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Modeling of Generation of Biofuel from Solid Biomass

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ABSTRACT

A model for generation of biofuel from solid biomass was derived in this study. The model would assist in utilization of biomass which has always been a reliable source of energy generation through sustainable technology. In this research study, standard methods were used to generate the biofuel and its calorific values. Model was derived based on the assumption that biofuel generation B_f, is related to biomass utilization B_m, by the expression $B_f = aB_m^b$. Linearizing and calibration of model using data corresponding to first to the sixth runs resulted in calculating the constants "a" and "b" which are 37.751 and 0.767 respectively, with coefficient of correlation $r =$ 0.75, while coefficient of correlation after verification of model using data from seventh to the twelfth runs was, $r = 0.965$ an indication that the model is adequate. Results also show that gross calorific value (GCV) and net calorific value (NCV) of biomass were 30400.28 kJ/Kg and 30022.84 kJ/Kg respectively. It is concluded that biomass can be recycled for sustainable energy and recommendation is given that biomass should not be indiscriminately disposed into the environment. Rather, collection stations should be established centrally for effective utilization.

1. INTRODUCTION

Biomass has always been a reliable source of energy (Lee and Lavoie, 2013). Biofuels are fuels derived from biomass which are natural sources that can be replenished by nature (Pandey and Kumar, 2017). Sustainable globalization requires increased fuel feedstock. However, major research work center on the development of fuel from cheap natural resources for heating of homes and electricity supplies (Bender, 2000; Demirbas, 2006; Scott et al., 2010). Presently, fossil fuels are unsustainable and it is forecasted that oil reserves will deplete by the year 2025 (Greene et al., 2006).

Calorific values of solid and liquid fuels are found experimentally with the help of bomb calorimeter. It is the measurement

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of the heat value or amount of energy released and is either measured in gross calorific value (GCV) or higher calorific value (HCV). GCV or HCV is the amount of heat that complete combustion releases by burning a unit of fuel. It assumes all water vapor produced is fully condensed. The net calorific value (NCV) or lower calorific value (LCV) is determined by the subtraction of heat of vaporization of the water vapor from the higher heating value. In addition, it assumes that water vapor leaves with combustion products without full condensation.

The entire process of thermal utilization of solid biomass is affected by the type of biomass used, the chemical composition and physical characteristics such as particle size, bulk density, moisture content and calorific value (Obernberger et al., 2006). These parameters are fundamental for the definition of the commercial values of the biomass material (Fernandez-Llorente and Carrasco-Garcia, 2008). However, the increasing demand for energy globally which center on the use of fossil fuels, have resulted in over-dependence on energy source that is very expensive, unreliable and harmful to the environment (Caraschi et al., 2019). Amongst the various renewable options, vegetal biomass, which was in the past considered inferior fuel, has become increasingly attractive (Gravalos et al., 2016; Tao et al., 2012a; Tao et al., 2012b; Williams et al., 2012). This material can be used in a variety of systems to produce bioenergy and consequently contribute to the development of more sustainable human societies. (Caraschi et al., 2019). Energy generation from biomass is seen by various industries such as agroindustry and forestry industry as an opportunity, in which large amounts of biomass wastes are generated during the productive chain (Cortez et al., 2008; Santos et al., 2013).

Therefore, this study derived a model relating biofuel generation from solid biomass to provide effective guide in management of wastes from vegetable matter and other organic wastes from biomass. Also, the gross calorific value (GCV) and the net calorific value of solid biomass were computed to indicate the indispensable nature of solid biomass.

2. MATERIALS AND METHOD

The method used for bioethanol production was in accordance with Fuad (2010, 2011). In this study, 10 samples of biomass were used to obtain the data for analysis. Physiochemical analyses were carried out on the materials in accordance with the methodologies described in CEN technical normative for solid biomass preparation. The gross calorific value dry basis (GCV) and the net calorific value on dry basis (NCV) of biomass were determined using standard methods.

Assumption:

The relationship between biofuel generation as a function of biomass used is given by the expression;

$$B_f = aB_m^b \quad (1)$$

where;

B_f is the biofuel generated, B_m is the biomass utilized, a and b are constants.

To determine the values of a and b, the linear form of Equation (1) was used thus;

$\ln B_f = \ln a + b \ln B_m$

(2)

Regressing $\ln B_f$ on $\ln B_m$ enabled obtain the slope b, and to obtain the intercept a, Equation (3) below was used thus;

$\ln a = \ln \overline{B_f} - b \ln \overline{B_m}$

(3)

Gross calorific value (GCV) is given by;

$489.4C + 746.8H + 322.1O + 8N + S$

(4)

The net calorific value (NCV) is determined from the expression;

$NCV = GCV - 584 \left(\frac{9H_2\% + M\%}{100}\right)$

(5)

here C, H, O, N and S are the percent compositions of the elements respectively.

Table 1 presented the experimental results for biofuel generated (kJ/) for the corresponding quantities of solid biomass utilized. The biomass utilized in the experiments ranged from 5 g to 60 g at 5 g intervals and the corresponding energies generated were also depicted.

Table 1: Relationship between biofuel utilization and generation

Run	Biomass utilized B_m (g)	Biofuel generated B_f (kJ)
1	5	100.25
2	10	202.45
3	15	298.50
4	20	403.91
5	25	501.67
6	30	605.10
7	35	697.32
8	40	804.11
9	45	900.22
10	50	1000.94
11	55	1099.67
12	60	1202.31

2.1.Model calibration

Table 2 show the calibration of model. Data corresponding to the first six runs were used for calibration to determine the constants a and b, coefficient of correlation r, determined to ascertain the fit which would be assumed adequate if the r- value lie between 0.70 – 1.00.

