Advances in Environmental Biology, 5(7): 1900-1903, 2011
ISSN 1995-0756

This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLE

Optimization of Sugarcane Bagasse Hydrolysis Process by Economic Criteria

[1]Ehsan Darouneh, [1]Abolhassan Alavi, [2]Manouchehr Vosoughi, [4]Mehdi Ardjmand, [1]Ali Akbar Seifkordi, [5]Vahid Zabihi, [3]Rouhollah Radjabi and [5]Najaf Hedayat

[1]*Science and Research Branch, Islamic Azad University, Tehran, Iran.*
[2]*Sharif University of Technology, Chemical Engineering Department, Tehran, Iran*
[3]*Plant Protection Department, Dezful Branch, Islamic Azad University, Dezful, Iran*
[4]*Tehran South Branch, Islamic Azad University, Tehran, Iran*
[5]*Dezful Branch, Islamic Azad University, Dezful, Iran*

Ehsan Darouneh, Abolhassan Alavi, Manouchehr Vosoughi, Mehdi Ardjmand, Ali Akbar Seifkordi, Vahid Zabihi, Rouhollah Radjabi and Najaf Hedayat: Optimization of Sugarcane Bagasse Hydrolysis Process by Economic Criteria

ABSTRACT

Various processes are used for production of value-added materials from sugarcane bagasse. Hydrolysis processes are the most commonly used methods for producing new products from this low value byproduct. Sulfuric acid hydrolysis processes are the best processing options due to their fast reaction and low process cost. The goal of this study was to investigate an optimized hydrolysis method which can produce fermentable sugar-containing liquor economically. In the other words it was designed to minimize the toxic materials to a level that cannot affect the citric acid production by *Aspergillus niger.* Results showed the optimum condition for one-step hydrolysis processes occurs at the temperature of 438K and sulfuric acid concentration of 4 percent. Under such condition the sugar production to sulfuric acid consumption ratio is around 1.2. The primarily pricing of this operations shows that one-step hydrolysis processes are not economical. Further analysis shows that the application of two-step hydrolysis process at its optimum condition is more economic.

Key words: sugar cane bagasse, hydrolysis process, fermentable sugar, production yield.

Introduction

Sugarcane bagasse is the byproduct of sugar processing industry. Thousands of tons of sugarcane bagasse are produced daily by sugar industries in the Khuzestan province in Iran. Thus there is an urgent need to convert this byproduct to the new high value products. Citric acid is one of the most commonly used organic acids in food and pharmaceutical industries [1]. One alternative for the economic utilization of sugar cane bagasse is to use it as a substrate for the production of citric acid. It must be pretreated in order to achieve high fermentable sugar yields from sugarcane bagasse [2,3]. The pretreatment methods include physical, chemical and thermal or some combination of these. Because of the fast reaction and low pretreatment cost, dilute acid hydrolysis processes are the best options [2,4,5,6].

One of the main disadvantages of these processes is that they produce toxic material fermentation inhibitors which are often in the form of aldehydes, ketones and some phenolic compounds. These toxic materials hinder the bioconversion of fermentable sugar which is produced in hydrolysis processes [2].

These materials can be removed from the fermentable sugar liquor by adding an oxidizing agent but this reduces the sugar production yield (the oxidizing agents also react with sugars). The goal of this study

Corresponding Author
Ehsan Darouneh, Science and Research Branch, Islamic Azad University, Tehran, Iran.
E-mail: Darouneh@gmail.com

was to investigate an optimized hydrolysis method which can produce fermentable sugar containing liquor economically.

Material and methods

A semi-pilot (25L) reactor was used under different conditions of temperature and acid concentrations in order to optimize the hydrolysis methods of sugarcane bagasse. The schematic design of the reactor system used for acid hydrolysis is shown in figure1.

