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Research Article

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The mechanical pretreatment to increase biomass and bioethanol production from rice straw

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ABSTRACT

Rice straw is one of the very abundant lignocellulosic waste and does not interfere with the availability of food. Lignocellulose can be broken down into simple sugars and fermented into bioethanol with the help of yeast. Lignin which is very strong in lignocellulosic materials resulting lignocellulose breakdown cannot occur directly and require pretreatment to destroy the lignin. Mechanical pretreatment is one of the methods that can be developed in the hydrolysis of lignocellulosic compounds using Liquid Hot Water methods. The research was conducted by comparing the 3 variations of mechanical pretreatment (regular heating, heating with additional heating with pressure and high pressure) and 3 variations of the operating time (1 hour, 2 hours and 3 hours). Hydrolyzate obtained, fermented using yeast Saccharomyces cereviceae with concentration of 3%, 5% and 10% for 72 hours. The purpose of this study was to obtain a variety of methods, mechanical pretreatment time and the best yeast concentration in breaking the bonds of lignocellulose. The results showed that the best mechanical pretreatment is heating under high pressure within 2 hours of operating with ethanol content of 9.35% and 1.47 g biomass. The concentration of yeast to get the highest biomass and ethanol was 5%.

Keywords: straw, mechanical pretreatment, bioethanol, Liquid Hot Water, *Saccharomyces cerevisiae*

INTRODUCTION

Rice straw is the largest agricultural waste in Indonesia and there are almost all provinces in Indonesia. Kim and Dale in his study of 2004 states that every ton of dry rice capable of producing 1.4 tons of hay and straw yield per kilo of 0.28 L of bioethanol [1]. Chemically straw containing lignocellulose large enough, which is about 39% so that it can be used for processing into ethanol through fermentation with the help of yeast [2].

Materials containing lignocellulosic materials can theoretically be broken down into simple sugars and fermentation techniques can be converted into bioetnol. However Cellulose and hemicellulose is bound by very strong protected by lignin that can not be broken down into simple sugars. To that end, it is necessary to initial treatment (pretreatment) to destroy lignin and cellulose to change the crystal structure of amorphous [3].

Pretreatment process aims to break down and eliminate lignin and hemicellulose by damaging the crystal structure of cellulose. Damage cellulose crystal arrangement can facilitate the disintegration of cellulose into glucose and break down hemicellulose into simple sugars [4]. Compounds - compounds this simple sugars can then be fermented with the help of microorganisms to produce bioethanol [5].

Various methods of hydrolysis has been used to break down the materials lignosellulosa. Acid hydrolysis and enzymatic hydrolysis are two main methods are the most widely used mainly for agricultural waste materials [6]. Enzymatic hydrolysis, yielding ethanol better than acid hydrolysis, but this method requires a very expensive cost and complexity in the process [7].

Usually acid hydrolysis using a weak acid levels such as H_2SO_4 or HCl to a concentration of 2-5% [6]. Acid hydrolysis can be carried out without any prior pretreatment process and until now the method is still preserved. Acid hydrolysis require higher precision, because the acid concentration and temperature greatly affect the formation of toxic compounds that interfere with the process of fermentation. Higher temperatures, will facilitate the decomposition of simple sugars and lignin [3,6].

One alternative pretreatment method that can be considered in the hydrolysis of lignocellulosic compounds is a method Liquid Hot Water [8]. This method is able to dissolve most of the hemicellulose and reducing sugar degradation [9]. This method works parse structure through hydrothermal lignin, cellulose and hemicellulose while going dissolved in water. As a result of this incident, the cellulose structure will be more permeable to proceed to the next process stage. Liquid Hot Water Method is a simple method that only requires mechanical treatment or physics without the addition of catalysts or other special treatment. This method does not cause corrosion on the equipment used and do not produce residues that are inhibitors, so this method is very promising [10].

In this research, three variations of pretreatment meknik ie regular heating, heating with additional pressure and heating with high pressure using Liquid Hot Water (LHW) methods. Operational time for each variation is 1 hour, 2 hours and 3 hours. Hydrolyzate obtained for each mechanical pretreatment variation subsequently fermented with yeast *Saccharomyces cereviceae* 5% for 72 hours. The goal of this research is to gain variation and the best time of mechanical pretreatment to produce bioethanol. Parameters measured were biomass and bioethanol highest levels obtained after fermentation.

