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Comparative Studies of Bio-ethanol Production from Different Fruits Biomasses

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Abstract

Depletion in the next few decades and the trends in biofuel production from biomass are gaining popularity to encounter the expected energy crisis in the world. Ethanol is the most widely used liquid biofuel and is produced as a result of fermentation process from sugars, starches or cellulosie biomass including fruit wastes. This study was designed to utilize the rotten fruits for the production of biofuel and waste management purposes. The ethanol production from rotten fruits was compared with the data regarding fermentation of rambutan, mango, banana and pineapple for ethanol production. Rotten fruits were used to produce bioethanol by fermentation process. The maximum bioethanol production was obtained from the experiments conducted using pulp fruit part in pH 5 for 2 days producing ethanol 9.4 (v/v)%. to the detailed chemical analysis of residual metals. The ethanol obtained as a result of fermentation was subjected to engine test and revealed a remarkable reduction of hazardous gases (NOx) in the blends of bioethanol (E10, E5). The emission test was performed using a car (Proton Gen 2 Multicylinder). Finally, the ethanol produced from rambutan rotten fruit was of high quality which can be utlized as a fuel in the engine and qualified the ASTM standards regarding emission standards, viscosity and residual matter.

Key word: bio fuel**,** Bioethanol, rotten fruit, viscosity, emission

Introduction

Rising oil prices in the last few years and environmental concerns because of climate change have lead to an increasinginterest in biofuels. Biofuels are renewable, can substitute fossil fuels, reduce fossil greenhouse gas emissions and they can be produced, where they are needed, to reduce the dependence on oil producing countries. The biofuels that are currently in use, known as first generation biofuels, are mainly produced from sugarcane, maize or soy.

The main producers are Brazil and the USA. Bioethanol, produced from sugarcane, pineapple, banana, maize, and biodiesel, produced from soybeans, sunflower, corn oil are presently that are produced on an industrial scale (Hossain et al, 2008 ; Hossain and Fazliny, 2010, Hossain and Boyce, 2009). Biofuels are mostly used as fuel additives, because if they are blended with gasoline or diesel in low proportions these mixed fuels can be used in normal cars without major changes of the engine. This is a major advantage of biofuels compared to e.g. hydrogen, because the same distribution system can be used as with normal fuels. In Brazil, however, there exist also cars that can use neat ethanol or so called flex-fuel vehicles that can use both neat ethanol or normal gasoline (Antoni et al. 2007; Walter et al. 2008). Ethanol can be blended with petrol or used as neat alcohol in engines without any modification, taking advantage of the higher octane number and higher heat of vaporization; furthermore it is an excellent fuel for future advanced flexi-fuel hybrid vehicles (2Hahn-Hagerdal et al 2006). Bioethanol is an excellent alternative to fossil fuels, either as a pure fuel with high efficiency and performance or as a gasoline additive. Bioethanol is produced by fermentation. Bioethanol can also be produced from a variety of rotten fruits/fruits. Ethanol has several attractive features as an alternative fuel. As a liquid it is easily transported and it also can be blended with gasoline to increase the octane rating of the fuel. The huge fluctuations in the price of petroleum within the past twenty years have made commercial production of fermentation ethanol a more attractive. Because of current interest in the economic conversion of renewable resources into alcohol, residues of a number of crops were evaluated as substrates for alcohol production (Han& Cho 1983, Jones *et al* 1981). Fruits and fruit wastes are always considered as a potential substrate for bio ethanol production. The present study is encompassing the production of ethanol from rotten fruits including banana, pineapple, mango and rambutan. The study was conducted with the following aims: to determine the proper enzymes for different rotten tropical fruits in view to bio-ethanol production , optimum temperature to produce bio-ethanol and determine the engine properties (viscosity and acid value) and emission from produced bio-ethanol.