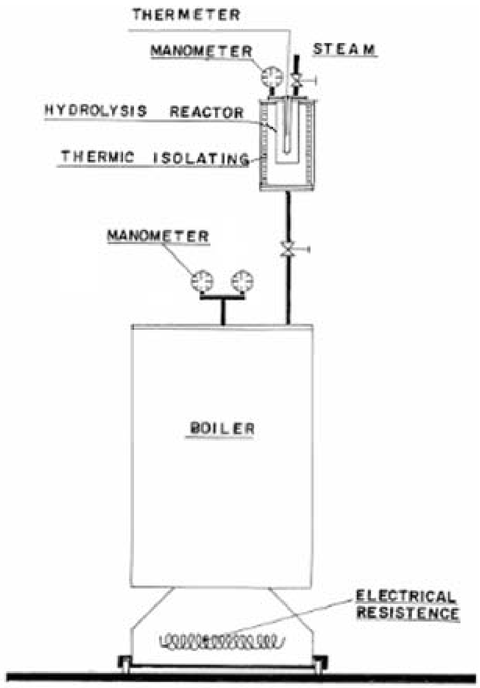

Fig. 1: Schematic design of the semi-pilot reactor system used for acid hydrolysis

Hydrolysis methods contain one or two-step batch reactions. In one-step methods, the reactor was fed on fresh sugar cane bagasse at 150 gram/liter of liquid phase. Sugar cane bagasse with the following chemical composition (table 1) prepared from the Khozestan province in Iran and was dried at 323K until reaching constant weight. It was then milled to obtain small particles(less than 10mm). All chemicals used in this study were of analytical grade and were purchased from Merk GmbH (Darmstadt, Germany). The reactions were performed in different conditions of temperature and sulfuric acid concentrations during 10 minute reaction period. The liquid phase of the reactor was then used as one-step hydrolysis sugar liquor product. In two-step methods, the first reactor was performed based on the forgone procedure but the second reactor was fed on the solid phase removed from the first reactor without any additional treatment. After 10 minutes hydrolysis reaction, the content of this reactor was completely mixed with the liquid phase of the first reactor.

The produced solution was subsequently filtered in order to make non solid-containing liquor, which was used as the two-step hydrolysis product. After the hydrolysis, neutralization process was achieved by adding lime, which also removed the toxic materials by absorption in the precipitated CaSO4.

The composition of the liquor was determined after the neutralization, using HPLC system consisting of a Hewlett Packard 1050 pump and a waters 410 refractive index detector. The applied column was Aminex HPX-87P. HPLC-grade water at flow rate of 0.55 cm3 min-1 was used as the mobile phase and the column was operated at 353 K [7, 8,9]. The products of hydrolysis methods were then used for preliminary economic estimation using essential criteria such as sugar production yield, sugar production to sulfuric acid consumption ratio and microbial inhibition level. The sugar production yield of the hydrolysis method was calculated based on the ratio of fermentable sugar content of liquid product of the process per total carbohydrate content of sugarcane bagasse feed in the first reactor. The sugar production to sulfuric acid consumption ratio was calculated based on the ratio of fermentable sugar content of liquid product of reactors per sulfuric acid content of first reactor. The last essential parameter was not measured directly rather *Aspergillus niger* pellets were grown on the concentrate sugar liquor products to ensure that the remaining toxic material cannot inhibit the citric acid production. These liquid medium were enriched with essential minerals to the optimum concentrations [1,10,11]. Then 100 ml of these solutions was employed for citric acid fermentation by *Aspergillus niger*. Fermentation tests were carried out in 500 ml shake flasks at the temperature of 303K and rotation rate of 250 rpm [1]. The initial pH of the medium was adjusted to 7 without any control during fermentation. The final pH of the media was measured after 10 days of fermentation and used as an indicator to show the microbial inhibition level of hydrolysis products.

Results and discussion

Results of one-step hydrolysis runs are shown in table 2. As can be seen the maximum production yield was achieved at temperature of 298K and sulfuric acid concentration of 80 percent but under this condition the sugar production to sulfuric acid consumption ratio is very low rendering the process uneconomic.

According the final pH of the fermentation broth, it can be appreciated that the lowest inhibition level was obtained in this condition. It can be inferred from the results that the economic yield of the hydrolysis methods increases with increasing the temperature until a maximum point which then starts to decrease. This maximum point is the optimum condition in which the sugar production to sulfuric acid consumption ratio is maximal while the inhibition level remains negligible. The optimum condition for one-step hydrolysis processes occurs at the temperature of 438 K and sulfuric acid concentration of 4 percent. Under such condition, the sugar production to sulfuric acid consumption ratio is around 1.2. The primarily pricing of this operations shows that one-step hydrolysis processes are not economical.

