Modelling the Cumulative Biogas Produced from Sawdust, Cow dung and Water Hyacinth

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Abstract— *This research was carried out to model cumulative Biogas produced from sawdust cow dung and water hyacinth as an alternative means of sawdust disposa. The model was done using statistical tools via determination of coefficients of regression for the following digester setups which were made up A, B, C, D, E, F, and G with varying sawdust concentrations but with a constant concentration of cow dung and water hyacinth. The linear, exponential and polynomial models were tested with the obtained data, and the results obtained for each of the digesters showed that polynomial model best fitted the cumulative biogas production at any given day with R^2 values of 0.9904, 0.9962, 0.9981, 0.987, 0.9938, 0.9882 and 0.9857 respectively while linear models came second best with R^2 = 0.9889, 0.996, 0.998, 0.9851, 0.9934, 0.9836 and 0.9836 respectively for Digester A, B, C, D, E, F, and G. Therefore, for accurate prediction of cumulative production of biogas at any given day, it can be recommended that polynomial models be applied*.

Keywords*— *Sawdust, Cow dung, Water hyacinth, Biogas production.

I. INTRODUCTION

The large amount of agricultural wastes produced annually and the indiscriminate dumping of the sawdust, especially from lumbering activities, in the environment has caused a lot of environmental management issues, the decomposing of the sawdust waste and animal dung has led to pollution of the land areas where they are dumped, causing diseases as a result of the breeding of microbes. Of all the forms of solid organic wastes, the most abundant is animal dung primarily from small farms, and it is from these farms that the pollution problem originating from waste disposal is more intense (Ismail *et al*, 2012). Organic solid waste includes garbage, vegetable, and food waste consists 52%, straw and wood consist 14%, clothes 3.1% and paper 3.5% (Elango et al, 2006). The utilization of microbial activity to treat agricultural, industrial and domestic wastes has been a common practice for half a century. This treatment includes the aerobic activated sludge process and the anaerobic or fermentation method (Hill, 1983). The current method of disposal, like landfills, are not suitable in big cities due to space constraint.When landfills are used to dispose of wastes, valuable land that can be used for diverse purposes is wasted. In other treatment methods, like incineration and pyrolysis, air pollution problems are predominant and initial investments are also usually too high. Anaerobic digestion has been demonstrated to be technically viable (Elango*et al*, 2006). Anaerobic digestion is a multi-stage process occurring in the absence of oxygen, where bacteria are the primary organisms involved (Bingemer*et al*, 1987). In very well-designed digesters, the fermenting mass pH is usually buffered in the region of 6.8 and 7.4. Dueto the highly sensitive nature of bacteria to temperature, they have a limited range of temperatures, within which they are active. Methanogens, in particular, are very sensitive to temperature changes. In this manner, the optimum temperature of the anaerobic digestion ranges from 30 to 40 ◦C (Ranade, 1988). During the fermentation of organic wastes, acetic acid is usually the main product. The excess production of volatile fatty acids (VFA) may result in an inhibitory effect on the fermentation of organic wastes (Noike, 2000). The nitrogen and phosphorus contained in the Municipal solid Waste (MSW) and domestic sewage are sufficient to satisfy the cell growth requirements during biogas production. The other elements, such as sodium, potassium, calcium, magnesium, and iron are present in low concentrations. However, they may exhibit inhibitory effects at higher concentrations

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(Speece*et al*,1998). This study is aimed at establishing a predictor model that can predict the cumulative biogas produced in any given days for sawdust, cow dung and water hyacinth system

II. MATERIAL AND METHODOLOGY

2.1 Experimental Set-Up

The experiment is based on a batch type of digester. Biomass is added to the batch reactor at the start of the process and is sealed for the duration of the process as shown in Fig.1.A 500ml capacity Buckner flask digester is used as batch reactor and biogas collection is done by water displacement method (Habmigern, 2003) and while mixing (agitation) was done daily.

Fig.1: Experimental Setup for Studying the Biogas Evolution

2.2 BIOGAS MEASUREMENT

Biogas produced was measured by water displacement method in which biogas produced displaced an equal volume of water equivalent to the volume of biogas produced. The displaced water is the saturated brine solution, which makes the biogas insoluble in the solution. (Itodo et al.,1992).