Materials and Methods

Sample Preparation

All experiments were conducted using rotten fruit to produce ethanol and compared with the unpublished data to each other regarding rambutan, Mango, Banana and Pineapple for the ethanol production under same conditions. The fruits were washed, cut into small pieces together with their skin and blended in a Philips household juice blender for 3 minutes. The skin and the juice obtained were mixed together before dispensing them into 1L schott bottles and experiments were done in triplicates. Each bottle contained 100 ml of the mixture. The fresh weight was measured. The Total Soluble Solids (TSS) and the pH of the mixture before fermentation were also measured. The initial pH for Rambutan, Mango, Banana and Pineapple juices were measured and tabulated properly.

Fermentation

The general process of fermentation is described as a reaction in a schott bottle containing fruit contents and yeast. The optimum ethanol production as a result of fermentation was investigated by using different parameters as following:

The optimum yeast concentration for maximum ethanol production was determined with the addition of 4g/l of yeast in the mixture containing fruit contents, and the bottles were shaken so that the yeast was mixed together with the samples. The samples were then placed in the incubator at 30°C and left there for 3 days. Parameters that were studied were fermentation incubation time, fermentation temperature, fermentation by using different components of fruits and fermentation by using rotten and fresh fruits. Fermentation incubation time was conducted at 1 day, 2 days and 5 days. The skin, pulp and mixture of the fruits were separated to be used for the fermentation involving different components of fruits. For fermentation with skin, water was added to the skin that has been blended to activate the yeast. Fermentation was followed after the enzymatic digestion of the pH was adjusted using 5 M natrium hydroxide (NaOH) to increase the pH and 1 M acid hydrochloride (HCl) to decrease the pH whenever needed.

Enzymatic hydrolysis

The enzymatic hydrolysis was performed to facilitate the fermentation by yeast by releasing sugars from cellulosic fruit's biomass. Enzymatic hydrolysis was carried out at the temperature recommended by the manufacturer. The reaction was emanated by boiling the reaction contents and subjected to fermentation n by yeast.

All experiments were performed in triplicates.

1-Fermentation of pH parameter:

The fermentation method of pH was same as previously stated. The pH of samples was adjusted to 4, 5 and 6.

2-Fermentation of different fruit part:

The fermentation method of different fruit part was same as stated above. The fruit part was used is skin, pulp and mix.

3-Fermentation of different time:

The fermentation method was same as stated above, instead of change in the days to 1, 3 and 5 days.

Filtration

After a specific reaction time, the mixtures in the bottles were then filtrated using a beaker covered with a piece of folded cheese cloth. The liquid obtained inside the glass was the raw bioethanol. The volume of the raw bioethanol was measured using the measuring cylinder and it was then transferred into a plastic bottle and labeled. The pH and TSS of the raw bioethanol were measured and weight of the residues was also checked.

Chemical and Viscosity Test

Samples from fermentation pH parameter were tested for chemical components and viscosity test. Chemical analysis by using Multi Element Oil Analyzer (MOA) II was conducted to measure various chemical components that can be found in the bioethanol. Samples for parameter time were also analyzed for the viscosity of the bioethanol produced Table 1, 2

Engine Test

Samples that have been tested for chemical and viscosity analysis were then being tested to run the multicylinder engine of Proton Gen2.

Rsults and Discussion

A comparative study was made to highlight the efficient ethanol production from rambutan as compared to the other fruits like mango, banana and pineapple. Different parameters were investigated and compared regarding ethanol production from all of the four fruits. The parameters involved were including the pH, retention time, and different parts of fruits.

1-Effect of pH on ethanol production from fruits:

Bioethanol yield was investigated at different pH content from rotten rambutan, mango, banana and pineapple Figure1. At pH 4 the rambutan was producing 5.9% (v/v) of ethanol and 4.32%, 5.77% and 5.32% were produced by mango, banana and pineapple. At ph 5, the ethanol (v/v) was produced as 7.5%, 6.3%, 5.88% and 6.64 % from rambutan, mango, banana and pineapple respectively. At ph 6, the ethanol (v/v) was produced as 6.16%, 5.07%, 5.81% and 5.46 % from rambutan, mango, banana and pineapple respectively.

