Production of Bio-Ethanol with Fermentation Wastewater of Cassava in Nigeria

Tolumoye J. Ajoko and Tolumoye J. Tuaweri

Department of Mechanical/Marine Engineering, Faculty of Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria

***Abstract*— The focus of research on the techno-industrial advancement and innovation on bio-fuel generation for complete replacement of conventional fuel sources are welcomed developments. This paper seeks to present the production of bio-ethanol using the fermentation water of cassava as a viable source of renewable energy. It was achieved by conducting laboratory experimentations. The results obtained confirm the authenticity of bio-ethanol as useable domestic fuel. It attests that the thermodynamic characteristics of bio-fuel met the standard values. Thus, from study the bio-ethanol obtained a flash point of 40°C with 0.819m/hr and 26.1MJ/Kg burning rate and calorific value respectively. However, it was found denser than water by 1068kg/m^3 against 1000kg/m^3. Therefore, bio-ethanol production with fermentation waste water of cassava is a viable and sustainable source of renewable energy.**

***Keywords*— Bio-fuel, Burning rate, Combustion, Distillation, Fermentation, Flash point**

I. INTRODUCTION

The issue of environmental catastrophic emissions generally caused by fossil fuel is never new in research. It is widely reported [1,2] that the earth has experienced an increase in the mean temperature since the 19th century due to greenhouse gas (GHG) emissions with carbon dioxide in lead for the combustion of coal, natural gas and other petroleum products. Conversely, fossil fuel reserves in energy banks saved for future energy challenges globally is reported [2] to cause more harm than good to the society. This has triggered the effort of scholarly research focusing their searchlights towards renewable energy. The harnessing of energy via bio-fuels is increasingly recognized as an important form of renewable energy. Bio-fuel as a source of renewable energy is expected to reduce the over dependence and continuous importation of petroleum products with associated political and economic vulnerability to third world countries like Nigeria. The investment and development of bio-fuels production like bio-ethanol in Nigeria will not only reduce the emission of GHGs and other pollutants but it will also revitalize the nation's economy towards the agricultural sector.

Bio-ethanol is a major substitute for fuel used in automobiles. It can serve about 10 – 20% mixture with petrol of 80 – 90% to form good blend of fuel to enhance complete combustion; thus, reducing the emission of pollutants [3]. It could be obtained by microbiological conversion of simple sugar into ethanol and carbon dioxide from varieties of agricultural products rich in sugar, starchy and cellulosic sources, such as sugarcane, whey, cassava, maize, sorghum, cornstalk, straw, wheat crops, guinea corn husk, rice husk, millet husk, sawdust etc. [4] - [6]. In an attempt to optimize energy from these sources, series of studies have been carried out using different agricultural products with different methods. It has been recommended that cassava peels could be subjected to pretreatment with dilute sulphuric acid to obtain higher ethanol content [7]. Also, the search for bio-fuel for domestic use (cooking) by decomposing waste cassava peels was equally carried out by research study and found its capability of generating fuel with close match properties of methane and propane gas [8]. A similar study for the production of bio-ethanol from cassava peel using different organisms like saccharomyces cerevisiae, gloeophyllum sepiarium and pleurotus ostreatus for hydrolysis was reported [9] – [13].

Meanwhile, the challenge of using some of these feedstocks in bio-ethanol production has been an issue of concern since they serve as human food sources in some countries; though in Nigeria the case is different. Nigeria is identified as the largest cassava producer in the globe. According to reference [5], Nigeria produced about 40,000,000 tonnes of cassava in 2005; followed by Brazil with 25,000, 000 tonnes and the rest of the world producing 20,000,000 tonnes. Currently, the production after a decade plus precisely in 2016, is in an increasing trend with Nigeria at the lead, producing 57,134,478 tonnes, followed by Thailand with 31,161,000 tonnes. Others countries are Brazil, Indonesia, Ghana with 21,082,867; 20,744,674 and 17,798217 tonnes respectively [14]. This trend encourages the study of bio-ethanol production from cassava, though research is focused on the cassava wastewater which has all the potentials for its conversion to usable energy. Thus, cassava wastewater is as a result of the fermentation of cassava which is poured away at the end of the process increasing environmental pollution associated with its disposal. Interestingly, this study seeks to establish that it could be utilized as a source of wealth generation and serve as alternative fuel.

II. MATERIALS AND METHOD

The experimental investigations were carried out in the chemical laboratories of Niger Delta University, Wilberforce Island in Bayelsa State. Prior to the practical, 5kg sample of cassava was taken from harvest of local farmers and was fermented. For fast decomposition and complete dissolution, 2kg of yeast was added to the sample and mixed with water in an air tight condition. Samples were left for 5-days for proper fermentation, decantation and filtration. However, at the end of the first set of experiments, filtered cassava fermentation wastewater was distilled using simple distillation columns as shown in figure 1 to get the first distillate products and finally it was re-distillated for second distillate product of bio-ethanol. Figure 2 shows samples of cassava fermentation wastewater; first and second distillate products respectively.

