International Scientific Journal
Journal of Environmental Science
http://environment.scientific-journal.com/

Bioethanol Production from Waste Office Paper

R. Maceiras, V. Alfonsín
Centro Universitario de la Defensa,
Escuela Naval Militar, Plaza de España 2,
36920 Marín, Spain

J.E. Poole
Escuela Naval Militar, Plaza de España 2,
36920 Marín, Spain

***Abstract*—In this research, bioethanol was produced from office waste by acid hydrolysis and subsequent fermentation using *Saccharomyces cerevisiae*. Conditions for the acid hydrolysis of waste paper were optimized by varying acid volume from 100 to 300 mL, reaction time 30-180 min, with a sulfuric acid concentration of 5.0 at 121 ºC in an autoclave. The best results were obtained for acid hydrolysis of waste paper with the following conditions: an acid volume of 200 mL during 120 min of reaction time. After the fermentation process with *Saccharomyces cerevisiae* during 24 hours at 30 ºC and 150 rpm, 0.1035 mL ethanol /g dried paper were obtained. Finally, some physical properties of obtained bioethanol were determined and compared with the standards.**

Keywords*—*bioethanol, waste office paper, acid hydrolysys, fermentation

I. INTRODUCTION

Bioethanol is a fuel derived from renewable sources of feedstock, divided in three main groups: sugary, starchy and lignocellulosic biomass. The first generation biofuels presents the drawback of competing using sources of human and animal nutrition. For that reason, second generation raw materials for bioethanol production are gaining interest [1]. They are non-food biomass sources, mainly lignocellulosic materials, such as agricultural residues, waste materials or municipal solid waste. During the process, cellulose is hydrolyzed to produce fermentable sugars (glucose, xylose,…) followed by fermentation of sugars into ethanol [2]. Ethanol obtained from cellulose is an environmental friendly fuel. It is biodegradable and water soluble and produces lower emissions of carbon monoxide [3].

The hydrolysis can be carried out by enzymes or acids [4]. The main disadvantages of enzymatic hydrolysis are that it requires a pretreatment of the raw material to improve the enzymatic digestibility [5] and longer retention time [6]. Acid hydrolysis may be carried out with diluted or concentrated acid. The advantages of diluted acid hydrolysis are that it attacks polysaccharides, being easier to hydrolyze than cellulose and acid losses are not important [7].

The present research is based on bioethanol production from waste office paper. This feedstock results to be attractive for biofuel production due to its availably. Despite of recycling efforts have been strengthened in the last years, the recycling rate is about a 65%, since the quality of the paper decreases with the recycling process [8]. Then, waste office paper could be a suitable raw material for obtaining bioethanol. Recent studies have indicated the potential of this feedstock [9-11].

Many researchers have investigated the different technologies for the bioethanol production from paper and paper-derived materials. Li et al. [12] showed a cellulose conversion efficiency about 40% from newspaper saccharification at solids loading of 10% (w/w). Guerfali et al. [13] obtained 0.38 g/g ethanol with enzimatic hydrolysys and 36 h of fermentation with *Saccharomyces Cerevisiae* from newspaper and office paper residues. Young et al. [7] reported glucose yield of 92.1% for paper sludge with acid hydrolysis (H_2SO_4 70.8%) during 3.6 h. Byagdi and Kalburgi [14] got a 6.9% (v/v) of ethanol from newspaper using enzymatic hydrolyss and 6 days of fermentation.

In this study, the influence of different parameters on bioethanol production from waste office paper has been analyzed. Acid hydrolysis was carried out at various reaction time and amount of acid.

II. EXPERIMENTAL SECTION

The bioethanol production from waste office paper is divided in three stages: pretreatment of raw material, acid hydrolysis and fermentation. The scheme of the process is shown in Fig. 1.