2-Effect of different time on ethanol production from fruits

Different time duration were investigated to optimize the required time for maximum ethanol production. One day, three days and five days were used to precede fermentation of different fruits as mentioned in Figure2. The ethanol (v/v) production after one day were found as 8.4 %, 6.32%, 5.51% and 8.23% were produced by rambutan, mango, banana and pineapple. After two days the ethanol (v/v) was produced as 9.4%, 7.3%, 6.86% and 8.64 % from rambutan, mango, banana and pineapple respectively. The ethanol (v/v) production was recorded after three days and it was found as 8.5%%, 5.07%, 5.09% and 7.46 % from rambutan, mango, banana and pineapple respectively. The ethanol (v/v) production was also recorded after five days and it was found as 7.4%%, 8.07%, 6.09% and 7.46 % from rambutan, mango, banana and pineapple respectively.

3-Ethanol production from different fruit parts:

Ethanol production from different fruit parts were also investigated
Figure 3 the fruit stuff was divided into three parts skin, pulp and maxi. All parts were subjected to fermentation for ethanol production. The experimental vessel containing skin of the fruits were able to ferment the cellulosic material into bioethanol (v/v) as 7.46 %, 5.6%, 3.72% and 4.31% by rambutan, mango, banana and pineapple respectively. The pulp was able to produce bioethanol (v/v) as 9.96 %, 7.69 % 5.86 %, and 8.73 % from rambutan, mango, banana and pineapple respectively. The fermentation of maxi was able to produce ethanol (v/v) as 7.6 %, 6.38 %, 5.22 % and 8.28% from rambutan, mango, banana and pineapple respectively.

Discussion

1-Optimization of different pH :

As shown in Figure1, at pH 5, the ethanol (v/v) was produced as 7.5%, 6.3%, 5.88% and 6.64 % from rambutan, mango, banana and pineapple respectively. The efficiency of the rambutan to produce ethanol was also higher at pH 4 and pH 6.

All biological processes are affected by pH because all biological processes are catalyzed by enzymes which are by definition proteins, and tertiary structure can be broken by extremes in Hydrogen and Hydroxyl ion concentration which is what pH measures. The suitable pH found for fermentation of fruit was pH 5 to facilitate the enzymatic catalysis of the available sugars into ethanol. (Chongxiao Gao and G. H. Fleetn 1988) has reported the survival and growth of *Saccharomyces cerevisiae*, according to the authors this yeast can tolerate the ethanol concentration up to 15% but the sensitivity of yeast cells to ethanol was marginally increased on decreasing the pH from 6-0 to 3–0. It shows the pH has an important impact on ethanol production and yeast cell concentration. (Ogunya et al. 2006) reported that when the experiment was conducted at 3.4 and 4.1 ethanol production was enhanced from pineapples juices. It is also reported that the pH did not affect the ethanol's yield in the range of 3.5 to 6.0 when using pineapple effluent as substrates (Muttamara et al., 1982).

2-Fermentation at different days:

As the incubation time of the fermentation is concerned, the 48 hours were chosen as the optimum incubation time Figure 2. (Sonali Patle et al 2007) has reported that maximum ethanol can be produced within 48 hours of incubation time. Measurement of TSS revealed that the maximum clarity was observed in experimental vessel carrying fermentation for one day, as it was reducing the TSS from 12 to 3.0. In case of fermentation with 2 to 4 days, the final TSS values were found to 3.5, 3.17 and 3.17 respectively. The residual glucose concentration was measured and found that glucose is being consumed with the residual values as 3.5, 3.8, 3.6 and 3.6 in one to four day cultures respectively.