Let $\ln B_f = y$ and $\ln B_m = x$

Table 2: Model calibration

Run	x	y	x^2	y^2	xy
1	1.609	4.608	2.589	21.234	7.414
2	2.303	5.310	5.304	28.196	12.229
3	2.708	5.699	7.333	32.479	15.433
4	2.996	6.001	8.976	36.012	17.979
5	3.219	6.218	10.362	38.664	20.016
6	3.401	6.405	11.567	41.024	21.783

$\sum x = 16.236, \quad \sum y = 34.241, \quad \sum x^2 = 46.131, \quad \sum y^2 = 197.609, \quad \sum xy = 94.854$

$$b = \frac{n\sum xy - \sum x \sum y}{n(\sum x^2) - (\sum x)^2} \quad (4)$$

$$b = \frac{6(94.854) - 16.526(34.241)}{6(46.131) - 16.236^2}$$

$$= 0.767$$

$\ln \bar{y} = \ln a + b \ln x$

$\therefore 5.707 = \ln a + 0.767(2.706)$

$\ln a = 3.631$

$a = 37.751$

$\Longrightarrow B_f = 37.751(B_m)^{0.767}$

(5)

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

(6)

$$r = \frac{6(94.854) - 16.526(34.241)}{\sqrt{\begin{matrix}[6(46.131) - 16.236^2] \\ x[6(197.609 - 34.241^2)]\end{matrix}}}$$
$$= 0.75$$

2.2.Model verification

Table 3 present the model verification. The essence of model verification is to assure that the model is adequate. Here, let experimental quantity of biofuel generated $B_{f_{exp}}$ be represented by x, and the predicted quantity of biofuel generated $B_{f_{pred}}$ be represented by y.

Table 3: Model verification

Run	x	y	x^2	y^2	xy
7	697.32	577.07	486255.18	333009.78	402402.45
8	804.11	639.31	646592.89	408717.28	514075.56
9	900.22	699.75	810396.05	489650.06	629928.95
10	1000.94	758.65	1001880.88	575542.24	759363.13
11	1099.67	816.18	1209274.11	666149.79	897528.66
12	1202.31	872.51	1445549.34	761273.70	1049027.50

$\sum x = 5704.57, \sum y = 4363.47, \sum x^2 = 5599948.45, \sum y^2 = 3231642.85, \ \sum xy = 4252326.25$

$$r = \frac{6(4252326.25) - 5704.57(4363.47)}{\sqrt{[6(5599948.45 - 5704.57^2)][6(3231642.85) - 4363.47^2]}} = 0.965$$

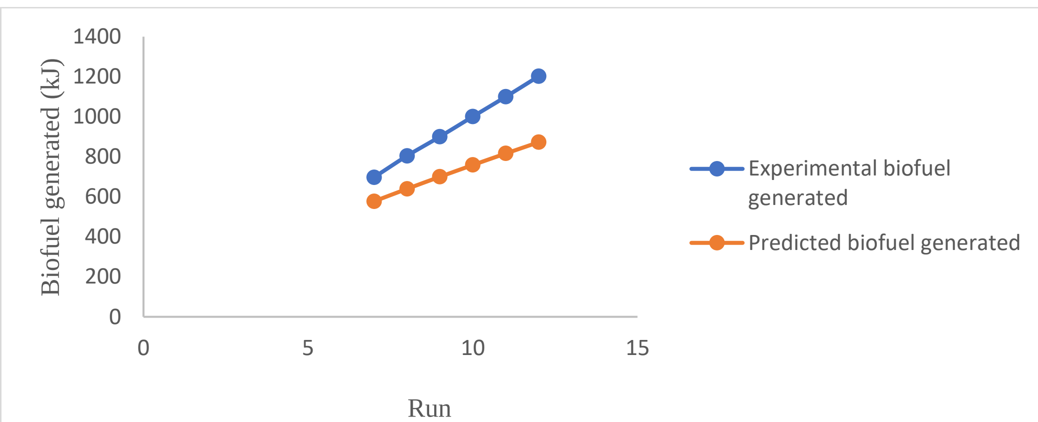

Fig. 1: Verification plot for experimental and predicted biofuel generated

Table 4: Molar composition of elements in biomass

Element	Mass (kg)	Kg/mol	Moles	% Composition
Carbon	34.68	12.01	2.8876	34.68
Hydrogen	4.45	1.01	4.4059	4.45
Oxygen	30.41	16.0	1.9006	30.41
Nitrogen	0.66	14.01	0.0471	0.66
Sulfur	0.19	32.06	0.0059	0.19
Moisture content	24.58			24.58
Ash content	5.03			5.03

Therefore, Gross calorific value (GCV) of solid biomass was obtained by substituting the per cent compositions of constituent elements in Equation (4) thus;

$$[(489.4 \times 34.68) + (746.8 \times 4.45) + (322.1 \times 30.41) + (8 \times 0.66) + 0.19] = 30400.28\ kJ/kg$$

Similarly, the net calorific value (NCV) was computed by substituting per cent constituent elements in Equation (5) thus;

$$NCV = 30400.28 - 584\left[\frac{(9 \times 4.45) + 24.58}{100}\right] = 30022.84\ kJ/Kg$$

3. CONCLUSION

A model relating biofuel generation from solid biomass was derived in this study. Gross and net calorific values, GCV and NCV of the solid biomass were also evaluated. The results indicate that the model would provide effective guide in biomass recycling terms of conversion to energy for power generation. It is concluded that biomass can be recycled for sustainable energy and recommendation is given that biomass should not be indiscriminately disposed into the environment because of its high energy content. Rather, collection stations should be established centrally for effective utilization.

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