EXPERIMENTAL SECTION

Materials and Devices Research

The main ingredient in the form of rice straw fermentation obtained in the area of paddies in the area KamangAgam District of West Sumatra. Other materials used include 10% H_2SO_4, NaOH (E.Merck), ethanol pa (E.Merck), Nutrient Broth, the yeast *Saccharomyces cerevisiae* and *Rhizopus sp*, distilled water, urea, NPK. While the equipment used is a distillation aparatus, grinder, incubator shaker, analytical scales, centrifuge, Erlenmeyer 250 ml and 500 ml, pipette, timers, thermometers, pH meters, pycnometer (Iwaky Pyrex).

Preparation

Rice straw is obtained in the area of paddies in the area Kamang Agam District of West Sumatra. Then chopped rice straw and reduced size, using a grinder. Further fine straw stored at room temperature for pretreatment process.

Pretreatment and hydrolysis

Rice straw that had been prepared, hydrolyzed using methods Liquid Hot Water with three variations of mechanical pretreatment, namely: normal heating (P), heating with high pressure (PT), and heating with additional pressure (PK). Variations pretreatment time is 1 hour, 2 hours and 3 hours.

Hydrolyzate obtained from each of the various pretreatment (± 300) shall be 4.5 to 4.8 pH and then inoculated with *Saccharomyces cerevisiae* inoculum. (3%, 5% and 10% of the hydrolyzate obtained). Added urea 0.13% and NPK 0.028% of the amount of water. The fermentation was carried out at room temperature with a shaker incubator at 100 rpm for 72 hours at 30 ° C.

Fermented and then centrifuged at a speed of 4000 rpm for 15 minutes. The alcohol content of the supernatant was determined by the method while the specific gravity of the sediment (precitipate) biomass weigh (*Dried cells weight*).

Analysis method

Series of raw ethanol solution with a concentration determined 5,10,15,20 and 25% Relative weights each of the water using a pycnometer 5 ml. Furthermore, made the relationship between the concentration of the solution series with a specific gravity relative to the linear regression equation between the two.

To analyze the level of alcohol (ethanol) is obtained, used density analysis using a pycnometer. Density obtained, can be determined levels of alcohol (ethanol) by plotting its ethanol distillate density of the linear regression equation of the standard curve while biomass determined gravimetrically.

This analysis was performed on the results to determine the weight of the biomass fermentation and alcohol content (ethanol) as an indicator of the performance of the process.

RESULTS AND DISCUSSION

The results of measurements of biomass and ethanol levels were performed on straw after mechanical pretreatment and fermented using *Saccharomyces cerevisiae* are presented in the following table

Table 1. Biomass and ethanol levels mechanical pretreatment hydrolyzate treatment outcome

variation of Mechanical Pretreatment	Time (hr)	concentration Of yeast (%)	Biomass (g)	Ethanol (%)
heating	1	3	0.12	2.90
		5	0.69	2.90
		10	0.45	3.70
	2	3	0.69	3.70
		5	0.81	7.74
		10	0.79	4.51
	3	3	0.45	2.09
		5	0.80	3.70
		10	0.44	2.09
Heating with additional pressure	1	3	0.20	2.09
		5	0.70	4.51
		10	0.42	2.90
	2	3	0.53	3.70
		5	0.75	5.52
		10	0.68	3.70
	3	3	0.27	2.09
		5	0.64	4.51
		10	0.49	2.90
Heating with High Pressure	1	3	0.73	2.09
		5	0.97	3.70
		10	0.71	2.90
	2	3	1.01	5.32
		5	1.47	9.35
		10	1.21	7.74
	3	3	1.10	5.32
		5	1.20	6.93
		10	1.09	5.32

Table 1 shows a pattern of increases and decreases in the same between pretreatment time and concentration of yeast to the biomass and ethanol. Increasing the pretreatment time of 1 hour to 2 hours and yeast concentration of 3% to 5%, results an increase in biomass and ethanol. Improved pretreatment of biomass and ethanol at 1 hour and 2 hours was caused by the addition of the contact time between the material with water so that the reaction time of the hydrolysis of cellulose to glucose and hemicellulose into sugar constituent units was also longer.