3-Fermentation of different fruit parts:

The fermentation of mix was able to produce ethanol (v/v) as 7.6 %, 6.38 %, 5.22 % and 8.28% from rambutan, mango, banana and pineapple respectively showing higher ethanol production from pineapple Figure3. The pulp was able to produce bioethanol (v/v) as 9.96 %, 7.69 % 5.86 %, and 8.73 % from rambutan, mango, banana and pineapple respectively. Skin, pulp and maxi of the fruits were investigated for ethanol production using yeast fermentation. Ethanol produced from pulp which was recorded as 9.96%.(J Obeta Ugwuanyi and Jason AN Obeta 1999) have reported maximum hydrolase activities in fruit tissues instead of the skin and maxi. It is always in practice to make treatment of the hard cellulosic tissues to soften enough for the penetration of enzymes. In case of pulp, it looks enough soft and pretreated to be acted upon by enzymes properly as compared to the other parts of the fruits. (According to Reddy and Reddy, 2007), there were three types of sugars that had been identified in mangoes, namely glucose, fructose and sucrose.

Chemical analysis

The metal contents in bioethanol produced were analyzed and tabulated in table 1 showing the reduction of hazardous metal content especially Pb, Al, Fe and Cu in the bioethanol produced from waste banana. However there were some metal contents in bioethanol which were found to be high in bioethanol i.e Sn, Ag and Na. The metal content in bioethanol should be less or reduced, so that it is more suitable for being used as biofuel. The reason why metal content in bioethanol was high, because the analysis of chemical content in bio ethanol was delayed and maybe because of this, the other microbes tend to grow in the bioethanol solution and rapidly. However, most of the metal such as Pe, Mn, Zn, P, Ca, Mg, Si, Na, B and V were observed to be lowered, thus decreased the risk of corrosion to the engine. The other metals seem to be zero as compared to the values of including Cr, Al, Cu, Pb, Ni, Ti, Mo and Ba indicate that bioethanol produced have the quality to be used as biofuel on generating the engine car. A drastic decrease in exhaust emission and fuel consumption was observed and analysed when the 5 and 10% of bioethanol rnixcd with gasoline on generating the engine Multicylinder of Proton Gen-2 car. Based on the table 1, there was a reduction in the emission of Nitrogen oxide (NOX) using 5 and l0 % of bioethanol in the mixture of gasoline. Fuel consumption of the mixture of bioethanol and gasoline was less and the emission of NO, was I reduced. This is because of the highly oxygenated component of ethanol fuel. There is a little difference in the amount of emissions of nitrogen oxides from ethanol-blended fuels in relation to conventional fuels. Reports cite this difference in the range of 5% decrease to 5% increase for low-level ethanol blends. For ethanol blends in the range of 5-95%, the reduction in emissions of nitrogen oxides may be of the magnitude of 20% (Environment Canada, 1989). However, in this study, the emission of nitrogen oxide was reduced approximately 80% when using mixture of 5% of I bioethanol with 95% of gasoline (E5) and 10% bioethanol with 90% gasoline, compared to I 100% gasoline used as fuel.

Viscosity

The viscosity of the bioethanol produced was important when considering the spray characteristics of the fuel within the engine, since the change in spray could greatly alter the combustion properties of the mixture. From the result obtained in Table 2, it could be seen that the bioethanol produced from fermentation of mango pulp at temperature of 30°C with different amount of yeast were in the range of ASTM standard considered, which were within l to 5 centi stroke. This would give an indication that ethanol produced from fruits was suitable as a possible biofuel substitute. Additionally, low viscosity value was good for engine and reduced the problems of corrosion to the engine (Rashid Abro *et al* 2013). So, the higher glycerol content could cause higher viscosity to the solution. However, the viscosity obtained was still maintained under ASTM standards, presenting it as a qualified alternative fuel. Table 2 shows the results of acid value test from samples fermented at different amount ph. From the result, the acid values measured were almost the same for all fermentation reactions of fruits. The results obtained were in the best range and under ASTM standard specification.

Engine Test

Burning of fossil fuel and emission of hazardous gases are considered as a main source of global warming and environmental pollutions (Partha, D,2008). The ethanol produced from this experiment was tested by using the Proton Gen 2 multi-cylinder engine for 1 hour at 2000rpm (60km/hour). The hydrocarbon content for fuel consumption (ml/sec) was measured at 100% gasoline, E5 (A blend of 5% bioethanol/95% gasoline) and E10 (A blend of 10% bioethanol/90% gasoline). From Figure4, the hydrocarbon content in E5 and E10 were found about 33 ppm and 50 ppm respectively, were significantly lower than in 100% gasoline with hydrocarbon of 75 ppm. This showed that the fuel was burned more completely in E5 and E10 as compared to the 100% gasoline permitting emission with fewer unburned hydrocarbons(HC).

