World Academy of Science, Engineering and Technology
International Journal of Biotechnology and Bioengineering
Vol:10, No:10, 2016

Production of Bioethanol through Hydrolysis of Agro-Industrial Banana Crop Residues

Sánchez Acuña, Juan Camilo, Granados Gómez, Mildred Magaly, Navarrete Rodríguez, Luisa Fernanda

Abstract**—**Nowadays, the main biofuels source production as bioethanol is food crops. This means a high competition between foods and energy production. For this reason, it is necessary to take into account the use of new raw materials friendly to the environment. The main objective of this paper is to evaluate the potential of the agro-industrial banana crop residues in the production of bioethanol. A factorial design of 2^4 was used, the design has variables such as pH, time and concentration of hydrolysis, another variable is the time of fermentation that is of 7 or 15 days. In the hydrolysis phase, the pH is acidic (H_2SO_4) or basic (NaOH), the time is 30 or 15 minutes and the concentration is 0.1 or 0.5 M. It was observed that basic media, low concentrations, fermentation, and higher pretreatment times produced better performance in terms of biofuel obtained.

Keywords**—**Bioethanol, biofuels, banana waste, hydrolysis.

I. Introduction

At present, the biofuels have taken a great importance due to the various energetic and environmental problems generated by the fossil fuels. The bioethanol is a biofuel derivative of sources with high sugar content, preferably those do not interfere with food chain. The biofuels of second generation use the lignocellulosic materials as raw material in the process of production. The wastes of the crops are considered lignocellulosic materials; these are in big amounts and have a low cost [1].

The lignocellulosic materials are compounds of cellulose, hemicellulose and lignin. The pretreatment produces a rupture of the lignin structure, which may be greater or lesser depending of the material composition. Each kind of raw material has a different pretreatment with the objective of rising the availability of sugar in the fermentation stage. The most known pretreatment includes the acid hydrolysis because of its low cost of operation, in spite of having problems like machine corrosion and the necessity of a neutralization. It has a high efficiency in the conversion of cellulose to monosaccharides, increasing the digestibility of the cellulose in the obtained solid wastes [2]. The basic pretreatment increases the internal surface of the raw material, decreases the polymerization degree and the crystallinity [3].

Five banana species are cultivated in Colombia and these plants produce fruit once during their life cycle. The harvest produces a big amount of waste because the plant has a big size, the stem reaches up seven meters of high and the leaves may have fifteen centimeters of width and three meters long.

When the waste has a good management, this is used as compost but requires a high workforce cost and it has a slow biodegradation. In cases when a bad management exists, the waste could finish contaminating soil and water sources [4], [5]. The banana crop waste would have a benefit for the producers when it is used in ethanol production. This paper evaluated two pretreatments for bioethanol generation, using agro-industrial waste of banana crop as raw material.

II. Methodology

A. Experimental Design

The identification of variables was set up according to [6]; the variables considered as essential in the production of bioethanol are fermentation time, pH of hydrolyzing agent, concentration and hydrolysis time [7]. The influence of the previous ones was evaluated through a factorial experimental design of 2^4 as shown in Table I.

TABLE I
EXPERIMENTAL DESIGN

Factor	Levels		Unit
Fermentation Time	7	15	Days
pH of the hydrolyzing agent	Acid	Basic	-
Concentration of hydrolyzing agent	0,1	0,5	Molar
Hydrolysis Time	15	30	Minutes

B. Gathering and Characterization of Raw Material

The raw material used in the present evaluation was taken from the municipality of Yopal, department of Casanare, Colombia. This zone is characterized by being a large producer of banana.

The raw material was subjected to a characterization in order to determine their composition and establish their potential as a possible source of biofuel production [8].