Figure 1: Bio-ethanol distillation Process

Figure 2: Cassava Fermentation Wastewater and Distillate Products

The experimentation process is similar to the local production of alcohol (local dry gin) distilled from raphia palm tree juice (palm wine). Normally in this process an incision is made in the trunk of the tree and the juice is collected in a can where the sap is boiled to form steam. The steam is then condensed into a final product collection vessel by passing it via a series of water drums (2 or 3) for cooling and conversion of the vapour (steam) to liquid. Meanwhile, the refined liquid is the local dry gin which contain 30 – 60% concentration of ethanol.

For the bio-ethanol production; a round bottom flask with the cassava fermentation wastewater is placed on a thermoelectric heater connected to a condenser which is used for cooling the vapor to liquid. The condenser is held with a retort stand, while a conical flask is placed below the condenser for collection of the condensed products. The process is repeated a second time and redistilled with ice to get better products (bio-ethanol). The final product of the bio-ethanol and a petroleum product (kerosene) is subjected to a combustion test as shown is figure 3. This is to ascertain the thermodynamic characteristics of the produced fuel.

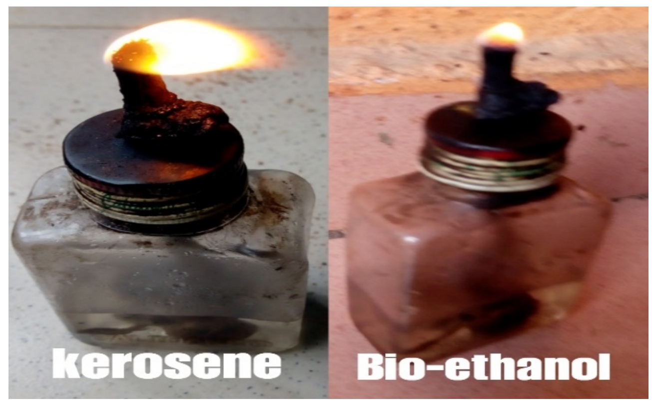

Figure 3: Comparison of Burning Rate

III. COMBUSTION STOICHIOMETRY OF BIO-ETHANOL

The potential capability of bio-ethanol as an alternative source to petroleum products is the ability for it to reduce emissions and other toxic pollutants when put to use. Meanwhile, the purpose of this section is to x-ray the thermodynamic features of bio-ethanol. This analysis was carried out using the stoichiometric chemical combustion equation of bio-ethanol as shown in table 1 whereas other thermofluid characteristics are presented in table 2. The process is to determine the burning rate of the product to ascertain its thermodynamic reliability and viability. The sample tool for these analytical measurements is based on the ability of bio-ethanol to undergo complete combustion process with basically theoretical or excess air. Table 3 shows results based on thermodynamic characteristics of the experimented bio-ethanol against standard ASTM International values of petroleum products. However, possible determination of these properties certainly uses the governing equations as presented in equations 1 – 3. The quantiy Q, is the internal energy change which is independent of the path between the two states and depends only on the initial and final values.

Table 1: Stoichiometric Chemical Combustion Equations for Bio-ethanol (C_2H_5OH)

Air Supply		Equations
Theoretical Air	100%	$C_2H_5OH + 3O_2 + 3(79/21)N_2 \rightarrow 2CO_2 + 3H_2O + 3(79/21)N_2$
	90%	$C_2H_5OH + 2.7O_2 + 2.7(79/21)N_2 \rightarrow 1.4CO_2 + 0.6CO + 3H_2O + 2.7(79/21)N_2$
	80%	$C_2H_5OH + 2.4O_2 + 2.4(79/21)N_2 \rightarrow 0.8CO_2 + 1.2CO + 3H_2O + 2.4(79/21)N_2$
	70%	$C_2H_5OH + 2.1O_2 + 2.1(79/21)N_2 \rightarrow 0.2CO_2 + 1.8CO + 3H_2O + 2.1(79/21)N_2$
Excess Air	110%	$C_2H_5OH + 3.3O_2 + 3.3(79/21)N_2 \rightarrow 2CO_2 + 3H_2O + 0.3O_2 + 3.3(79/21)N_2$
	120%	$C_2H_5OH + 3.6O_2 + 3.6(79/21)N_2 \rightarrow 2CO_2 + 3H_2O + 0.6O_2 + 3.6(79/21)N_2$
	130%	$C_2H_5OH + 3.9O_2 + 3.9(79/21)N_2 \rightarrow 2CO_2 + 3H_2O + 0.9O_2 + 3.9(79/21)N_2$