The performance of the engine and emission of gases were strongly supporting the quality of the ethanol produced by the fermentation of fruits.

Table 1: Chemical Analysis

Chemical	Value			
	Different rotten fruit biomass			
	Rambutan Waste	Pineapple Waste	Banana Waste	Mango Waste
Fe	1.2	2.5	5.5	3
Pb	0	0	0	0
Cu	0.5	0	0	0
Al	0	0	0	0
Sn	2.5	2	3	1.5
Mn	6	4	2.5	4.5
Ag	1.8	5.5	2	1.9
Zn	3.5	6	7	5
P	9.1	75.5	70	65
Ca	8.5	3.6	3.5	4.5
Mg	8.1	1.5	1.5	1.7
Si	1.6	1.6	1.6	1.8
Na	1.3	1.4	3.5	1.13
B	1.5	1	1	1
V	5	5	5	5

Table 2: Viscosity and acid value

Feedstock	Viscosity (cst)	Acid value (mgKOH/g)
Rambutan	1.23 a	0.38 a
Banana	1.58 b	0.48 a
Pineapple	1.62 b	0.36 a
Mango	1.60b	0.37 a

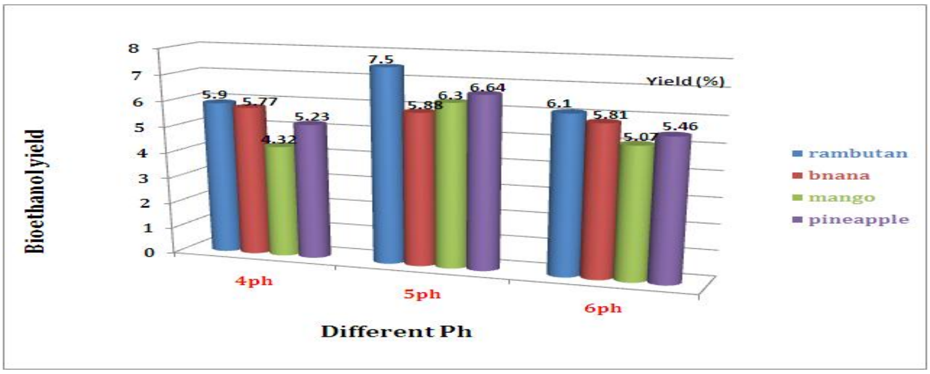

Figure 1. Showing the bioethanol yield in different pH.

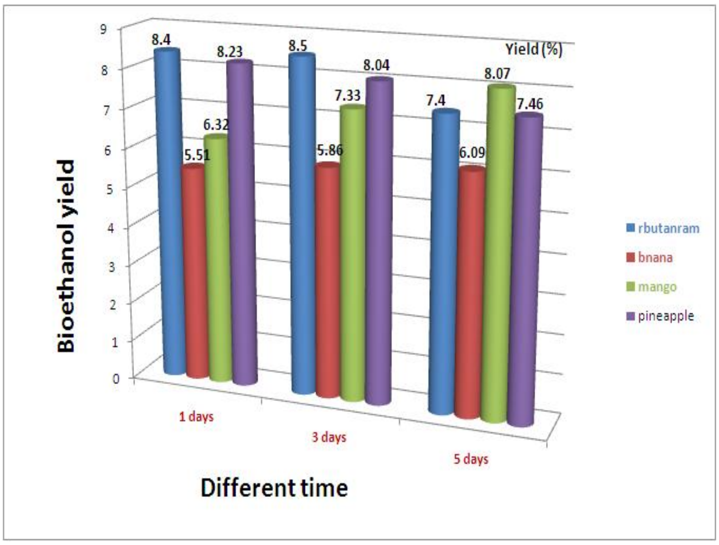

Figure 2. Showing the bioethanol yield in different time.

