

Hydrolysis Reaction Kinetics of Baggasse and Banana Peel in the Process of Bioethanol Production

Indah Purnamasari^(⊠), Endang Supraptiah, Rima Daniar, Cindi Ramayanti, Tri Lestari, and Eti Nurmahdani

Department of Chemical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia indah.purnamasari@polsri.ac.id

Abstract. The alternative biofuel that is inexpensive in terms of production and environmentally friendly is the development of bioethanol from agricultural wastes (biomass) which contains a lot of lignocellulose such as bagasse (solid waste from the sugar industry) and banana peel (waste from markets). One of the processes that occur in bioethanol production is the hydrolysis process. The review of the reaction kinetics was carried out at the time of the hydrolysis reaction from starch to glucose and then to form bioethanol by varying the composition of bagasse and banana peels, as well as by varying the reaction temperature to obtain a constant reaction rate. This research aims to influence bagasse and banana peel compositions, as well as good reaction temperature in producing bioethanol, and to calculate the reaction kinetics. Bagasse and dried banana peel were preparing and processed into starch. The starch from the two raw materials produced will be compared to the composition for the next step, namely the hydrolysis process. This starch hydrolysis process uses an acid, namely 0.4 M sulfuric acid with reaction times 15-60 min and reaction temperatures of 95 °C. The results showed that the hydrolysis reaction between bagasse and banana peels followed a pseudo-first order reaction with k values varying from 2×10^{-6} to 5×10^{-5} min⁻¹. The highest glucose levels were found in the ratio of bagasse and banana peels 1: 1 in 30 min, which was 752.766 ppm using 2% sulfuric acid as a catalyst.

Keywords: Bagasse · Banana peel · Kinetics · Hydrolysis

1 Introduction

Indonesia continues to experience oil decreasing production in nationality. It is because of naturally declining oil reserves, and also increasing population growth, increasing use of transportation, and industrial activities resulting in increased consumption of fuel oil. To overcome this problem, it is necessary to have alternative fuels that are environmentally friendly and can be renewed. One alternative to fuel oil is bioethanol. Bioethanol is ethanol derived from biological sources. Bioethanol is sourced from simple sugars, starch, and cellulose [1].

One of the alternative energy that is cheap in terms of production and environmentally friendly is the development of bioethanol from agricultural wastes (biomass) which

contains a lot of lignocellulose such as bagasse (solid waste from the sugar industry) and banana peels (waste from markets). The sugar industry produces bagasse which is quite abundant, such as at the Cinta Manis Sugar Factory managed by PTPN VII, Inderalya, South Sumatra. Another advantage of bioethanol is that it can be used as premium mixed material. If we compare bioethanol with fuel oil, bioethanol has several advantages. There are: a) containing high oxygen around 35% so that the burning process is perfectly happened, b) green energy because it is containing less carbon monoxide emissions (19–25% lower than fuel oil) so it does not provide carbon dioxide accumulation in the atmosphere and it is renewable, while fuel will run out because the raw materials are fossils [2].

Bagasse is a fibrous waste product from the sugarcane milling process. In the sugarcane milling process, there are five milling processes from sugarcane stalks to bagasse. In the first and second mills, brownish-yellow raw sap was produced, then in the third, fourth, and fifth milling processes, sap with unequal volumes was produced. After the initial milling process, namely the first and second milling, wet bagasse is produced.

Based on Ikatan Ahli Gula Indonesia (Ikagi), there 30 million tons of bagasse production in each 57 sugarcane companies. As much as 60% of the bagasse is used by sugar factories as fuel, paper, canvas industry, mushroom industry, and others. However, it is estimated that as much as 45% of the bagasse has not been utilized [3].

Banana peels are by product of banana fruits. Banana peels are usually used as organic fertilizer, and fodder livestock for animals. Banana peels have beneficial value if they can be used as raw materials for the manufacture of ethanol, biogas, etc. [4]. The biggest components of the peels are water and carbohydrates. Carbohydrates in banana peel waste can be used as animal feed nutrients. Along with advanced research, banana peels can be fermented into bioethanol with Saccharomyces cerevisiae helping.