Table 2: Thermodynamic Analysis for C_2H_5OH

Theoretical Air	Air/Fuel Ratio		Volumetric Composition			Gravimetric Composition				Internal Energy of Combustion
	Mole	Mass	% Production of			% Production of				
(%)	(mol)	(kg)	CO_2	CO	N_2	CO_2	CO	H_2O	N_2	ΔUo (KJ/Kg)
100	14.28	9.00	15.06	-	84.94	19.20	-	11.76	69.04	-6164.78
90	12.86	8.11	11.11	4.93	83.55	14.79	4.08	12.91	68.21	-6180.93
80	11.43	7.21	7.25	10.88	81.87	9.43	8.94	14.33	67.30	-6197.09
70	10.00	6.31	2.02	18.18	79.80	2.62	15.08	16.10	66.20	-6213.25
Excess Air	Mole	Mass	% Production of			% Production of				Internal Energy of Combustion
(%)	(mol)	(kg)	CO_2	CO	N_2	CO_2	CO	H_2O	N_2	ΔUo (KJ/Kg)
100	14.28	9.00	15.06	-	84.94	19.20	-	11.76	69.04	-6164.78
110	15.71	9.90	13.59	2.04	84.36	17.60	1.94	10.78	69.68	-6164.78
120	17.14	10.81	12.39	3.72	83.89	16.27	3.58	9.97	70.19	-6164.78
130	18.57	11.71	11.38	5.12	83.50	15.11	4.98	9.26	70.65	-6164.78

Table 3: Properties of Bio-ethanol against ASTM Values of Petroleum Products

Thermodynamic Characteristics	Products					
	Experimentation Test Results for Bio-Ethanol			ASTM Results		
	Cassava Fermentation Wastewater	First Distillate	Second Distillate	Kerosene	Diesel	Gasoline
Burning rate (m/hr)	0	0.909	0.819	1.471	-	-
Density (Kg/m^3)	1072	1068	1068	810	832	719.7
Flash Point (^{0}C)	0	42	40	39	55	-43
Conductivity (ps/m)	2.00E-11	4.30E-07	4.10E-07	0	25	5
Calorific Values (MJ/Kg)	21.2	24.7	26.1	43	45.5	45.8

Thus, Q is considered as the heat transfer and also the internal energy of combustion or constant volume heat of combustion at T_o.

$$Q = (U_2 - U_1) + W \quad (1)$$

$$\Delta Uo = (UP_o - UR_o) + W \quad (2)$$

Hence, U = h – Pv at a standard state of 25° at 1atm.

$$\Delta Ho = \Delta Uo + R_oT_o (n_P - n_R) \quad (3)$$

Where ΔHo = Enthalpy of combustion @ T_o

To = Reference temperature (25°)

Meanwhile, assumed value of -281102KJ/mol for ΔHo is used for C_2H_5OH from reviewed literature, while; value for universal gas constant, R_o = 8.3144KJ/Kmol and reference temperature at standard state of 25° (T_o = 298K) at 1atm are used as well for the calculations [15, 16].

IV. RESULTS AND DISCUSSION

The analysis of the experimented results for the bio-ethanol burning rate indicate a low value compared to the value of the kerosene. This factor depends on the time taken for the product to undergo complete combustion process. This means the higher the time taken for complete burning, the lesser the burning rate. Thus, it is established that the bio-ethanol takes more time for burning with corresponding burning rate of 0.819m/hr as tested with the local lamp in figure 3. This is an indication that it is more economical than kerosene. Also, the production of carbon emission is a function of high burning rate as established from relevant study for kerosene product with 1.471m/hr. Bio-ethanol fuel was observed to produce little or no emission as compared to the fossil fuel product. Meanwhile, as confirmed from studies; the product quick ignition lies on the flash point. It attests that the lower the flash point the easier the product gets ignited. Conversely, higher calorific value, allows better ignition of the product. The results indicate that bio-ethanol with a flash point of 40℃ - second distillate, has close approximation to that of kerosene with close range of 26.1MJ/Kg calorific value of bio-ethanol against 43MJ/Kg of kerosene.

Another significant observation was the heat evolved during the combustion process. Numerical analysis confirms that the generated internal energy of combustion reduces from -6164.78KJ/Kg to -6213.25KJ/Kg with respect to decrease in theoretical air supply to the combustion process of bio-ethanol. Also, reduction in theoretical air by percentage decreases the air/fuel ratio which is a resultant effect for increasing the products from the combustion process. This is confirmed as the summation of CO_2 and CO generate high volumetric composition value of 69.43% in terms of theoretical air against excess air of 63.20%. Therefore, this justify the reason for the supply of excess air in a combustion process to aid burning while reducing exhaust pollutants to the environment.

V. CONCLUSION

The study of bio-ehtanol production locally by the fermentation of cassava is proven to be another means of bio-fuel generation through alternative sources. Thus, the following conclusions were reached.

- The thermofluid properties of the bio-ethanol satisfies the standard condition for fuel test in terms of its burning rate, flash point and calorific value.
- Based on numerical approach, the bio-ethanol also emits pollutants to the environment like its fossil counterpart when theoretical air for combustion is reduced. Although, in the comparative test for pollution production, bio-ethanol is positively outstanding.
- It is recommended that more distillation test for bio-ethanol be conducted to obtain a density less than the density of water (1000kg/m^3).

Generally, the investigations show that arable crops like cassava has the potential of generating bio-fuels. Therefore, countries like Nigeria with abundant agricultural resources should encourage massive production of agro-crops for the production of bio-fuels. This would enable the diversification of her economy, create job opportunities for the youths and reduce the over dependence on crude oil with its increasingly bleak future.

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