Advanced Research Journal of Biochemistry and Biotechnology: Vol. 1(1): pp 001-005, March, 2014.

Full Length Research Paper

Bioethanol Production by Coffee Husk for Rural Area

Omprakash Sahu

Department of Chemical Engineering, KIOT, Wollo University, Ethiopia

*Correspondence Author's Email:ops0121@gmail.com

Accepted 19th March, 2014

Bioethanol is a renewable energy source produced through fermentation of sugars. A dramatic increase in ethanol production using the agriculture waste is currently been practical because production for ethanol will compete for the limited agricultural waste. A potential source for low cost ethanol production is to utilize lignocellulosic materials such as crop residues, grasses, sawdust, wood chips, solid animal waste and industrial wastes. The objective of this work was to evaluate the feasibility of ethanol production and optimization from coffee husk by using commercial bakery yeast, i.e., S. cereviciae. The study was conducted, at fermentation temperature 30 °C and pH 5, and treated using different acid concentrations and residence times. Coffee husk was hydrolyzed by refluxing, a solid to liquid ratio of 1:10, using dilute sulfuric acid (1 to 5 %) and distilled water at hydrolysis time of 1 to 11 hours keeping boiling temperature. 90 % maximum total sugar concentration was obtained at 5 h acid free hydrolysis. Based on these hydrolysis results, fermentation process was performed.

Keywords: Biomass, bioenergy, fuel, suitability, transportations

INTRODUCTION

The term bio-fuels can refer to fuels for direct combustion for electricity production, but is generally used for liquid fuels in transportation sector (Linoj et al., 2006). Ethanol has potential as a valuable replacement of gasoline in the transport fuel market. However, the cost of bioethanol production is more compared to fossil fuels. The world bioethanol production in 2001 was 31 billion liters (Mosier et al., 2005). It has grown to 39 billion liters in 2006 and is expected to reach 100 billion liters in 2015. Brazil and the USA are the two major ethanol producers accounting for 62% of the world production (Himmel et al., 2009). Large scale production of fuel ethanol is mainly based on sucrose from sugarcane in Brazil or starch, mainly from corn, in the USA. The use of bio-fuels can contribute to the mitigation of greenhouse gas emissions, provide a clean and therefore sustainable energy source, and increase the agricultural income for rural poor in developing countries (Chandel et al., 2009). Today, bio-fuels are predominantly produced from biomass resources. Biomass appears to be an attractive feedstock for three main reasons (Xiang et al., 2004): (1) it is a renewable resource that could be sustainably developed in the future, (2) it appears to have formidably positive environmental properties resulting in no net releases of carbon dioxide and very low sulfur content, and (3) it appears to have significant economic potential provided that fossil fuel prices increase in the future (Sun and Cheng, 2002). There is a growing interest worldwide to find out new and cheap carbohydrate sources for production of bio-ethanol (Ballesteros et al., 2004; Alemayehu et al., 2007). Currently, a heavy focus is on bio-fuels made from crops, such as corn, sugar cane, and soybeans, for use as renewable energy sources (Yishak et al., 2009).

Though it may seem beneficial to use renewable plant materials for bio-fuel, the use of crop residues and other biomass for bio-fuels raises many concerns about major environmental problems, including food shortages and serious destruction of vital soil resources (Uma and Polasa, 2000). For a given production line, the comparison of the feedstocks includes several issues (Taherzadeh and Karimi, 2007): (1) chemical composition of the biomass, (2) cultivation practices, (3) availability of land and land use practices, (4) use of resources, (5) energy balance, (6) emission of greenhouse gases, acidifying gases and ozone depletion gases, (7) absorption of minerals to water and soil, (8) injection of pesticides, (9) soil erosion, (10) contribution to biodiversity and landscape value losses, (11) farm-gate price of the biomass, (12) logistic cost (transport and storage of the biomass), (13) direct economic value

Of the feedstocks taking into account the co-products, (14) creation or maintain of employment, and (15) water requirements and water availability (Wyman et al., 2005).