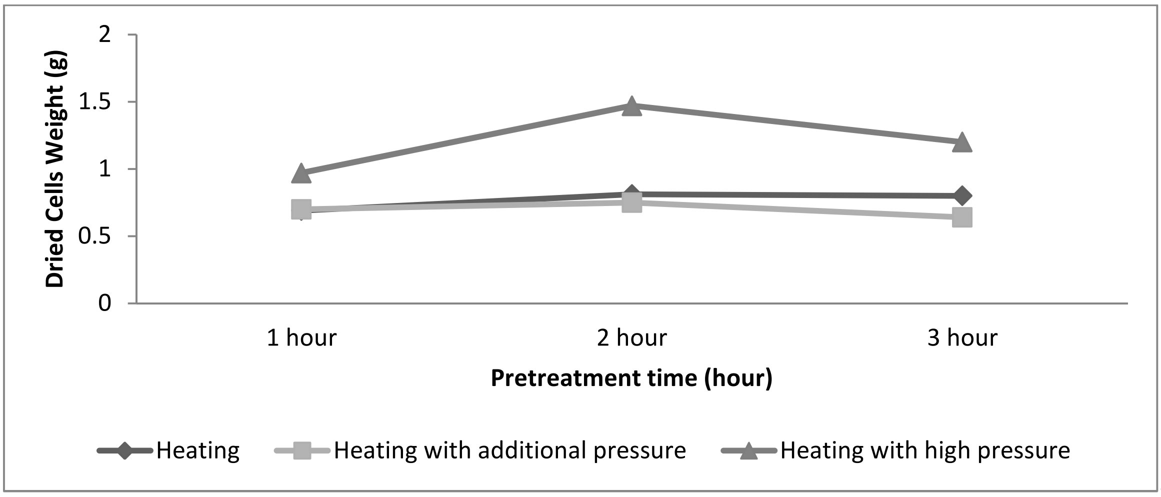

Figure 1. Dried Cells weight (g) of fermented rice straw hydrolyzate after mechanical Pretreatment at a concentration of 5% Saccharomyces cerevisiae for 72 hours

The addition of pretreatment time from 2 hours to 3 hours and an increase in yeast concentration of 5% to 10% actually resulted in a decrease in biomass and ethanol. The decline in biomass and ethanol was caused by all the hydrolyzed cellulose which transformed into sugar units which was completed in the previous pretreatment, so that the amount of hydrolyzed cellulose has also been on the wane. The data in Table 1 also shows that the concentration of yeast capable of producing the highest biomass and ethanol at a concentration of 5%.

The biomass settles determined using a gravimetric method. Figure 1 shows that the highest biomass generated after pretreatment for 2 hours for all variations of pretreatment. The heating with high pressure produces the highest biomass is 1.47g and followed by the heating is 0.81g. Heating with additional pressure biomass produces the smallest is 0.75g.

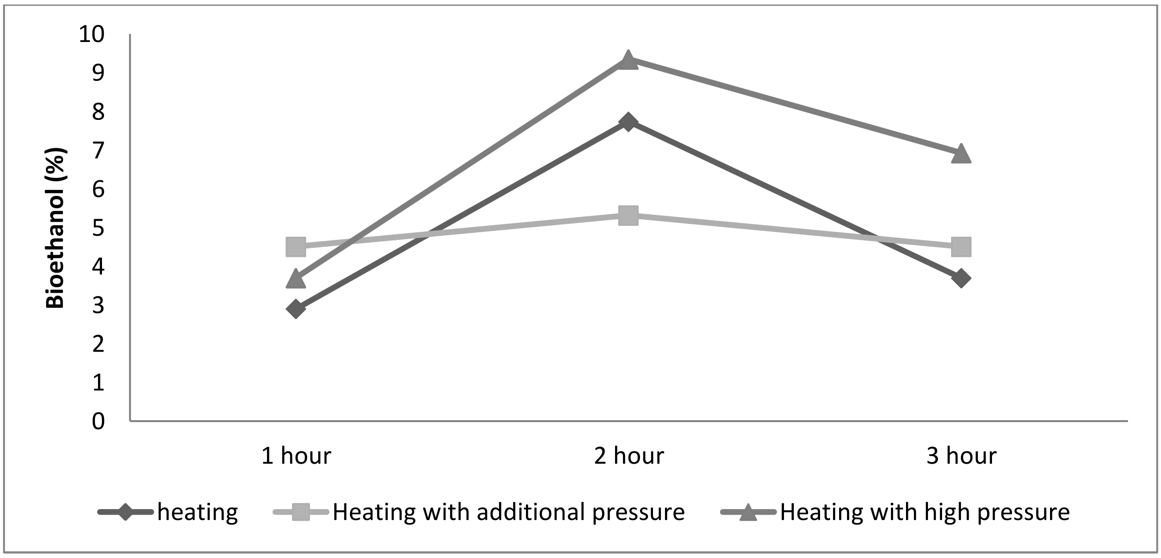

Figure 2. Levels of Ethanol (%) fermented straw hydrolyzate after pretreatment *Saccharomyces cerevisiae* mechanic at a concentration of 5% for 72 hours

Figure 2 indicates the same thing with biomass, which the highest levels of ethanol produced in each of the various pretreatment is after 2 hours of pretreatment. Pretreatment with the heating pressure was 5,32%, followed by the heating 7.74%. Pretreatment with high pressure to produce ethanol with the highest levels compared to pretreatment other variation is 9,35%.