Results obtained from two-step hydrolysis runs shows (table 3) that the optimum condition for two-step hydrolysis processes occurs at the temperature and sulfuric acid concentration of 438k and 4 percent in the first reaction respectively and 448 K in the second. The sugar production yield at the optimum condition of two-step processes is 10 percent higher than one-step processes. Further analysis shows that the application of two-step hydrolysis process at this optimum condition is more economic.

Results showed that although the increase in temperature will increase the inhibition level, but this increment until reaching the optimum temperature was negligible. However beyond it the inhibition intensity increases considerably.

Conclusion:

The results of this investigation showed that one-step dilute sulfuric acid hydrolysis processes are not economical. The sugar production yield and the sugar production to sulfuric acid consumption ratio at the optimum condition of two-step processes are much higher than one-step processes rendering the process more economic.

Acknowledgements

The authors would like to express their gratitude to the faculty technical and engineering of the Dezful Branch of Islamic Azad University, for their wholehearted support of this study.

Table 1: Chemical composition of the sugar cane bagasse

Constituent	wt %
Glucose and Galactose	40.0
Xylose and Arabinose	30.0
Lignin	25
Ash	5

Table 2: Results of one-step sugarcane bagasse hydrolysis processes

Run no.	Reaction conditions Temperature (K) & Sulfuric acid (%)	Sugar yield	Sugar production to sulfuric acid consumption ratio	Final pH
1	298 80	80	0.065	2
2	298 30	63	0.147	2.3
3	433 6	59	0.688	2.5
4	438 4	56	0.980	2.5
5	443 3	52	1.213	2.7
6	448 1.5	30	1.4	3
7	453 1	11	0.77	3.5
8	457 0.5	4	0.42	5.5

Table 3: Results of two-step sugarcane bagasse hydrolysis processes

Run no.	Reaction conditions in first and second reactor, Temperature (K) & Sulfuric acid (%)	Sugar yield	Sugar production to sulfuric acid consumption ratio	Final pH
2	298 433 30	73	0.170	2.5
3	433 448 4	65	1.137	2.7
5	443 453 3	45	1.05	5.5
6	448 457 1.5	30	1.4	7

References

1. Darouneh, E., A. Alavi, M. Vosoughi, M. Arjmand, A. Seifkordi and R. Rajabi, 2009. Citric acid production: surface culture versus submerged culture. Afr. J. Microbiol. Res., 3(9): 541-545.
2. Sun, Y. and J. Chen, 2002. Hydrolysis of lignocellulosic materials for ethanol production: A review. Bioresource Technol, 83: 1.
3. Sun, Y., J. Zhuang, L. Lin and P. Ouyang, 2009. Clean conversion of cellulose into fermentable glucose. Biotechnology Advances, 27: 625-632.
4. Lange, J.P., 2007. Ligno cellulose conversion: an introduction to chemistry, process and economics, Biofuels. Bioprod. Biorefining, 1: 39-48.
5. Moiser, N., C. Wyman, B. Dale, R. Elander, Y. Lee, M. Holtzapple and M. Ladisch, 2005. Features of promising technologies for pretreatment of lignocellulosic biomass, Bioresource Technol, 96: 673-686.
6. Wyman, C., B. Dale, R. Elander, M. Holtzapple, M. Ladisch and Y. Lee, 2005. Coordinated development of leading biomass pretreatment technologies, Bioresource Technol, 96: 1959-1966.
7. Sluiter, A., B. Hames, R. Ruiz, C. Scarlata, J. Sluiter and D. Templeton, 2005. Determination of structural carbohydrates and lignin in biomass, Biomass analysis technology team – Natural Renewable Energy Laboratory (NREL).
8. Rodriguez– Chon, A., J.A. Ramirez, G. Garrote and M. Vazquez, 2004. Hydrolysis of sugarcane bagasse using Nitric Acid: A Kinetic Assessment, J. Food. Eng, 61: 143-152.
9. Reeves, J., 1993. Chemical studies on the composition of fiber fractions and lignin determination. J. Dairy. Sci., 76: 120-128.
10. Jernejc, K., A. Cimerman and A. Perdih, 1982. Citric acid production in chemicaly defined media by *Aspergillus niger*. European J. Appl. Microbiol. Biotechnol, 14: 29-33.
11. Sodeck, G., J. Modl, J. Kominek and W. Salzburn, 1981. Production of citric acid according to the submerged fermentation process. Process. Biochem., pp: 9-11.