Bio-ethanol feedstocks can be divided into three major groups: (1) sucrose-containing feedstocks (e.g. sugar cane, sugar beet, sweet sorghum and fruits), (2) starchy materials (e.g. corn, milo, wheat, rice, potatoes, cassava, sweet potatoes and barley), and (3) lignocellulosic biomass (e.g. wood, straw, and grasses). In the short-term, the production of bio-ethanol as a vehicular fuel is almost entirely dependent on starch and sugars from existing food crops (Ohgrem et al., 2007). The drawback in producing bio-ethanol from sugar or starch is that the feedstock tends to be expensive and demanded by other applications as well (Stewart, G. and Russell,)[65]. Any bio-ethanol project attacks seven major national issues: (1) sustainability, (2) global climate change, (3) biodegradability, (4) urban air pollution, (5) carbon sequestration, (6) national security, and (7) the farm economy. Lignocellulosic biomass is envisaged to provide a significant portion of the raw materials for bio-ethanol production in the medium and long-term due to its low cost and high availability (Altintas et al., 2002; Gaur, 2006; Cardona and Sanchez, 2007).

Bio-fuels are liquid or gaseous fuels made from plant matter and residues, such as agricultural crops, municipal wastes and agricultural and forestry by-products (Subramanian et al., 2005). Liquid bio-fuels can be used as an alternative fuel for transport, as can other alternatives such as liquid natural gas (LNG), compressed natural gas (CNG), liquefied petroleum gas (LPG) and hydrogen. Bio-fuels could significantly reduce the emissions from the road-transport sector if they were widely adopted (Wyman and Hinman, 1990). They have been shown to reduce carbon emissions, and may help to increase energy security. There are many different types of bio-fuels, which are produced from various crops and via different processes. Bio-fuels can be classified broadly as bio-diesel and bio-ethanol, and then subdivided into conventional or advanced fuels (Bansal and Singh, 2003; Taherzadeh, 2009). The aim of this work was to study the optimum hydrolysis of coffee husk with diluted sulfuric acid and distilled water, and determining the influence of acid concentration and retention times. Also to evaluate the feasibility of ethanol production by fermentation of coffee husk by using commercial bakery yeast such as Saccharomyces cereviciae.

MATERIAL AND METHODS

Material

The coffee husk was arranged from the local area. The husk was oven-dried at 60 °C for 48 h (to moisture content of 15 %), grinded by coffee grinder and sieved (Urbaneja et al., 1996). The samples were stored in hermetically closed plastic containers at room temperature, until required for treatments (Kwiatkowski, 2006). Erlenmeyer flasks, round bottom flask, yeast (S. cereviciae), sulfuric acid, sodium hydroxide, Fehling solution, methyl blue, Ph-meter, thermometer, micropipette, measuring cylinder, Isopropanol (99 %), ethanol (96 %), gas chromatography, and icebox were used during the study.

Methods

Hydrolysis

Coffee husk was hydrolyzed with dilute sulfuric acid (H_2SO_4) at different concentrations (1 to 5% H_2SO_4). In order to break down the cellulose and hemicelluloses into simple sugar the ground coffee husk sample was maintained at solid to liquid ratio of 1:10, in 250 Ml round bottom flask, and refluxed, retaining samples of 1, 2, 4, 6 and 10 h for subsequent fermentation experiments. Similarly, the hydrolysis experiment was repeated with distilled water without using dilute sulfuric acid. After hydrolysis the liquid fraction of the hydrolysate samples were cooled, filtered, collected, and their sugar composition determined by Fehling method.

The distilled water and dilute sulfuric acid hydrolysates were adjusted to Ph 5 by adding concentrated sulfuric acid and 2N Sodium hydroxide, and the solutions were prepared for fermentation (Dawson and Boopaty, 2008).

Fermentation

The yeast *S. cereviciae*, purchased from local market which was used in experiments. After hydrolysis, the flasks containing the hydrolyzed samples were covered with cotton wool, wrapped in aluminum foil, autoclaved for 15 minutes at 121 °C and allowed to cool at room temperature. Fermentation was carried out in 250 Ml Erlenmeyer flask with 3 g/L of yeast (S. cereviciae) at incubation temperature of 30 °C (Thuesombat et al., 2007; Franca et al., 2008). Ethanol concentration was analyzed by gas chromatography at different fermentation times (06 to 50 h). Samples were withdrawn every 6 h and the fermentation was carried out for 50 h.