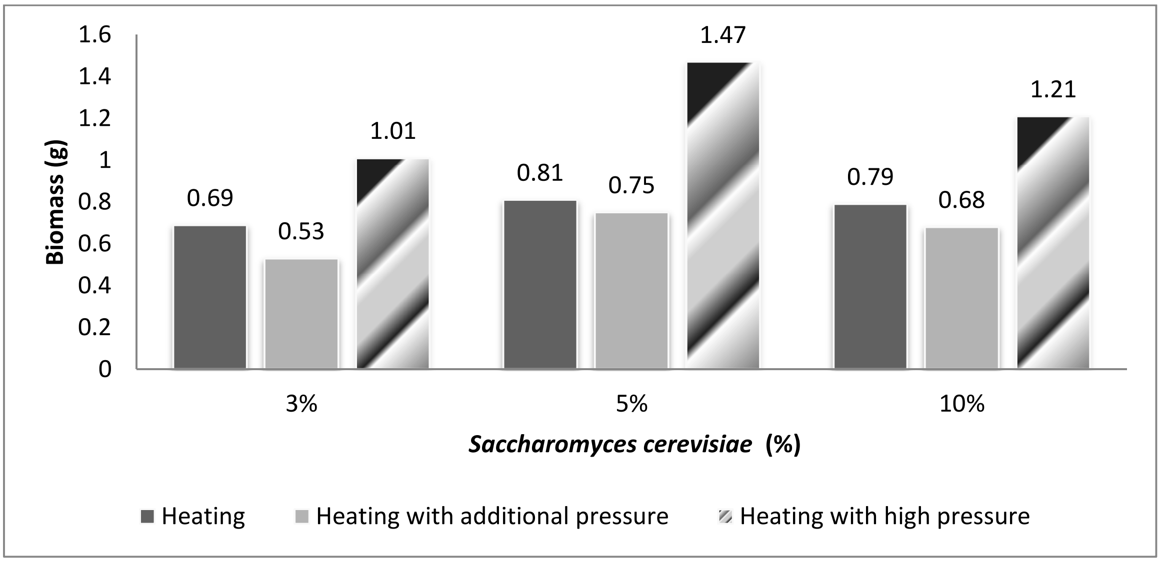

Figure 3. Graph biomass at various concentrations of the yeast *Saccharomyces cerevisiae* after 2 hours of mechanical pretreatment

Biomass measurements at various concentrations of the yeast *Saccharomyces cerevisiae* after 2 hours of pretreatment as shown in Figure 3. Figure 3 shows that the biomass has a tendency to increase in value with increasing pretreatment time and increase the concentration of yeast used. The highest biomass was obtained on heating method with high pressure for 2 hours ie 1:47 with *Saccharomyces cerevisiae* yeast concentration of 5%. This is related to the separation of the components of amorphous (lignin and cellulose) on straw with high pressure.

The rise time of pretreatment also increases the glucose content in the hydrolyzate, because the contact time between the materials with water increased along with the increase in time so that the pretreatment of lignocellulose decomposition becomes better [11,12, 13].