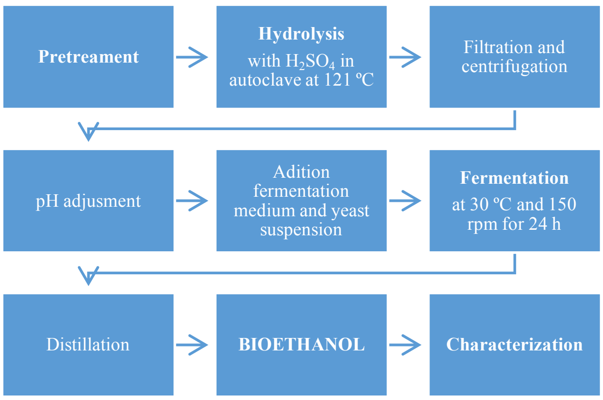

Fig. 1. Flow chart of bioethanol production from waste paper office

A. Pretreatment

Waste paper used in this research was collected locally from office and photocopy services waste. Previous the hydrolysis stage, the paper was prepared as pieces of dimensions 0.5x0.5 cm and the humidity content was determined using a moisture analyzer RADWAG (MA 110.R) with an accuracy of 0.001%.

B. Acid Hydrolysis

Acid hydrolysis was done to break down cellulose into glucose units. Experiments were carried out in 1 L Erlenmeyer flasks. For that, 5 g of paper was soaked in different amounts of H_2SO_4 (5% weight): 100, 200 and 300 mL. The mixture was place in an autoclave at 121 ºC. The influence of time on the process was determined in the rage of 30-180 min. After hydrolysis, the samples were filtered and centrifuged to obtain the hydrolysate product. After that, the pH of the obtained product was adjust at 4.5-5.0 by adding sodium hydroxide solution 5M.

Table 1 shows the experimental conditions of the different test carried out. It has been observed the hydrolysis time and acid volume in each experience.

TABLE I. EXPERIMENTAL CONDITIONS

Test	Time (min)	Volume (mL)
1	30	200
2	60	200
3	120	200
4	180	200
5	120	100
6	120	300

C. Fermentation

The fermentation of all the samples was done at 30 ºC with orbital shaking at 150 rpm during 24 hours with the yeast *Saccharomyces cerevisiae*. Anaerobic fermentation were performed in 250 mL Erlenmeyer flasks containing the hydrolysate product, 15% (v/v) of fermentation medium and 10% of yeast suspension. After fermentation, the obtained product was distilled in order to get the bioethanol. The sample was distilled twice to improve the quality of the obtained bioethanol.

D. Bioethanol Characterization

The bioethanol produced was characterized to determine some properties such as refractive index, density, acid value, and turbidity and color. The density was determined using a pycnometer type Gay-Lussac at 15 ºC. Acid value was measured according UNE-EN 15491 [15]. Turbidity and color were analyzed following the UNE-EN 15769 [16].

Ethanol concentration of the sample was determined using a refractometer ABBE-REF1. For that, the refractive index of different water-ethanol mixtures were measured and the obtained data allowed to obtain a calibration curve (Fig. 2).

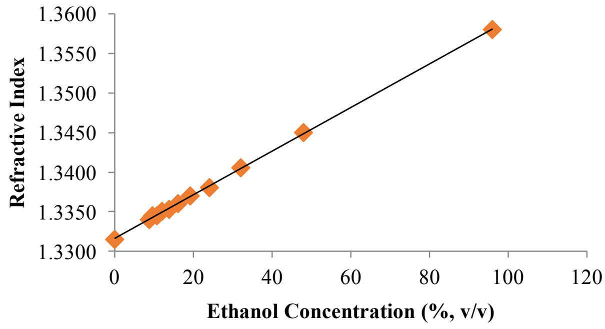

Fig. 2. Refractive index as a function of ethanol concentration in water-ethanol mixtures at 20 ºC

The fit of the curve relates the ethanol concentration with the refractive index of a sample, according to the following equation:

$$y = 0.0003x + 1.3316\,,\quad R^2 = 0.9996 \qquad (1)$$

III. RESULTS AND DISCUSSION

The focus of this research is to produce bioethanol from waste office paper by acid hydrolysis and subsequent fermentation. Acid hydrolysis needs the optimization of process parameters, including amount and concentration of sulfuric acid, reaction time, and reaction temperature. Then, the analysis of time and amount of acid on concentration of obtained bioethanol was carried out. Finally, some properties of the obtained bioethanol were determined.

A. Hydrolysis of Waste Paper Office

The hydrolysis consists of the conversion of cellulose present in the paper into the bioethanol. Hydrolysis was carried out using a solution of sulfuric acid of 5% weight at different reaction time. The graphical representation of the obtained results is shown in Fig. 3.