Analytical

Determination of sugar content*:*

The amount of sugar in the hydrolyzed samples was determined by Fehling method. 50 Ml of hydrolyzed

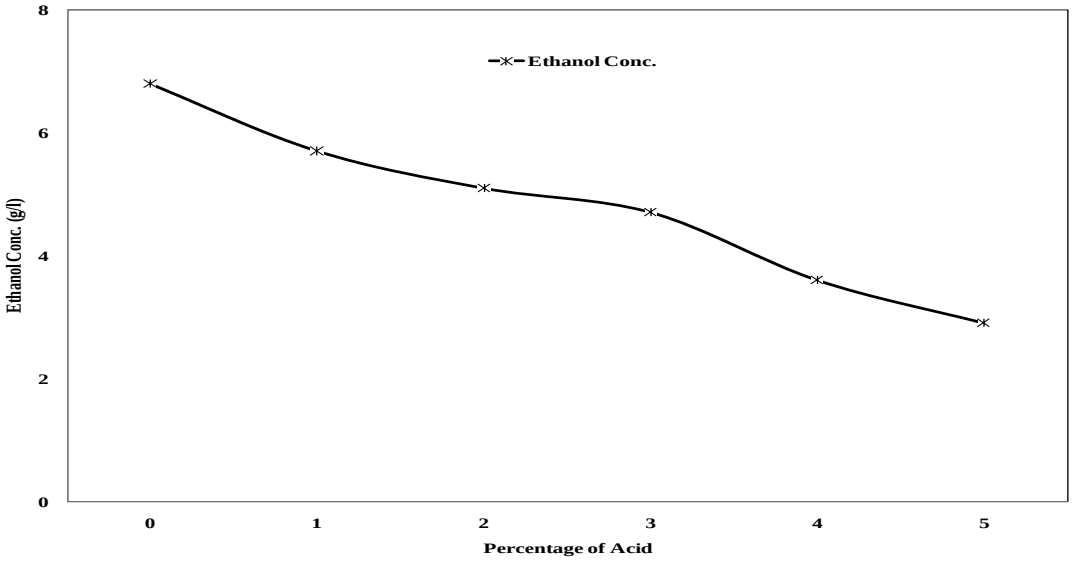

Figure 1. Effect of acid on ethanol concentration

sample solution was dissolved in 10 Ml of distilled water and 2 Ml of concentrated HCl was added and boiled. The obtained sample was neutralized with NaOH and the solution was made up to a volume of 300 Ml and taken into the burette. The 5 Ml of Fehling A and 5 ml of Fehling B were taken and mixed with 90 Ml of distilled water in 250 Ml Erlenmeyer flask and Methylene blue indicator was added. The solution in the flask was titrated with burette solution in boiling conditions until disappearance of blue color and the volume at which brick red color observed were recorded. For each sample the sugar content was calculated by using the formula given below (Periyasamy et al., 2009).

Sugar Content (%)= (300mlxf/V) x100

Where, f is Fehling factor and V is volume used in the titration

Ethanol concentration by gas chromatographic

The ethanol concentration was determined by gas chromatography. Gas chromatograph (DANI GC 1000) equipped with flame ionization detector (FID) was employed for the separation and quantification of ethanol. A fused silica capillary column (30m 0.32mm) coated with 95 % methylpolysiloxane (stationary phase) was fitted into the instrument to provide on column injection. The injector and detector temperature were maintained at 210 and 250 °C, respectively. The oven starting temperature was 50 °C, one minute hold time with heating rate of 30 °C per minute to 155 °C. Nitrogen was used as carrier gas at a flow rate of 0.5 bar and for H2 at 0.65 bar was adjusted. The concentration of ethanol in the samples was determined using isopropanol as internal standard

RESULT AND DISCUSSION

Effect of acid concentration

The effect of acid concentration on the production of ethanol was carried out 1h hydrolysis time is shown in Fig. 1.It was found that with the increasing the percentage of acid the concentration of ethanol was decreases. The maximum concentration ethanol was 6.8 g/l was obtained when acid percentage was zero hydrolysis time 1 h and fermentation time 24 h respectively. After that ethanol concentration 5.7, 5.1, 4.7, 3.6, 2.9 g/l decreases with increase in acid 1, 2, 3, 4, 5% (percentage). This condition is similar with the work of Negusu Tefera (2009) where maximum amount of ethanol from distilled water hydrolysate than acid hydrolysates of *Prosopis juliflora*. This decrease in bioethanol concentration may account for the further sugar degradation that occurred under the severe acidity. Overall, these results indicate that extreme acidity had an unfavorable effect on sugar conversion of coffee pulp (Nutawan *et al*., 2010)(figure 1).

