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Bioethanol Production from Coffee Mill Effluent as Potential Renewable Energy

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Abstract - Coffee is an important crop for developing countries, particularly in Indonesia. It provides essential income to millions of people, but the wastewater generated threatens the environment and human health. The basic needs in Indonesia are enormous, similar to many other coffee producing areas around the globe. This project has the ability to combat many of the problems facing humans today such as scarcity of potable water and energy supplies for the people that need it most. Coffee producers are all in developing nations and have serious problems disposing of the waste properly because they have no capital available to address the water contamination crisis and little environmental regulatory enforcement. Additionally, the people of rural coffee producing communities have inadequate health care so the availability of clean water is essential to quality of life. Responsible treatment of the wastewater will reduce the impact on the local ecology, and decrease the need for human health care by improving the water quality. This effluent is discarded every day during the processing season to lagoons where it putrefies. We saw these retention ponds and smelled the putrefactions occurring; it ran-off the hill and leached into groundwater. The acids from the fermentation of sugars in the mucilage make the wastewater very acidic, down to a pH of 4.5. The wastewater samples we taken in Ijen plateau in Indonesia during April to August 2014, showed a pH of 4, ammonia nitrogen at >10 mg/L, phosphates of 150 g/L, dissolved oxygen of 0.01 mg/L and BOD >200,000 mg/L. This effluent creates a potential for serious harm to human health and the environment because the contaminated wastewater is either directly discharged to streams or leaches into the groundwater tables like we saw in Ijen region. In developing nations people rely heavily on shallow groundwater tables and surface water for drinking water supply; thus,coffee processing causes great harm to people living within the vicinity.

Keywords: *Bio-fertilizers; biorefinery; coffee pulp; organic waste; Saccharomyces cerevisiae.*

I. INTRODUCTION

1.1 Background

Coffee processing is an energy intensive process and a potential source of contamination (Musebe et al., 2007). It is treated by wet and dry methods discard away 80% of the biomass generated by the coffee plants at different stages from harvesting to consumption (Novita, 2010). This includes cherry wastes, coffee parchment husks, coffee spent grounds, coffee leaves, and wastewater. Wet processing uses up to 15 m3 of water to produce one ton of clean beans and for every ton of beans produced, about one ton of husks is generated (Eakin et al., 2011).

It is estimated that coffee processing generates about 9 million m3 of wastewater and 600,000 tons of husks annually (Weldesenbet et al., 2008). Indonesia currently is one of the fourth largest coffee producers in the world after Brazil, Vietnam and Colombia (Bromokusumo and Slette, 2010) which produce more than 500 thousand tones and are expected to continue to increase significantly because the program is regular replanting and expansion of new plantations (Mutakin et al., 2008).

Conventionally Coffee Mill Effluent (CoME) is treated in open anaerobic ponds system to reduce the Dissolved Organic Carbon content to 350 mg/l as required by the effluent discharged regulation. During the anaerobic wastewater treatment process, large amount of methane gas is produced and emitted to the atmosphere (Wilkie et al., 2004; Wreford, et al., 2010).

The wastewater produced from the wet-processing of coffee places a heavy burden on the local ecosystems. Currently, there are few environmentally sound measures that monitor the discharge of this effluent. It is often discarded in a manner that disrupts both streams and the local water supplies. The purpose of this project is to design and

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develop a coffee wastewater treatment system that incorporates the production of bioethanol and bio-gas in the remediation process. The technologies required to implement this process are well established and broadly understood, but the system we are suggesting incorporates them in ways that, to our knowledge, have never been done before.

The innovative objectives of this project are to determine potential bioethanol production from coffee pulp and wash water for the design of scalable bioethanol distillation processing units and to determine potential production of methane and nitrate rich effluent for the design of scalable anaerobic digestion units.

1.2.2 Properties and Uses of the Coffee Pulp

Coffee pulp is a waste material from the coffee industry. It is the first product obtained during processing, and represents 40 – 42 % of the whole berry on dry weight basis. It represents the most abundant waste produced during the pulping operation of coffee. Every two ton of coffee produced delivers one ton of coffee pulp. Due to the rich organic matter content, coffee pulp can form an excellent substrate for production of value added products. Coffee pulp, also identified as coffee fruit without seeds, is an abundant agricultural by-product that causes serious environmental pollution problems. It represents around 43 % of the weight of the coffee fruit on a fresh weight basis, or approximately 28 % of the coffee fruit on a dry weight basis (Pushpa S. Murthy 2012).

1.2.3 Feedstock for Bioethanol Production

Coffee pulp is a renewable lignocellulosic source like wood, agricultural residues and agro industrial wastes like bagasse that can be used as feedstock in bioethanol production. The whole process involves hydrolysis of fermentable sugars in the coffee pulp using current commercial technologies (physiochemical/enzymatic prepara-tion) before they can be fermented to yield bioethanol. This involves using various strains (yeast) in the fermentation. This will form the basis of our study. However, a small review of bioethanol and its properties is made in the next section.

