New method for bioethanol production from waste wood

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Abstract

Bioethanol is one of the most important renewable fuels due to the economic and environmental benefits of its use. Lignocellulosic biomasses such as waste wood are the most promising feedstock for producing bioethanol in Iran. Conventional methods for bioethanol production from Lignocellulosic biomasses take two steps: pretreatment (commonly acid or enzyme hydrolyses) and fermentation. Dilute acid hydrolysis takes the time in the range of a few minutes but needs high temperature and pressure and has low efficiency. While the concentrated acid hydrolysis takes the time more than ten hours but needs moderate temperature and pressure and has high efficiency. In this paper, we introduce a new two-step pretreatment method for bioethanol production from waste wood, which has the advantages of dilute and concentrated acid hydrolyses. In the first step, the sawdust is soaked in sulfuric acid at room temperature and for more than 12 hours. In the second step, the temperature of the mixture was raised to boiling point and for duration less than 4 hours. Different acid concentrations such as 2, 5, 10 and 20 percent are used in pretreatment steps, and each experiment was repeated three times. The results after statistical analysis showed that the maximum amount of total sugar achieved after about 120 minutes in 5% acid concentration.

Keywords: bioethanol, waste wood, acid hydrolysis

1. Introduction

The term biofuel is referred to as liquid or gaseous fuels for the transport sector that are produced from biomass. Bioethanol is one of the most famous biofuels. The use of bioethanol as an alternative motor fuel has been steadily increasing around the world for the number of reasons. (a) Fossil fuel resources are declining, but biomass has been recognized as a major world renewable energy source. (b) Greenhouse gas emissions is one of the most important challenges in this century because of fossil fuel consumption, biofuels can be a good solution for this problem. (c) Price of petroleum in global market has raising trend. (d) Petroleum reserves are limited and it is monopoly of some oil-importing countries and rest of the world depends on them. (e) Also known petroleum reserves are estimated to be depleted in less than 50 years at the present rate of consumption [1]. At present, in compare to fossil fuels, bioethanol is not produced economically, but according to scientific predictions, it will be economical about 2030 [2].

Biomass commonly gathers from agricultural, industrial and urban residues. The wastes used for bioethanol production are classified in three groups according to pretreatment process in sugary, starchy and lignocellulosic biomasses [3]. In pretreatment step, biomass structure is broken to fermentable sugars and then, in fermentation step bioethanol is produced from these sugars.

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Environmental pollution in Iran is increasing every year, because of fossil fuels consumption [4]. Using biofuels or combined fossil and biofules is one of the solutions to this problem. One of the inexpensive biomasses in Iran is waste wood that may be used for bioethanol production. Wood is in class of lignocellulosic biomasses that has 40 to 50% cellulose, 25 to 35% hemicellulose and 15 to 20% lignin [3]. In pretreatment step, cellulose and hemicellulose specifically break to glucose and xylose sugars and in fermentation step ethanol is produced from these sugars. Lignin can not convert to fermentable sugars. The factors that have been identified to affect pretreatment step are porosity, cellulose and hemicellulose fiber crystallinity and lignin content [3]. There are a numbers of methods for pretreatment of wood. For example after combination of chipping, grinding and milling to reduce crystallinity, steam explosion, ammonia fiber explosion (AFEX), CO_2 explosion, acid hydrolysis and enzymatic hydrolysis can be used to break of polymeric chains of cellulose and hemicelluloses and extract the fermentable sugars [3].

There are two basic types of acid hydrolysis: dilute and concentrated acid hydrolysis. The reaction time for dilute acid hydrolysis is in the range of a few minutes that facilitates continuous processing. However, the dilute acid hydrolysis should be carryout under high temperature and pressure which needs expensive equipments. In addition, most dilute acid process are limited to a sugar recovery efficiency of about 50%. Concentration of acid which is used in dilute acid processes is less than 2%. The concentrated acid hydrolysis use relatively mild operating conditions (temperature of about 100˚C and atmospheric pressure). Concentration of acid in this process is about 10 to 70%. The advantage of the concentrated process is the high sugar recovery approximately over 90%. However, the required equipments for high concentrated acid processes are expensive due to corrosion. In addition, the reaction time of concentrated acid hydrolysis is more than ten hours [5].

In this paper, we introduce a new two-step pretreatment method for bioethanol production from waste wood, which has the advantages of dilute and concentrated acid hydrolyses. In the following sections the steps and materials used in our method are described, and then, after presenting the experimental results, a model is proposed for the hydrolysis step of the new method based on the resulted experimental data.