Effect of hydrolysis time

The effect of hydrolysis on ethanol concentration was carried out zero percentage of acid at 24 h fermentation time, which is shown in Fig. It maximum ethanol concentration 7.9 g/l was found at 5h hydrolysis time.

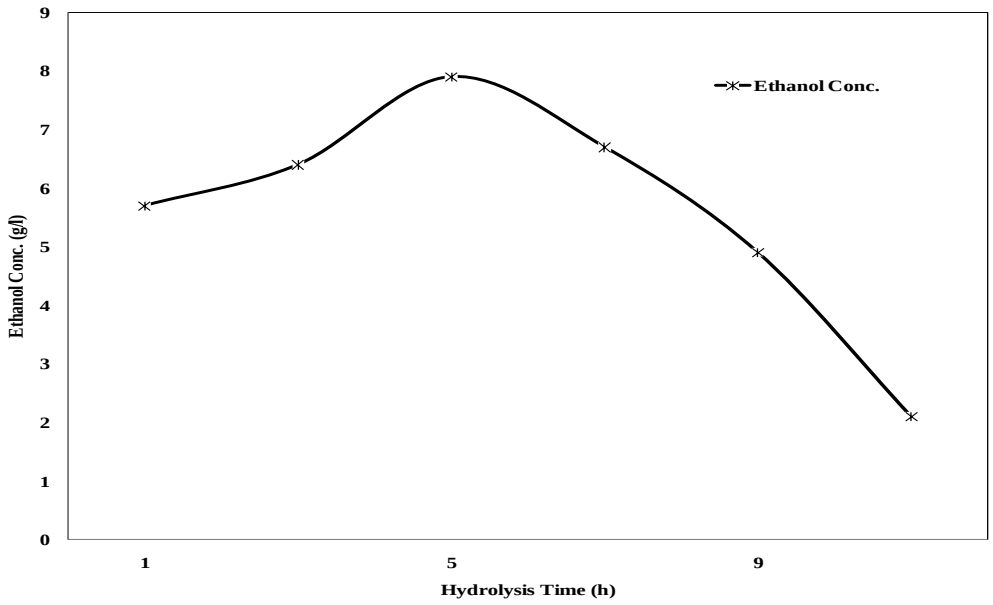

Figure 2. Effect of hydrolysis time on ethanol concentration

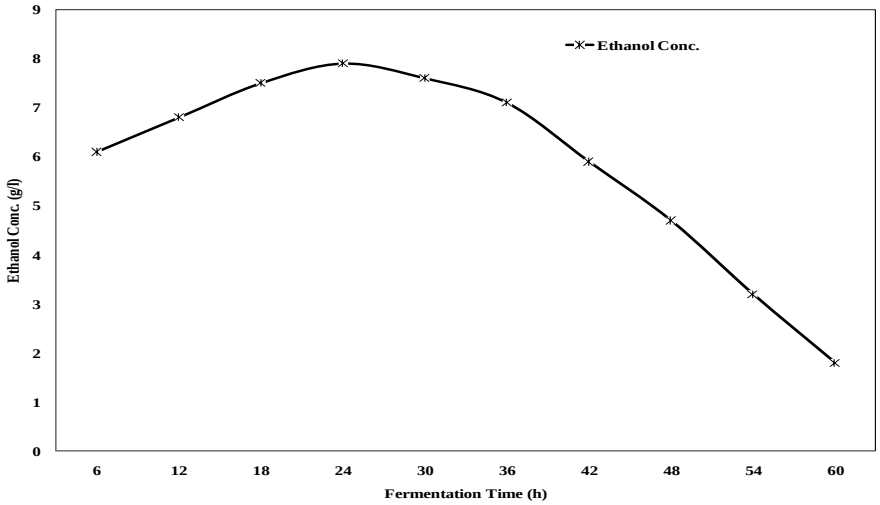

Figure 3. Effect of fermentation time on ethanol concentration

When hydrolysis times are 1 and 3h the ethanol concentration 5.7 and 6.4 g/l was observed. Further increase in hydrolysis times 7, 9, 11h the bioethanol concentration was 6.7, 4.9, 2.1 g/l respectively. This attribute to that longer residence time makes the sugars degraded to form inhibitors (furfural and HMF) (Nutawan *et al*., 2010). Therefore, distilled water hydrolysis and 5 h residence time were selected as the optimum conditions for hydrolysis of coffee pulp for bioethanol production (figure 2).

Effect of fermentation time

The effect of fermentation time on bioethanol concentration was carried out at 5h hydrolysis time, which shown in Fig. It was observed that 24h is the optimum time for maximum yield of 7.9 g/l bioethanol concentration. With the less fermentation time 6, 12, 18h the ethanol concentration was 6.1, 6.8, 7.5 g/l was observed. When fermentation time 30, 36, 42, 48, 54, 60h there no progress in the efficiency on bioethanol concentration i,e. 7.6, 7.1, 5.9, 4.7, 3.2, 1.8 g/l. This decrease in ethanol concentration with increase in fermentation time is might be due to the consumption of sugar by the microorganisms for ethanol production or the hydrolyzate does contain significant levels of metabolic inhibitors (e.g., furfural and HMF) that can interfere with fermentation (Weil *et al.*, 2002) (Figure 3).

CONCLUSION