C. Obtaining Bioethanol

The first phase is a mechanical treatment to the raw material; the treatment consists of crushing until a size of 5 mm or less. The second phase is the hydrolysis, the samples have each one 80 g of the mechanical treated material, these have been added 200 mL of hydrolyzing agent (H_2SO_4 or NaOH) with a concentration of 0.1 M or 0.5 M, later were carried to heat to 90 °C in 15 or 30 minutes. For the microorganism activation, which were used in the fermentation, 3.5 g of yeast (*Saccharomyces cerevisiae*) was used in 100 mL of distilled water to a temperature of 40 ºC. Finally, the product of the hydrolysis was washed with

J. Sánchez Acuña, M. Granados Gómez, and L. Navarrete Rodríguez are with Libre University, Department of Environmental Engineering, Bogotá, Colombia (e-mail: juanc.sancheza@unilibrebog.edu.co, mildredm.granadosg@unilibrebog.edu.co, luisaf.navarreter@unilibrebog.edu.co).

distilled water and filtered to avoid losses, reaching a pH between 4.5 and 8. For the fermentation phase, the filtering material and the microorganism activated was stored in an amber bottle of 1 L in which it was incubated over a period of 7 or 15 days with a temperature of 25 ºC. When the fermentation time was fulfilled, the content of the amber bottle was filtered and fractionally distilled to obtain the ethanol [8].

D. Tests Carried Out with Bioethanol

The refractive index by refractometer method, density by pycnometer method and IR spectrophotometry were determined for the obtained bio-alcohol samples.

E. Statistical Analysis

With the purpose of evaluating the single and combined influence of the critical variables and their respective levels on the production of bioethanol, a factorial ANOVA statistical analysis was carried out through a free version of program Statgraphics, downloaded on June 15, 2016.

III. Results and Discussion

A. Characterization of Raw Material

Table II shows the characterization performed to the raw material, as well as comparative values reported in the literature. It is appreciated that the percentage of cellulose is the highest, followed by hemicellulose, indicating that the waste of the banana crop is a potential source for obtaining bioethanol. Additionally, their low lignin contents indicate that there is not a need for strong pretreatment for its degradation [9], [10].

TABLE II
Raw Material Percentage Composition

Organic Fraction	Experimental	Theoretical
Lignin (%)	11,1	12,18 [9]
Cellulose (%)	50,4	28,34 [9]
Hemicellulose (%)	6,7	15,67 [9]

B. Obtained Ethanol Volumes

Fig. 1 shows the results obtained with the applied experimental design. In this one, it is possible to understand the combination of the established variables, which shows that the highest yields were obtained in processes with basic pH (NaOH) and high hydrolysis times. The best result was the treatment that was carried out with fifteen (15) days of fermentation time and 0,1 M of hydrolyzing agent concentration. On the other side, it is observed that processes with acidic pH (H_2SO_4) and fifteen minutes of hydrolysis time had the worst performance, in this way; the lowest result was the treatment that was carried out with fifteen days of fermentation and 0.5 M of hydrolyzing agent concentration.

Aforementioned behavior could be attributed to the fact that hydrolysis in high concentrations may form inhibitory agents, which affect the fermentation process; such agents are present in greater proportion when the hydrolysis pH is acid and times thereof are low. This fact could generate that processes with longer hydrolysis time, lower concentrations, longer fermentation times and basic pH, have a tendency to produce more ethanol volumes. Additionally, it was noted that such treatments have lower standard deviation [11], [12].

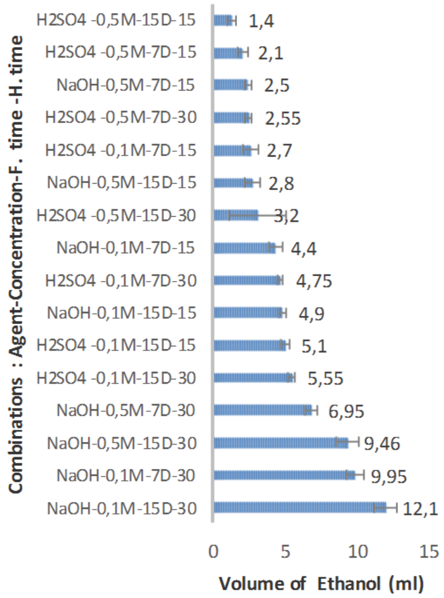

Fig. 1 Volumes of Ethanol (F: fermentation, H: Hydrolyzing)

C. Statistical Analysis

The results obtained from the statistical analysis are shown in Fig. 2, wherein the critical variables that govern the production of bioethanol are observed, such as time and pH of hydrolysis, and also the combined effect of these. Likewise, it is observed that the combined effects of the hydrolyzing agent concentration with the hydrolysis time and also the combined effect of the pH of hydrolyzing agent with the hydrolysis time are those that have less influence on the production of bioethanol. This result could be attributed to the essential role of hydrolysis in the release of cellulose for bioethanol formation.