2. Materials and Methods

2.1. Hydrolysis step

The experiments carried out in three steps, first pretreatment, hydrolysis and fermentation respectively. In first pretreatment step, 50 gr. of sawdust from waste wood of the university carpentry, weighted with a digital balance (LIBROR, EB3200D, Shimadzu), and soaked in 500 ml of four different concentration of sulfuric acid (MERK, with density of 1.98 gr/ml) for more than 12 hours in the 1000 ml balloon and at room temperature. After that, in hydrolysis step, the mixture of previous step was heated to boiling point under 900 rpm mixing with magnet heater (IKAMAGRET magnet heater) for four hours. During the hydrolysis step, eight samples were gained from the boiling mixture at times 0, 15, 30, 45, 60, 120, 180 and 240 min. Then, the resulted solution was separated from the solid residue with a filter and bleaching with Whatman paper No.4 and activated carbon. The total sugar (glucose and xylose mainly) of the obtained solution was measured using a spectrophotometer (UV-160A, Shimadzu).

2.2. Fermentation step

In fermentation step, obtained solution after pH regulating, fermented using commercial species of *Saccharomyces cerevisiae* (prepared from IRAN MOLLAS), at five incubation times (0, 24, 48, 72 and 96 hours). The used incubator has the following model: Memmert incubator, Shutzart DIN 40050-IP20. The amount of produced ethanol after fermentation was measured using a Gas Chromatograph (PHILIPS, PU4500).

2.3. Statistical method

Each experiment was repeated at least three times and the required raw data were analyzed statistically by multifactor Randomized Complete Block Design (RCBD) and the obtained means, evaluated by Duncan Multiple Range Test (DMRT). Statistical analysis of the experimental data is evaluated using Sigma State software (version 3.1). For modeling the hydrolysis step, a linear-logarithmic model was used, and its parameters are calculated using the least square method.

3. Results

In this investigation, different concentrations of sulfuric acid are used to identify the best acid concentration based on minimum process duration and maximum efficiency of hydrolysis process. Moreover, by using a new pretreatment step before hydrolysis step, the limitations of changing the acid concentration in the hydrolysis step were removed.

In figure 1, the total sugar produced in hydrolysis step using 2, 5, 10 and 20% acid concentrations during 240 minutes are shown. In viewpoint of efficiency and total sugar yield, the best result was achieved in 5% acid concentration. The resulted efficiency at 5% acid concentration is about 76%. Furthermore, Hydrolysis with 5% acid concentration achieved its maximum value after about 120 minutes.

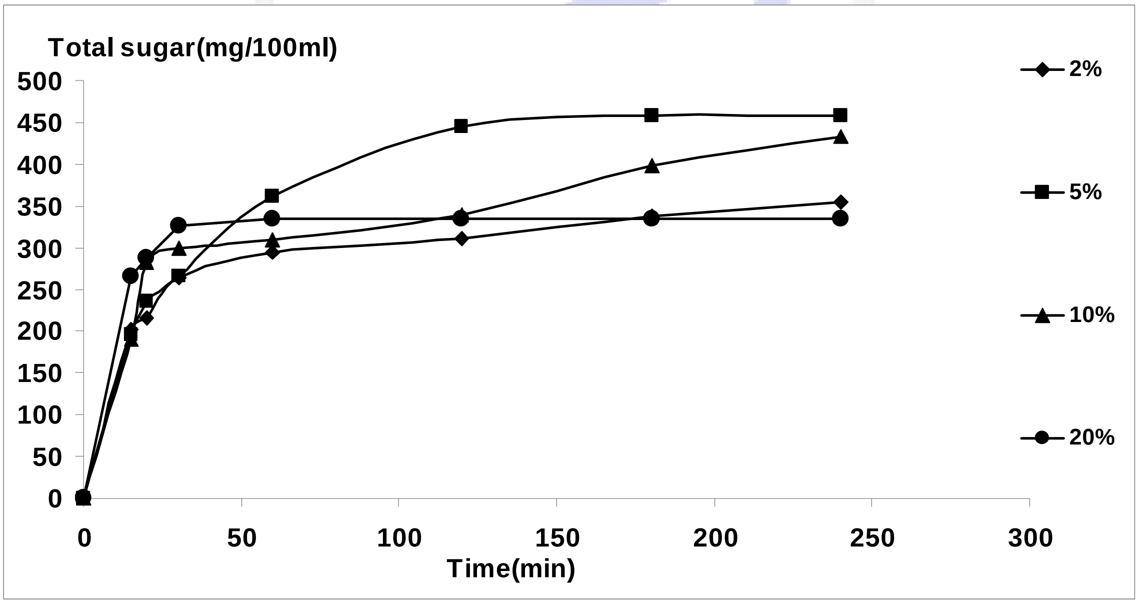

Fig. 1. Total fermentable sugar produced in hydrolysis step using four acid concentrations.

