.

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