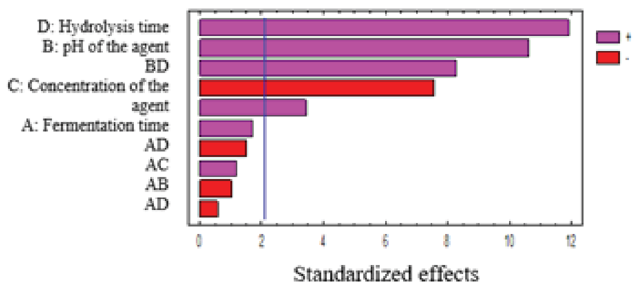

Fig. 2 Pareto diagram simple and combines effects

D. Refraction

The refraction index was determined for the samples of obtained ethanol. These results are recorded in Fig. 3, where it's possible to notice that the refraction that was experimentally obtained (Blue line) is compared with the theoretical value of the pure bioethanol refraction (Red line). In this way, the refraction values with 15 minutes of hydrolysis time have a tendency to move away from the value of pure ethanol (1.360 to 20 ºC) and be closer to water value (1,330 a 20 °C). Combinations with 30 minutes of hydrolysis time had an opposite behavior because they were closer to pure ethanol. Also, the combinations with acid pH have lower refraction than the combinations with basic pH. That comportment could indicate the presence of small fractions of water into the volumes of ethanol obtained with acid pH and times of hydrolysis of 15 minutes.

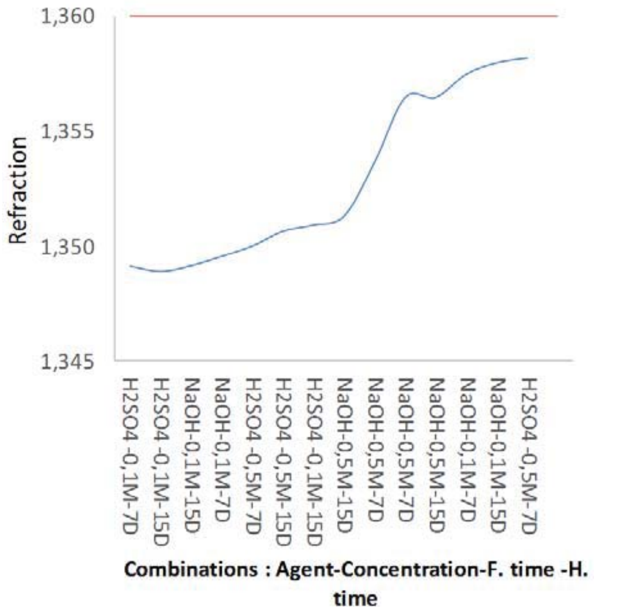

Fig. 3 Refractions Obtained for Different Factor Combinations (F: fermentation, H: Hydrolyzing)

E. Densities

Fig. 4 shows the obtained densities, in which a similar behavior of the refractions results can be noticed. In which, obtained volumes for combinations with hydrolysis times of 15 minutes or acid hydrolyzing agent had densities closer to that of the water than to that of pure ethanol (789 mg/l a 20 °C). While the obtained volumes from the combinations with hydrolysis time of 30 minutes or basic hydrolyzing agent had an opposite effect.

The results suggest a presence of water in mix with ethanol, the fraction of water reduce according as rise the time of hydrolysis and pH of hydrolyzing agent.

F. IR Spectrum

The IR spectrum of one of the samples obtained in Fig. 4 identified the presence of a functional group associated to alcohols in which absorption bands are found into 3050-3600 band O-H, into 2950-3000 band C-H, and into 1000-1100 band C-O [13].

IV. Conclusions

The waste that come from the banana crop could be considered like a potential source of bioethanol, due to its high cellulose content and low lignin content. The production of bioethanol is a process which is largely influenced by the hydrolysis time.

The most suitable experimental conditions are those involving fermentation times 15 days, with basic pH and concentration of agent hydrolyzing of 0,1M.