To show the advantages of new pretreatment method for bioethanol production, in compare to common dilute and concentrated acid hydrolysis, the data reported by other investigators are used in Table 1 [5]. As can be seen from Table 1, the new method not only has the mild operating conditions (100 ºC, 1 atm and 5% acid concentration), but also has higher efficiency than dilute acid process and lower duration time than concentrated acid process.

Table 1. The comparison among different hydrolysis methods.

Conditions	Concentrated acid	Dilute acid	This work
Acid concentration	40%-70%	1%-3%	5%
Pressure	1 atm	About 12 atm	1 atm
Temperature	100 ºC	200-300 ºC	100 ºC
Process time	About 840 min	About 1 min	About 120 min
Efficiency	About 90%	Below 50%	About 76%

The experimental data of acid hydrolysis, shown in figure 1, are fitted using a linear-logarithmic model. The resulted equations with the R2 values (goodness of fitting) are shown in Table 2. Additionally in figure 2, the total amount of produced sugars, predicted by the fitted models, are compared with the experimental data. As can be seen from the results, the predictions of the fitted equations are acceptable.

Table2. Fitted Equations for new acid hydrolysis method (t = time, min).

Acid concentration	Total sugar (mg/100ml)	R^2
2%	41.226 + 57.354 ln(t)	0.9794
5%	-113.462 + 109.091 ln(t)	0.9684
10%	-5.021 + 77.6 ln(t)	0.9766
20%	346.218 exp(-4.057/t)	0.9504

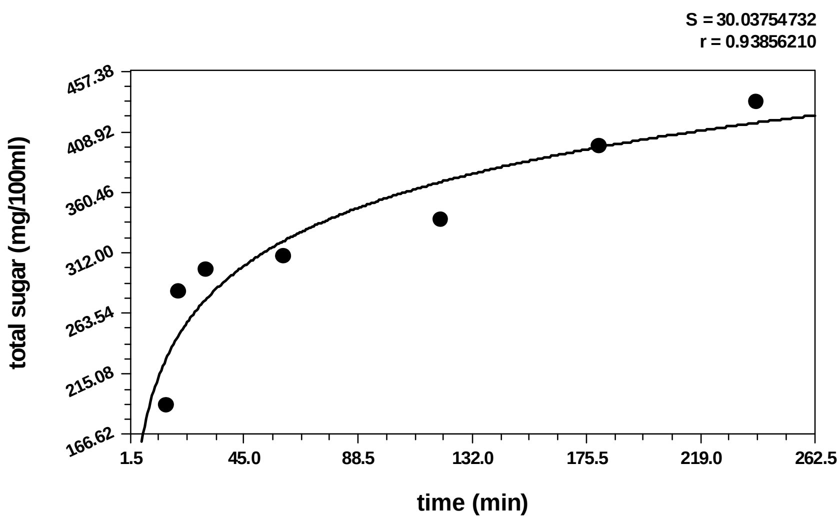

Fig. 2. Comparison of fitted equation and experimental data for 2% acid concentration.

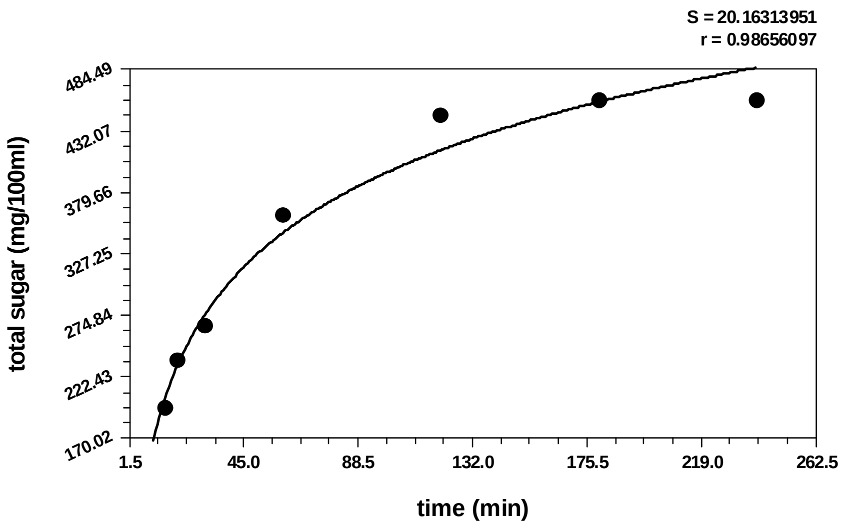

Fig. 3. Comparison of fitted equation and experimental data for 5% acid concentration.