1.2.4 Bioethanol

Bioethanol is gaining momentum as a viable fuel source due to recent fluctuations in the market of conventional fossil fuels. In addition to its common pharmaceutical and beverage uses, bioethanol has been used as a fuel additive, gasoline enhancer and even as an alternative fuel source. Bioethanol production from cellulosic materials mostly agro industrial waste by bioconversion is highly encouraging and its commercial production is established in countries like USA. The economics of bioethanol by fermentation is significantly influenced by the cost of raw materials which accounts for more than half of the production cost In the recent years, however, efforts have been directed towards the utilization of cheap renewable resources such coffee waste pulp, banana peel waste etc. as viable alternative substrates for bioethanol production.

2.4.1 Properties and uses of bioethanol

Bioethanol or ethyl alcohol, CH3CH2OH, has been described as one of the most exotic. The pulp was oven-dried at 60 °C for 48 hours (to Arabica was collected in icebox from a pulping center, and then taken to laboratory for analysis.get to a moisture content of 15 %), grinded by coffee grinder and sieved. The samples were stored in closed plastic containers at room temperature, until required for treatments.

3.3.2 Determination of Moisture Content

The moisture content of the samples was determined by oven drying method. The sample was weighed with glass crucible, placed in the air-drying oven for 48 h at 60 °C, cooled to room temperature in desiccators, and weighed. The process was repeated until a constant weight was achieved and thus making it free of moisture content.

3.4. Fermentation Microorganism

The yeast Saccharomyces cereviciae, purchased from a local market in Indonesia, was used in all experiments throughout this work. Saccharomyces cereviciae was used since it‘s the strain that produces the most bioethanol yield.

Fermentation process :

After hydrolysis, the flasks containing the hydrolysate 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. Bioethanol concentration was analyzed by gas chromatography at different fermentation times (12, 24, and 48 hours) to determine the fermentation time that will ensure maximum bioethanol yield. Samples were withdrawn every 12 h and the fermentation was carried out for a total 48 h period.

The effect of fermentation time on the hydrolysate obtained after a residence time of 5hours was investigated and discussed. The hydrolysate obtained from 5hours hydrolysis of the coffee pulp substrates with distilled water was collected and divided into three samples and used for the

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subsequent fermentation experiments. This experiment was done based on the optimization conditions (optimum hydrolysis time) for optimum bioethanol production with distilled water.

The fermentation was done at 12, 24 and 48 h respectively withdrawing samples after 12 hours respectively. The results obtained were tabulated in the table below and a graphical representation also made as shown. Fermentation periods conduct between 1 d, 2 d and 3 d. Bioethanol content is produced from every variable is not same. In the coffee bean content much chemistry material, for example saccharin. The sugar content in the coffee bean is available in the skin and mucilage of the coffee bean. Mesocarp is part of coffee bean with has sugar and high water content. Liquid waste on the coffee processing produces high pollution level. The mind component of the liquid waste are organic material which is come from depulping and skin of coffee bean.

The majority of material organic in the liquid waste content value of COD 50 000 mg L^{-1} and BOD reaches 20 000 mg L^{-1}. Temperature is mean factor which affected the life and growth of organism. The bean which is fermented will change of the skin and the temperature will be increase during fermentation.

Based on the results fermentation will be stopped when the fermentation has conducted for 75 h (3 d). The results obtained in this study have demonstrated that efficient ethanol production from coffee pulp is possible. Coffee pulp hydrolysis without the addition of dilute sulphuric acid proved more efficient ethanol yield than with dilute sulphuric acid. The production of ethanol from coffee pulp is a significant finding that can constitute a valuable way of using derivative products from coffee beans at farm level. Expanding bioethanol production could entail diverting valuable cropland from producing cereal crops needed to feed people to producing cereal crops for bioethanol factories.

II. CONCLUSION

There is a definite need for cost effective waste treatment to improve the water quality around coffee production facilities. While, Anaerobic biotechnology is particularly attractive for developing nations because of its good cost balance and ability to provide energy supply. Wet coffee processing results in two types of high strength saccharide-rich wastewater, the mucilage and the pulp. Coffee wastewaters have a high content of carbohydrates, which makes them suitable for biological anaerobic treatment. Anaerobic digestion can be used to produce biogas that can be used as distillation heat for bioethanol production. We have measured sufficient sugars to be able to make bioethanol from the wastewater and conducted fermentation experiments on coffee wastewater and banana waste that yielded burnable alcohol. The usable products improve the benefits of this type of waste treatment system.

The research objective is to determine the most appropriate method for effectively utilizing the waste to produce bioethanol. By producing valuable fuel from the waste, the potential is created to ensure long-term sustainable environmental protection. The challenge is to develop a bioremediation system that works towards a closed loop approach to coffee production that is affordable and appropriate for communities where the systems are implemented.