On bioethanol production, the raw material is processed into bioethanol and must go through several processes, namely the process of hydrolysis, fermentation, and distillation. Hydrolysis is a chemical reaction that breaks the P molecule with using H_2O , to convert polysaccharides into simple monomers. One part of the molecule has hydrogen ions (H⁺) and the other part has hydroxyl ions (OH). The general reaction is as follows [5]:

 $(C_6H_{10}O_5)n + nH_2O \rightarrow n(C_6H_{12}O_6)$ starch water glucose

Because the reaction between starch and water takes place slowly, so to increase the speed. The reaction requires the addition of a catalyst. The addition of this catalyst serves to increase the activity of water so that the hydrolysis reaction runs faster. The frequent catalyst used is sulfuric acid, nitric acid, and chloride.

The process of complex sugar components breaking into simple sugars is known as hydrolysis. The hydrolysis process is usually carried out by the addition of acids or enzymes. The hydrolysis process using water will break chemical compound bonds. Hydrolysis of starch will produce chemical compounds such as glucose, dextrin, isomaltose, and maltose [6].

The hydrolysis reaction kinetics is intended to calculate the speed of the reaction that occurs and the factors that influence it. Factors that affect starch hydrolysis include

reaction temperature, time reaction, mixing of reagents, concentration acidity, and starch suspension content.

The rate equation for hydrolysis reaction, in general, using a reagent in the form of water the amount can be exaggerated written as [7]

$$\mathbf{r}_{\mathrm{A}} = -\frac{\mathrm{d}\mathbf{C}_{\mathrm{A}}}{\mathrm{d}t} = \mathbf{k}\mathbf{C}_{\mathrm{A}}^{\mathrm{m}}\mathbf{C}_{\mathrm{B}}^{\mathrm{n}} \tag{1}$$

where:

 $\begin{array}{l} r_A = \text{rate of reduction A, (gmol/(L.minute))} \\ C_A = \text{Starch concentration, gmol/L} \\ C_B = \text{Water concentration, gmol/L} \\ C_C = \text{Glucose concentration, gmol/L} \\ t = \text{reaction time, minutes} \\ m, n = \text{reaction order} \end{array}$

With an excessive amount of water, it can be assumed that the water concentration remains constant throughout the reaction. Then the equation becomes a pseudo first order reaction equation.

$$r_A = -\frac{dC_A}{dt} = k'C_A^m \tag{2}$$

where is $k C_B^n$ considered constant = k'

If m = 1 then

$$r_{\rm A} = -\frac{{\rm d}C_{\rm A}}{{\rm d}t} = {\rm k}C_{\rm A} \tag{3}$$

However, if the reaction is assumed to be second order, then the equation becomes

$$r_{\rm A} = -\frac{dC_{\rm A}}{dt} = kC_{\rm A}^2 \tag{4}$$

2 Experimental Procedure

2.1 Materials

The raw materials are bagasse and banana peel with a ratio of 1: 1, 1: 2, and 2: 1, H_2SO_4 0.4 N as much as 2% and 3%, aquadest, and other supporting materials for analysis.

2.2 Equipments

The equipments used in this research are three necks rounded flask, cooler, condenser, stirrer, heater, thermometers, stative, iron clamp, and other glassware. The arrangement of the tools is depicted in the Fig. 1 as follows:



Fig. 1. Hydrolysis Equipment

Figure Information:

- 1. Clamps and Statives
- 2. Stirring Motor
- 3. Stirrer
- 4. Reverse Cooling
- 5. Three-Necks Rounded Flask
- 6. Thermometer
- 7. Heaters
- 8. Water Batch
- 9. Temperature Sensor
- 10. Thermostate

3 Results and Discussion

From the analysis result of the hydrolysis reaction, the glucose levels produced from the reaction are shown in Table 1.