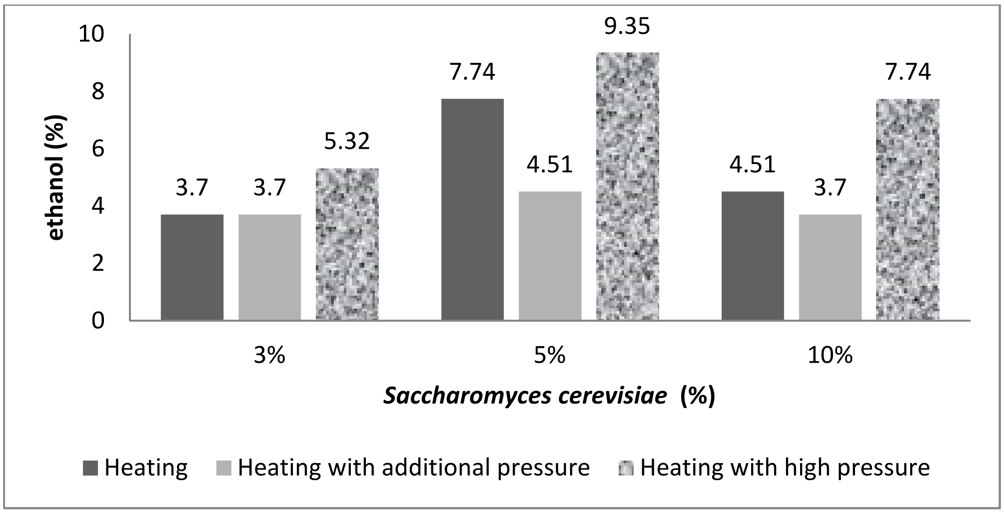

Figure 4. Graph levels of ethanol at various concentrations of the yeast *Saccharomyces cerevisiae* after 2 hours of mechanical pretreatment

Ethanol content obtained by heating using high pressure is higher compared with other mechanical pretreatment method (Figure 4). Heating with high pressure to produce ethanol at 9.35%, whereas the ordinary heating and heating were added to show the pressure difference is not too far away (7.74% and 5,32%). The use of high pressure is more effective in breaking down lignin so that the decomposition of glucose is better.

Pretreatment of lignocellulosic biomass is very important to obtain data in the development of bioconversion technology on a commercial scale, because pretreatment is one step which costs expensively and has a considerable influence on the overall cost of production [14, 15, 16]. According to Chang and Holtzaple (2000), effective early treatment will reduce the amount of lignin by 10%, so the hydrolysis rate will rise and will greatly affect the absorption of enzymes.

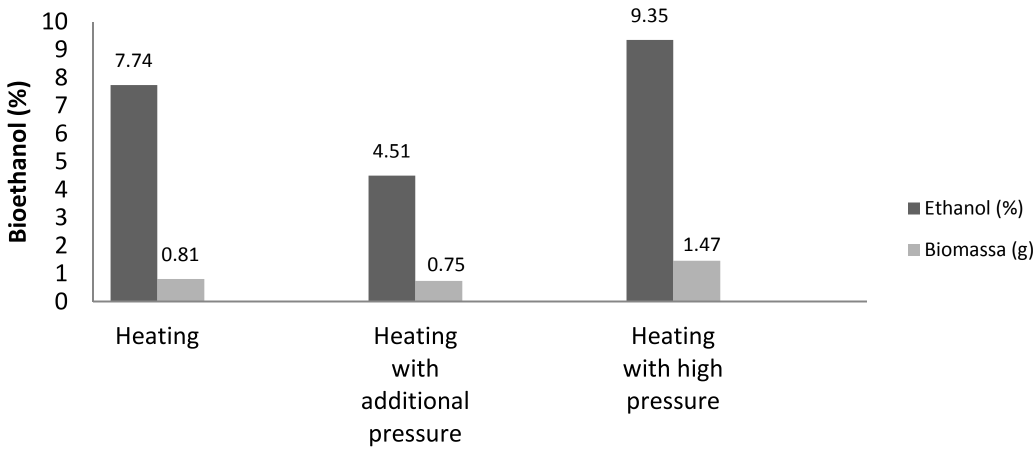

Figure 5. Graph ethanol after mechanical pretreatment for 2 hours and fermentation the yeast *Saccharomyces cerevisiae* a concentration of 5% for 72 hours

Based on the results obtained it can be concluded that the variation of mechanical pretreatment method Liquid Hot Water may cause a reduction in the content of hemicellulose and lignin in the straw (Figure 5). Biomass and the largest ethanol pretreatment hydrolyzate obtained by variation using high pressure for 2 hours is 9.35% ethanol and 1.47 g biomass. The concentration of the yeast *Saccharomyces cerevisiae* is required to obtain the highest biomass and ethanol was 5%. Mechanical pretreatment in high pressure with methods Liquid Hot water with higher operating conditions, is able to suppress the formation of simple sugar and does not produce inhibitory compounds.

CONCLUSION

From the research conducted, several conclusions can be drawn :

1. The highest ethanol concentration is 9,35% obtained using the yeast *Saccharomyces cerevisiae* using heating method with high pressure during the operational time of 2 hours
2. The highest biomass obtained at 1,47 with the same methods and variations with ethanol
3. The mechanical pretreatment with high pressure at the time of 2 hours and the concentration of 5% yeast *Saccharomyces cerevisiae* is able to enlarge the fuel cell structure damage and produce biomass and alcohol better than other mechanical pretreatment used in this study.

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