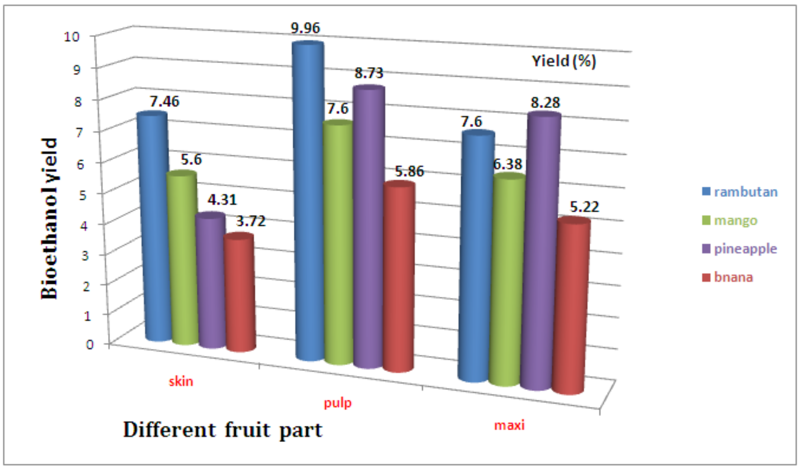

Figure 3. Showing the bioethanol yield in different fruit parts.

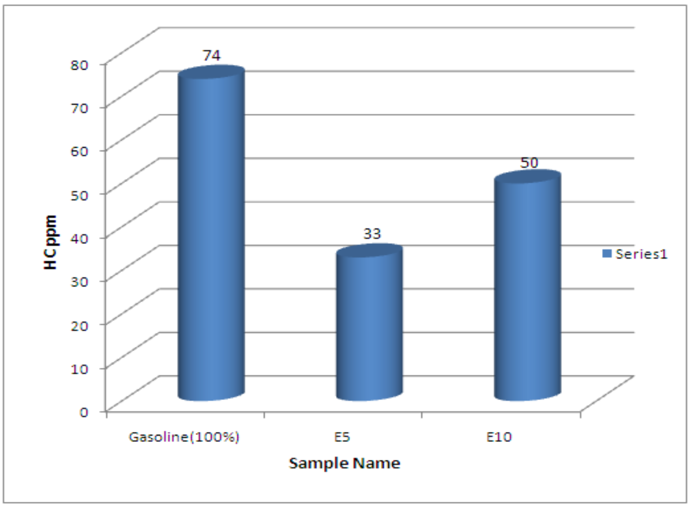

Figure 4 shows the amount of hydrocarbon (HC) from engine test of 100% gasoline, E5: A blend of 5% bioethanol 95% gasoline and E10:A blend of 10% bioethanol 90% gasoline. The HC content in E5 and E10 were significantly lower from 100% gasoline.

Conclusion

This study was designed to utilize the waste fruits for ethanol production and reduce the possible pollution because of the waste fruit material. The results of this study has revealed that the fruit wastes including rambutan, banana, mango and pineapple can efficiently be utilized for ethanol production with the help of Saccharomyces cerevisiae in a process of fermentation. A comparison of the yield of ethanol from different fruits has made it evident that the rambutan is the most efficient fruit/fruit waste to produc`1qe maximum ethanol as compared to the other fruits. The efficiency of fermentation or the yield of ethanol production is depending on the time, concentration of yeast and optimum conditions as described in results and discussion section. The chemicals content, viscosity and acid values of the bioethanol produced were within ASTM (American Society for testing and Materials) specifications. The reducing sugar content, total soluble solid (TSS) and pH values were reduced as a result of fermentation due to conversion of glucose into ethanol and carbon dioxide by yeast. The engine test showed low amount of hazardous chemicals content, thus this bioethanol could potentially be used as good biofuel. Viscosity and acid values measured indicated that this bioethanol was safer to be used for engine purposes and reduced corrosion problem to the engine. In short, this study is enough encouraging promoting the ethanol production from fruit wastes as well as for the solid waste management.

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