Table 1 shows that the most abundant glucose is produced in the composition of bagasse and banana peel 1:1 with a reaction time of 30 min and the use of a catalyst of 2%. Glucose level analysis was carried out using a UV Vis Spectrophotometer. The resulting glucose level decreases further with the change in the ratio of the composition of raw materials. This can be caused due to the inability of the catalyst to catalyze, It can be seen from the table that bagasse has more glucose than banana peel. at the ratio of banana peel and bagasse 1:2 with the use of catalyst 2% and reaction time of 15 min, the glucose produced is 612.100 ppm, Contrary, when the ratio of banana peel and bagasse is 2:1 with the use of catalyst 2%, the glucose produced is 133.833 ppm. However, the use of 3% catalyst with a time reaction of 15 min gave a different result. At a ratio of

Banana peel: Bagasse	Hydrolysis time (minutes)	Glucose (ppm)	
		2% Catalyst	3% Catalyst
1: 1	15	748.533	444.933
	30	752.766	453.008
	45	660.883	463.083
	60	561.433	481.233
1:2	15 30 45 60	612.100 505.500 398.902 185.703	466.081 470.499 474.918 483.755
2: 1	15 30 45 60	133.830 115.489 97.146 60.496	486.400 489.522 492.704 495.857

Table 1. The Glucose Level from Hydrolysis Reaction



Fig. 2. The Conversion Result in Hydrolysis Time with using 2% Catalyst

banana peel and bagasse 1:2, the glucose produced is 466.0816 ppm. Conversely, at a ratio of banana peel and bagasse 2:1, the glucose produced is 486.4 ppm.

The data from the hydrolysis reaction with reactant comparison variations of 1: 1, 1: 2, and 2:1 with hydrolysis times of 10–40 min at hydrolysis temperature maintained at 95 °C in various catalyst can be seen in Fig. 2 and Fig. 3.

From Fig. 2 we can see that the highest conversion was achieved in 30 min with a ratio of 1: 1. However, the conversion decreased during the reaction time. This is due to the inability of the catalyst to re-catalyze the reaction. According to [8] disadvantage of dilute acid, hydrolysis is the degradation of sugar results in the reaction of small hydrolysis and the formation of by-products undesirable.

The initial treatment of lignin breakdown in raw materials was not carried out so it inhibited the hydrolysis reaction carried out. Lignin can interfere with the hydrolysis process which results in disruption of glucose formation [9].



Fig. 3. The Conversion Result in Hydrolysis Time with using 3% Catalyst

Variables	$k_1 (min^{-1})$	
	2%	3%
1: 1	5×10^{-5}	9×10^{-6}
1:2	1×10^{-5}	4×10^{-6}
2: 1	2×10^{-5}	2×10^{-6}

Table 2. Rate Constant of Hydrolysis Reaction

According to Fig. 3, it can be seen that the longer the time it takes to react, the greater conversion achieved. It shows that the longer the time it takes to react so the bigger chance to react. Besides using a catalyst, a reaction that is carried out over time will result in a continuously increasing conversion over time. This is in line with that the use of a catalyst can reduce the activation energy so that more products are formed.

Hydrolysis is a process between reactants and water so that a compound breaks or breaks down decomposed. This reaction is considered a first-order reaction because excess water is used, so the change in reactants is negligible. From the results of the calculations, using pseudo 1st order and 2nd order, the value of k is obtained which is quite good for the first order reaction, because the calculations for the second order graph have a lot of deviations. It is obtained from the least squares result that the value of \mathbb{R}^2 for pseudo 1st order is in the range of 0.97–1.

From Table 2 it can be seen that the reaction takes place very quickly at a variable 1: 1 with the use of a catalyst concentration of 2%. This is inversely proportional to the statement in the Arrhenius equation which states that the more catalysts eat, the lower the activation energy, which causes the reaction rate constant to be greater.