Coffee husk is promising lignocellulosic feedstock's for bioethanol production. One of the most important factors in the acid treatment of ignocelluloses is the determination of optimal conditions required to provide the maximum yield of fermentable sugars and the least amount of inhibitors. In this study, the feasibility of ethanol production from coffee husk by means of dilute acid and distilled water hydrolysis techniques and ethanol fermentation time by *S. cerevisiae* was investigated. Dilute acid and distilled water hydrolysis was applied to produce simple sugars from coffee husk which followed by fermentation for production of bioethanol. The bioethanol production from coffee husk and optimization test have shown that distilled water is preferable than dilute acid hydrolysis. The optimization study showed that the highest bioethanol concentration of 7.9 g/l was observed under the optimum conditions of with distilled water hydrolysis for 5 h by keeping boiling temperature with reflux, and fermentation time of 24 h held at 30 °C with backer yeasts, which is appreciable.

REFERENCE

Alemayehu T, Esayas K, Kassu K (2007). Coffee development and marketing improvement plan in Ethiopia. Pp. 375-387.

Altintas M, Ulgen K., Kirdar B, Onsan Z, Oliver S 2002. Improvement of ethanol production from starch by recombinant yeast through manipulation of environmental factors. Enzyme Microb. Technol. 31: 640-647.

Ballesteros M, Oliva J, Negro M, Manzanares P (2004). Ethanol from lignocellulosic materials by a simultaneous saccharification and fermentation process (SFS) with Kluyveromyces marxianus CECT 10875. Process Biochem. 39: 843–848.

Bansal R, Singh R (2003). A comparative study on ethanol production from molasses using Saccharomyces cerevisiae and Zymomonas mobilis. Indian J. Microbiol. 43: 261-64.

Cardona C, Sanchez O (2007). Fuel ethanol production: process design trends and integration opportunities. Biores. Technol. 98: 2415–2457.

Chandel A, Rudravaram R, Narasu M, Rao L, Ravindra P (2007). Economics and environmental impact of bioethanol production technologies: an appraisal. Biotechnol. Molec. Biol. Rev. 2: 14–32.

Dawson L, Boopaty R (2008). Cellulosic Ethanol production from sugarcane bagasse

Franca A, Gouvea B, Torres C, Oliveira L, Oliveira E (2008). Feasibility of ethanol production from coffee husks. J. Biotechnol. 136:269–275.