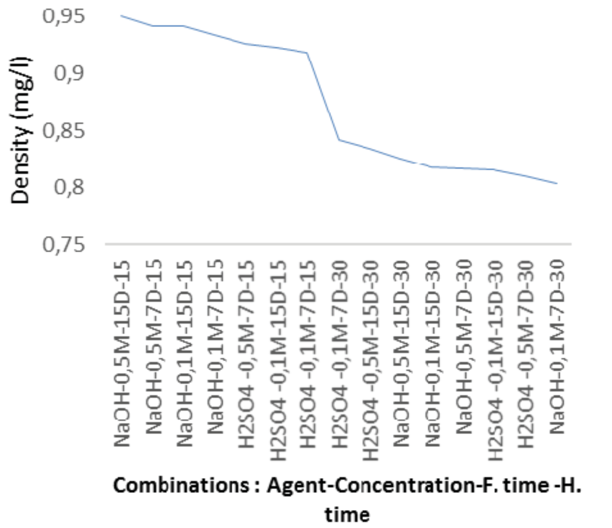

Fig. 4 Densities Obtained for Different Combination of Factors (F: fermentation, H: Hydrolyzing)

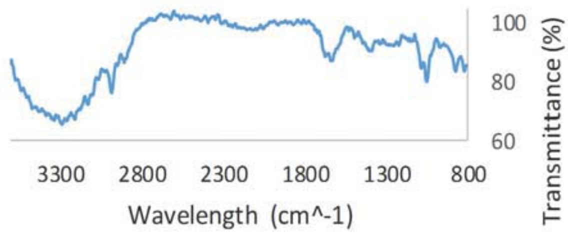

Fig. 5 IR Spectrum Experimental Sample Bioethanol

References

[1] G. O. Young, "Synthetic structure of industrial plastics (Book style with paper title and editor)," in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.
[2] K. Albarracín, "Obtención de Bioetanol Anhidro a Partir de Paja (Stipa ichu)", *Revista Politécnica*, vol. 36, 2nd, 2015.
[3] M. Fernandes,"Bioethanol production from extracted olive pomace: dilute acid hydrolysis", *Bioethanol*, vol. 2, 1st, pp. 103-111, 2016.
[4] M. García,"Alkali treatment of fungal pretreated wheat straw for bioethanol production", *Bioethanol*, vol. 2, 1st, pp. 32-43, 2016.
[5] M. Moretti, "Posible proceso productivo de etanol con residuos de banano y sus impactos en el Valle del Chira", Ingeniero Industrial y sistemas, Universidad de Piura, 2014.
[6] D. Benarji, "Statistical Optimizations of Fermentation Factors on Bioethanol Production from Mahua Flower (Madhuca indica) with Saccharomyces cerevisiae by Response Surface Methodology in Batch Bioreactor", *Journal of Microbiology and Biomedical Research*, vol. 2, 1st, pp. 1-7, 2016.
[7] A. Guarnizo, "Pretratamientos de la celulosa y biomasa para la sacarificación.", *Scientia et Technica*, vol. 42, 1st, pp. 284-287, 2009.
[8] A. Gutiérrez, J. del Rio, "Composición química de diversos materiales lignocelulósicos de interés industrial y análisis estructural de lignina", *Biotecnología,* Universidad de Sevilla, 2010.
[9] J. Sánchez,"Análisis tecno-económico de una biorefinería a partir de residuos del plátano", *Revista de la Facultad de Ciencias Químicas*, vol. 13, pp. 32-38, 2015.

[10] L. Cuervo,"Lignocelulosa Como Fuente de Azúcares Para la Producción de Etanol", *BioTecnología*, vol. 13, 3rd, pp. 11-21, 2009.
[11] P. Meléndez, "Análisis del pretratamiento de residuos lignocelulósicos para la producción de biocombustibles y bioproductos de alto valor agregado", *Jóvenes en la Ciencia*, vol. 1, 2nd, pp. 534-538, 2015.
[12] L. Niño López; A. Acosta Cárdenas; R. Gelves Zambrano, “Evaluación de pretratamientos químicos para la hidrolisis enzimática de residuos lignocelulósicos de yuca”, Revista facultad de ingeniería universidad de Antioquia, núm. 69, pp. 317-326, 2013.
[13] R. Silverstein, “*Spectrometric identification of organic compounds”*. New York: Wiley, 1981.