According to [10] high lignin levels low will facilitate the contact of cellulose to be degraded to glucose monomers. Lignin contained in the sample can inhibit the HCl catalyst in the formation of glucose so that glucose levels are produced less. Based [11] the use of a temperature of 121 °C is more effective in the pretreatment process because a temperature that is too high will cause degradation of cellulose. While at low

temperatures, lignin will be difficult to delignify so that it still covers the cellulose, and the reduced lignin content will be slight. The reaction temperature used is 95 °C, it cannot degrade lignin, this is what causes the reaction to take place very slowly and the resulting conversion is small even though the reaction treatment has used a catalyst.

4 Conclusion

The highest conversion of glucose in hydrolysis reaction between bagasse and banana peel occured at 30 min with weight comparison 1: 1 and temperature 95 °C. Pretreatment of lignin in raw materials needs to be carried out so as not to interfere with the work of the catalyst and temperature selection also needs to be considered again. The hydrolysis reaction between bagasse and banana peels followed a pseudo-first order reaction with the value of the reaction rate constant varying between $2 \times 10^{-6}-5 \times 10^{-5}$ min⁻¹.

Acknowledgments. The authors thank for supporting and facilitating the funding research in 2022 to the State Polytechnic of Sriwijaya.

Authors' Contributions. All of the authors are contributed in the process of hydrolysis reaction between bagasse and banana peel. The contributions of the authors are identifying problems, preparing all raw materials, observing the processes that occur, analyzing the resulting products, preparing proposed equations, and collaborating in writing research papers.

References

- 1. Ardian, N.D., Endah, R.D., and Sperisa, D. Pengaruh Kondisi Fermentasi terhadap Yield Etanol pada Pembuatan Bioetanol dari Pati Garut, Jurnal Gema Teknik Vol 2, (2007).
- 2. Broto, L. Teknologi Pembuatan Etanol Berbasis Lignoselulosa Tumbuhan Tropis untuk Produksi Biogasoline. LIPI, (2010).
- 3. Akasuma, S.N., and Raiza, M. Pembuatan Bio-Etanol dari Ampas Tebu dengan Variasi Waktu Hidrolisa, Berat Ragi, dan Jenis Ragi. Universitas Sriwijaya, (2011).
- 4. Anonymous. Kulit Pisang. Online di http://www.scribd.com, 2009. Accessed 27 Maret (2022)
- Agra, I.B., Wairniyati, S., and Pujiyanto. Hidrolisis Ketela Rambat pada Suhu lebih dari 1000 C. Yogyakarta: Universitas Gadjah Mada, Forum Tehnik Jilid 3, (1973).
- 6. Purba, E., Hidrolisis Pati Ubi Kayu (Manihot Esculenta) dan Pati Ubi Jalar (Impomone batatas) menjadi Glukosa secara Cold Process dengan Acid Fungal Amilase dan Glukoamilase. Thesis, Universitas Lampung, 2009.
- 7. Levenspie, O. Chemical Reaction Engineering. Affilated East West Press DVT. New Delhi: Ltd , (1972).
- Moore, H.K. Process of Making Ethyl Alcohol from Wood. Patent No 1,323,540. United State of America, (1919).
- Sari, E., and Bahtiar, A. Delignifikasi Lignin Dalam Enceng Gondok Secara Kimiawi. Jurnal Teknika. 2016, Vol. 12 No. 1, pp 114–120.

II. Purnamasari et al.

- Oktavianus, F., Sigiro, R.M., and Bustan, M.D.2013. Pembuatan Bioetanol dari Batang Jarak Menggunakan Metode Hidrolisa dengan Katalis Asam Sulfat. Universitas Sriwijaya. Jurnal Teknik Kimia, 2013, Vol. 19 No. 2, pp 27–32, (2013).
- Permatasari, H.R., Gulo, F., And Lesmini, B. Pengaruh Konsentrasi H₂SO₄ dan NaOH terhadap Delignifikasi Serbuk Bambo (Gigantochloa apus). Program Studi Pendidikan Kimia FKIP. Universitas Sriwijaya, (2014).

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