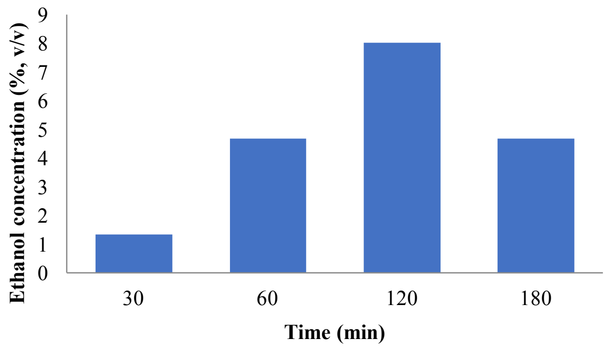

Fig. 3. Influence of hydrolysis time on ethanol concentration.

The results showed that maximum ethanol concentration is achieved at 120 min. Similar research was carried out by Kumar et al. [17] who obtained the best results for 2 hours of acid hydrolysis. Therefore, time taken is 120 min for further study.

Other important parameter on the process is the amount of acid. Then, three experiences were carried out varying the acid volume with the same concentration and 120 min at 121 ºC in an autoclave. The graphical representation of the obtained results is shown in Fig. 4. The data revel that there was substancial decreases in ethanol concentration when waste office paper was treated with 100 and 300 mL of acid. This finding is in agreement with earlier work reported by Young et al. [7].

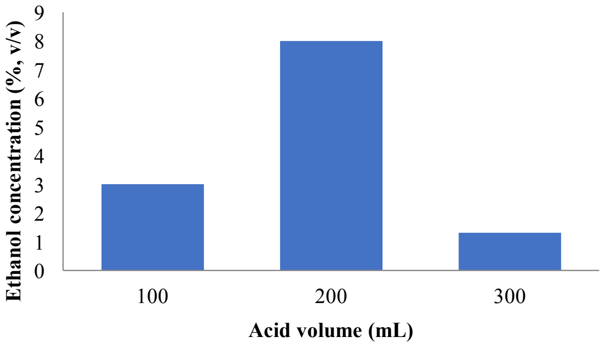

Fig. 4. Influence of hydrolysis time on ethanol concentration.

B. Fermentation and Purification

Fermentation of sugars was carried out by yeast Saccharomyces cerevisiae at pH 4.5-5.0, 30 ºC, 150 rpm and 24 hours. After that, the product was distilled twice and the purity of obtained bioethanol was measured, resulting in 0.1035 mL/g waste office paper with a purity of 9.67%.

C. Bioethanol Characterization

The density of a material is defined as the mass of the material per unit its volume. The density of the bioethanol produced from the waste office paper was 0.9806 g/cm^3. According to ASTM 4806 [18], the value of density for fuel ethanol is 0.99 g/cm^3, then the obtained bioethanol meets the density value of this type of biofuel.

The acidity value measures the presence of low molecular mass organic acids, such as acetic acid. It is important to keep such acids at a very low level because they are highly corrosive to many metals. UNE-EN 15376 [19] establishes a maximum of 0.007%, the obtained bioethanol has an acidity value of 0.0009%, lower that the set limit.

Finally, turbidity and color were measured. Following the standard procedure, the obtained bioethanol meets with the specification of transparent and colorless (Fig. 5).

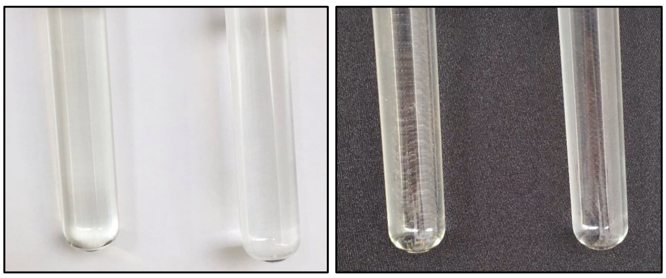

Fig. 5. Determination of turbidity and colour according UNE-EN 15769.

IV. Conclussions

The bioethanol production from waste paper office was successful. The best conditions for acid hydrolysis of 50 g of raw material were 200 mL of sulfuric acid and 120 min of reaction time in an autoclave at 121 ºC. After fermentation with *Saccharomyces cerevisiae*, 0.1035 mL of bioethanol/ g waste office paper with a purity of 9.67 %.