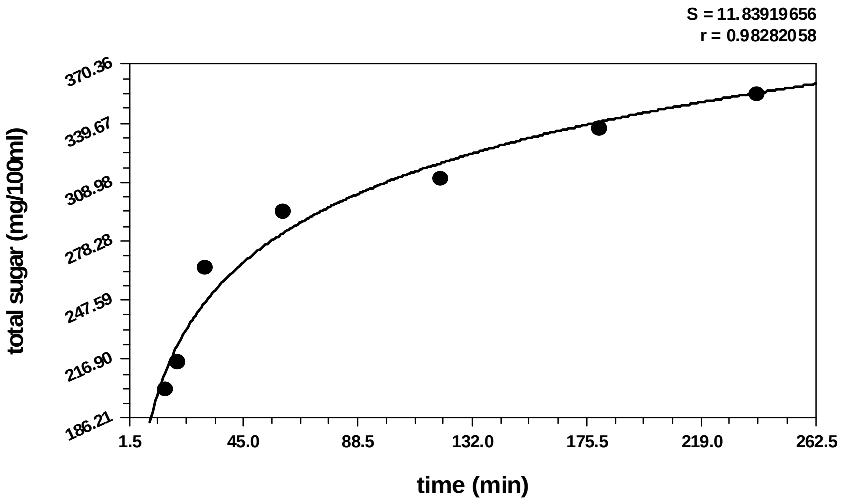

Fig. 4. Comparison of fitted equation and experimental data for 10% acid concentration.

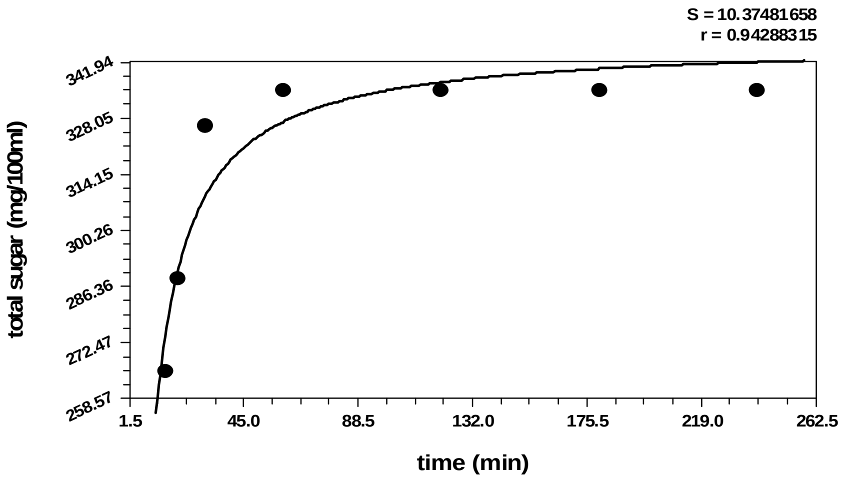

Fig. 5. Comparison of fitted equation and experimental data for 20% acid concentration.

4. Conclusions

Waste wood biomasses are abundant agricultural wastes for bioethanol production in Iran. One method for extraction of fermentable sugar from this biomass is acid hydrolysis in two types: dilute acid and concentrated acid hydrolysis. Dilute acid hydrolysis takes the time in the range of a few minutes but needs high temperature and pressure and has low efficiency (less than 50%). In contrast, the concentrated acid hydrolysis takes the time more than ten hours but needs moderate temperature and pressure and has high efficiency (greater than 90%). In this paper, we introduce a new two-step pretreatment method for bioethanol production from waste wood, which has the advantages of dilute and concentrated acid hydrolyses. In the first step, the sawdust is soaked in sulfuric acid at room temperature and for more than 12 hours. In the second step, the temperature of the mixture was raised to boiling point and for duration less than 4 hours. Different acid concentrations such as 2, 5, 10 and 20 percent are used in pretreatment steps, and each experiment was repeated three times. The results after statistical analysis showed that the maximum amount of total sugar achieved after about 120 minutes in 5% acid concentration.

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