Gaur K (2006). Process optimization for the production of ethanol via fermentation. Master thesis, Thapar Institute of Engineering and Technology, Patiala.

Himmel M, Ruth M, Wyman C (2009). Cellulase for commodity product from cellulosic biomass. Current Opinion in Biotechnol. 10: 358-364.

Kwiatkowski J, McAloon A, Taylor F, Johnston D (2006). Modeling the process and costs of fuel ethanol production by the corn dry grind process. Ind. Crops Products 23: 288–295.

Linoj N, Kumar V, Dhavala P, Goswami A, Maithel S (2006). Liquid biofuels in South Asia: resources and technologies. Asian Biotechnol. Develop. Rev. 8: 31–49.

Mosier N, Dale B, Elander R, Holtzapple Y, Ladisch M (2005). Features of promising technologies for pretreatment of lignocellulosic biomass. Biores. Technol. 96: 673–686.

Negusu T (2009). Potential of of Prosopis Juliflora for Bioethanol Production. Master thesis (unpublished), Addis Ababa University, Ethiopia.

Nutawan Y, Phattayawadee P, Pattranit T, Mohammad N (2010). Bioethanol Production from Rice Straw. Energy Research J. 1: 26-31.

Ohgrem K, Bura R, Lesnicki G et al 2007 A comparison between simultaneous saccharification and fermentation and separate hydrolysis and fermentation using steam pretreated corn stover. Process Biochem 42:834–839.

Periyasamy S, Venkatachalams S, Ramasamy S, Srinivasan V (2009). Production of Bioethanol from Sugar Molasses Using S. cerevisiae. Modern Appl.Science 3: 32-36.

Stewart G, Russell I (2007). Biochemistry and genetics of carbohydrate utilization by industrial yeast strains. Pure Appl. Chem. 59: 1493–500.

Subramanian K, Singal S, Saxena M, Singhal S (2005). Utilization of liquid biofuels in automotive diesel engines: An Indian perspective. Biomass Bioenergy 29: 65-72.

Sun Y, Cheng J (2002). Hydrolysis of lignocellulosic materials for ethanol production: a review. Biores. Technol. 83: 1-11.

Taherzadeh M (2009). Ethanol from lignocellulose: physiological effects of inhibitors and fermentation strategies. Ph.D. thesis. Chalmers Univ, Göteborg, Sweden.

Taherzadeh M, Karimi K (2007). Acid- based hydrolysis processes for ethanol from lignocellulosic materials: A Review. BioRes. 2: 472-499.

Thuesombat P, Thanonkeo P, Laopaiboon L, Laopaiboon P, Yunchalard S, Kaewkannetra L, Thanonkeo S (2007). The batch ethanol fermentation of jerusalem artichoke using S. cerevisiae. J. sci. Technol. 7: 93-96.

Uma V. and Polasa, H. 2000. S. cerevisiae of palm wine enhanced ethanol production by using mutagens. J. Indust. Microbiol. Biotechnol. 5: 1-4.

Urbaneja G, Ferrere J, Paeza G, Arenas L, Colina G (1996). Acid hydrolysis and carbohydrates characterization of coffee pulp. Renew. Energy 9: 1041-1044.

Weil J, Dien B, Bothast R, Hendrickson R, Mosier N, Ladisch M (2012). Removal of fermentation inhibitors formed during pretreatment of biomass by polymeric adsorbents. Ind. Eng. Chem. Res. 41: 6132–6138.

Wyman C, Hinman N (1990). Ethanol: Fundamentals of production from renewable feedstocks and use as transportation fuel. Appl. Biochem. Biotechnol. 24/25: 735-775.

Wyman C, Dale B, Elander R, Holtzapple M, Ladisch M, Lee Y (2005). Coordinated development of leading pretreatment technologies. Biores. Technol. 96: 1959–1966.

Xiang, Q, Lee Y, Torget R (2004). Kinetics of glucose decomposition during dilute hydrolysis of lignocellulosic biomass. Appl. Biochem. Biotechnol. 113-116, 1127-1138.

Yishak S, Mulugeta A, Yared H (2009). Biomass Energy for cement production: Opportunities in Ethiopia. United Nations Development Program, New York, New York, 10017, USA.