Finally, some properties were measured according the standards and the obtained bioethanol conforms to the set limit. Based on the obtained results, it can be concluded that waste paper office is a suitable raw material for bioethanol production.

References

[1] S.N. Naik, V.V. Goud, P.K. Rout, and A.K. Dalai, “Production of first and second generation biofuels: A comprehensive review,” Renew. Sustain. Energy Rev., vol. 14, pp. 578-597, 2010.

[2] G.M. Walker, Bioethanol: Science and technology of fuel alcohol, 1st ed., Graeme M. Walker & Ventus Publishing ApS, 2010.

[3] D. Pimentel, Global Economic and Environmental Aspects of Biofuels, vol. 17, CRC Press. New York, 2012.

[4] I. Romero, E. Ruiz, E. Castro, and M. Moya, “Acid hydrolysis of olive tree biomass,” Chem. Eng. Res. Design, vol. 88, pp. 633-640, 2010.

[5] Y. Sun, and J. J. Cheng, “Dilute acid pretreatment of rye straw and bermudagrass for ethanol production,” Bioresour. Technol., vol. 96, pp. 1599-1606, 2005.

[6] L.O. Ingram, H.C. Aldrich, C.C. Borges, T.B. Causey, A. Martínez, and F. Morales, “Enteric bacterial catalysts for fuel ethanol production,” Biotechnol. Prog., vol. 15, pp. 855-866, 1999.

[7] J. Young Jung, M. Suk Choi, and J. Kyung Yang, “Optimization of Concentrated Acid Hydrolysis of Waste Paper Using Response Surface Methodology,” J. Korean Wood Sci. Tech., vol. 41, pp. 87-99, 2013.

[8] A. Kumar Dubey, P.K. Gupta, N. Gara, and S. Naithani, “Bioethanol production from waste paper acid pretreated hydrolyzate with xylose fermenting Pichia stipitis,” Carbohydr. Polym., vol. 88, pp. 825-829, 2012.

[9] L. Wang, M. Sharifzadeh, R. Templer, and R.J. Murphy, “Bioethanol production from various waste papers: Economic feasibility and sensitivity analysis,” App. Energy, vol. 111, pp. 1172-1182, 2013.

[10] B. Zainab, and A. Fakhra, “Production of Ethanol by fermentation process by using Yeast Saccharomyces cerevisae,” Int. Res. J. Environ. Sci., vol. 3, pp. 24-32, 2014.

[11] M. Guerfali, A. Saidi, A. Gargouri, H. Belghith, “Enhanced Enzymatic Hydrolysis of Waste Paper for Ethanol Production Using Separate Saccharification and Fermentation,” Appl Biochem Biotechnol., vol. 175, pp. 25-42, 2015.

[12] A. Li, B. Antizar-Ladislao, and M. Khraisheh, “Bioconversion of municipal solid waste to glucose for bio-ethanol production,” Bioprocess Biosyst. Eng., vol. 30, pp. 189-196, 2007.

[13] M. Guerfali, A. Saidi, A. Gargouri, and H. Belghith, “Enhanced enzymatic hydrolysis of waste paper for ethanol production using separate saccharification and fermentation,” App. Biochem. Biotechnol., vol. 175, pp. 25-42, 2014.

[14] S. Byagdi, and P. Kalburgi, “Production of Bioethanol from Waste Newspaper,” Procedia Environ. Sci., vol. 35, pp. 555-562, 2016.

[15] UNE-EN 15491. Ethanol as blending component for petrol. Determination of total acidity. Colour indicator titration method, AENOR, Madrid, 2007.

[16] UNE-EN 15769. Ethanol as blending component for petrol. Determination of appearance. Visual method, AENOR, Madrid, 2009.

[17] A. Kumar, P. Gupta, N. Garga, and S. Naithani, “Bioethanol production from waste paper acid pretreated hydrolyzate with xylose,” Carbohydr. Polym., vol. 88, pp. 825-829, 2012.

[18] ASTM D4806-16a, Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel, ASTM International, West Conshohocken, PA, 2016.

[19] UNE-EN 15376. Automotive fuels. Ethanol as a blending component for petrol. Requirements and test methods, AENOR, Madrid, 2015.