Surveys were conducted in Indonesia in order to ensure that the design is appropriate and will be accepted by community members. This field research was an invaluable tool for determining the best biofuel systems for the users based on evident and unmistakable needs: clean drinking water and an inexpensive and clean cooking fuel. Therefore, bioethanol as a cook fuel has tremendous potential to do well in this situation.

1.2 Coffee Waste

1.2.1 The Wet Mill Process

The process in the wet mill begins by bringing the coffee cherries in the previously described bags (filled by baskets) to a reservoir. From here on the cherries are transported by gravity to the de□pulping machines in the pulping unit. This step can be enhanced with water, or can be performed dry (more environmentally friendly) when the reservoir has been designed to this purpose. In Indonesia, the transport to the depulping machines is brought forth by water and gravity. One major advantage of this method is that dirt, notripe and overripe grains will float on the water surface. In the de□pulping machines the cherries are selected based on their size and depulped, which is the process in which the pulp and the outer skin are removed.

For 100 kg of ripe cherries delivered to a washing plant, 60 % by mass ends up as washed coffee pulp with the remaining 40 % consisting of the green bean and endocarp (parchment). Of this 40 % washed coffee cherry, only 20 kg remains after sun-drying of the bean and parchment. This is then shipped to the washed coffee processing facility where the parchment is removed. The result is 16 kg of washed coffee beans ready for export and 4 kg of parchment as residues.

The average residue production per metric ton of wet red cherry is about 600 kg, i.e. based on

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green coffee bean production, the residue potential would be 1.4 times the mass of green beans produced.

synthetic oxygen-containing organic chemicals because of its unique combination of properties as a solvent, germicide, beverage, antifreeze, fuel, depressant, and especially because of its versatility as a chemical intermediate for other organic chemicals.

It is a volatile, flammable, and colourless chemical compound. It is a monohydric primary alcohol and it boils at 78.5 °C. It is miscible with water in all proportions. Bioethanol that is completely free of water is called absolute bioethanol. Bioethanol forms a constant-boiling mixture, or a zeotrope, with water that contains 95 % bioethanol and 5 % water and that boils at 78.15 °C. Bioethanol is a psychoactive agent and it produces a variety of physiological and behavioral effects.

III. MATERIAL AND METHODS

3.1 Sample Collection

Fresh wet coffee processing waste (pulp and wastewater) was collected in plastic bottles and an open plastic container respectively and kept fresh in an icebox ready for laboratory testing.

3.2 Information Obtained

It was discovered that 7 kg of fresh coffee cherries produced 1 kg of clean coffee beans and therefore most of the produce was the coffee pulp. The coffee pulp was dumped in the soak pits together with the wastewater, which were a waste and a hazard to the environment.

3.3 Laboratory Work

The process of converting waste coffee pulp into green bioethanol consists of three stages: pretreatment, hydrolysis and fermentation into green bioethanol . Furthermore, purification by distillation and dehydration of bioethanol in the presence of a chemical (ziolet) which is basically limestone can be carried out. However the purification will not be carried out since the aim of the experiment is to determine the potential of coffee pulp to produce green bioethanol only. Further studies and experiments may be conducted for cleaner bioethanol. The whole process is a chemical process and therefore the assistance of the Department of Food Science at UNEJ was sought.

3.3.1 Pretreatment (Sample Preparation)

Wet coffee residue (coffee pulp) of Coffee

IV. RESULT AND DISCUSSION

The concentration of bioethanol increased with increasing fermentation time and decreased at the end of fermentation time. Maximum bioethanol concentration, 6.12g/L was obtained at hour and the result started to decrease after 24 hour of fermentation time (Figures 15 and 16). The figure also indicated that the lowest concentration of bioethanol production of 6.09 and 5.90 g/L was obtained at fermentation time of 12 and 48 hour, respectively. From the optimization experiment, the highest concentration of bioethanol was achieved at 24 hour of fermentation and started to level off.

The bioethanol production decreased as the fermentation time increased beyond 24 hour, this might be due to the consumption of sugar by the microorganisms for bioethanol production or the hydrolysate does contain significant levels of metabolic inhibitors that have accumulated and that can interfere with fermentation.

The literature review of data for the bioethanol obtained from different agricultural and agro industrial wastes was made, and a comparison made with the bioethanol obtained in the experiment to determine the viability of coffee waste pulp, as a feedstock for bioethanol production.

Table 1. Result of bioethanol from liquid waste of coffee processing

Time (days)	Mass of yeast	Content (%)	Bioethanol concentration(%)
1	0	1.8	6.4
	40	1.6	53.1
	80	1.8	51.4
2	0	1.8	17.1
	40	1.2	57.8
	80	1.8	60.2
3	0	0.5	5.4
	40	0.6	51.4
	80	0.9	51.4

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