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Table 1. Experimental Input Data

Digester	Water hyacinth(g)	Cow Dung (g)	Saw dust waste (g)	Total Solids (g)
A	7	7	0	14
B	7	7	5	19
C	7	7	10	24
D	7	7	12	26
E	7	7	15	29
F	7	7	20	32
G	7	7	20	34

For the preparation of brine solution: To about 5400m1 of water, sodium chloride is added until the solution becomes supersaturated, that is, the sodium chloride no longer dissolves and then stirred vigorously. This forms the stock solution from which portions are drawn to fill the 1000ml Buckner flask as shown in Fig.1. As biogas production commences, it moves from the 500ml Buckner flask into the second Buckner flask (1000ml) where it exerts a pressure that causes water to rise in the connecting pipe into the measuring cylinder. The amount of water displaced is proportional to the biogas produced

III. RESULTS AND DISSCUSION

The Cumulative Biogas produced from the various Digesters, that is, from Digester A to G was plotted against the production days and are presented as shown in Figures 2 to 8.

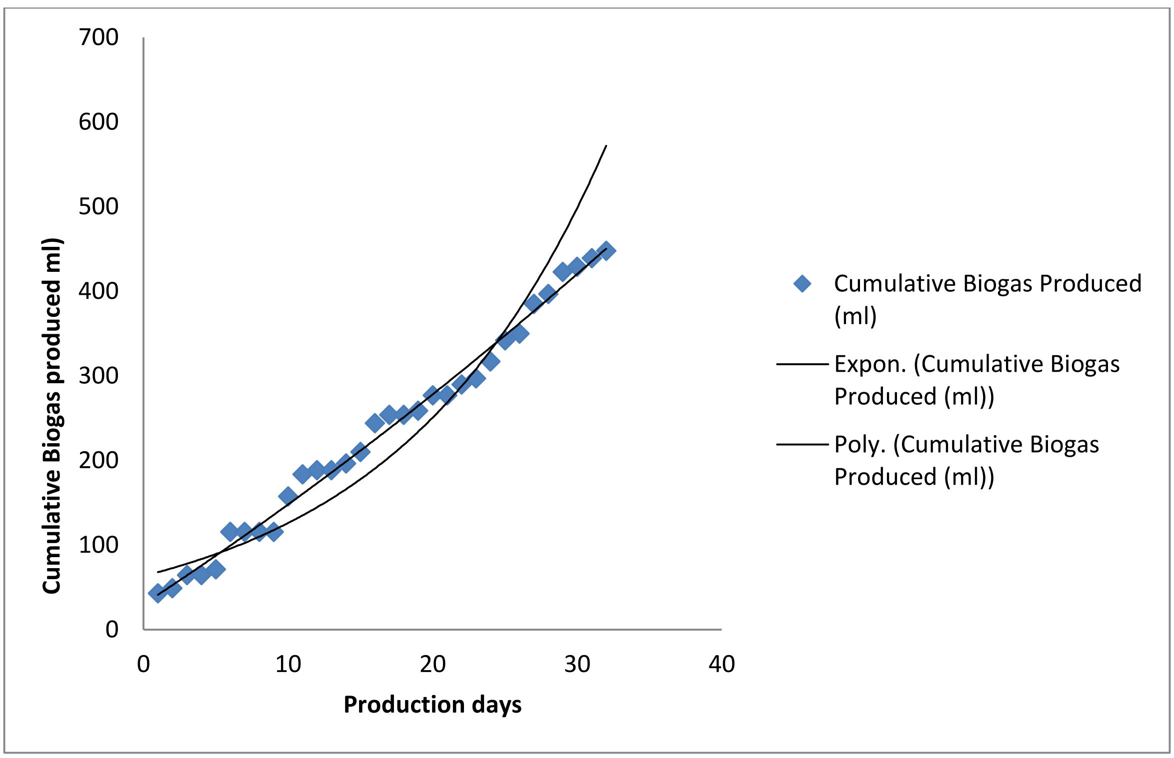

Fig.2: Cumulative Biogas produced from Digester A

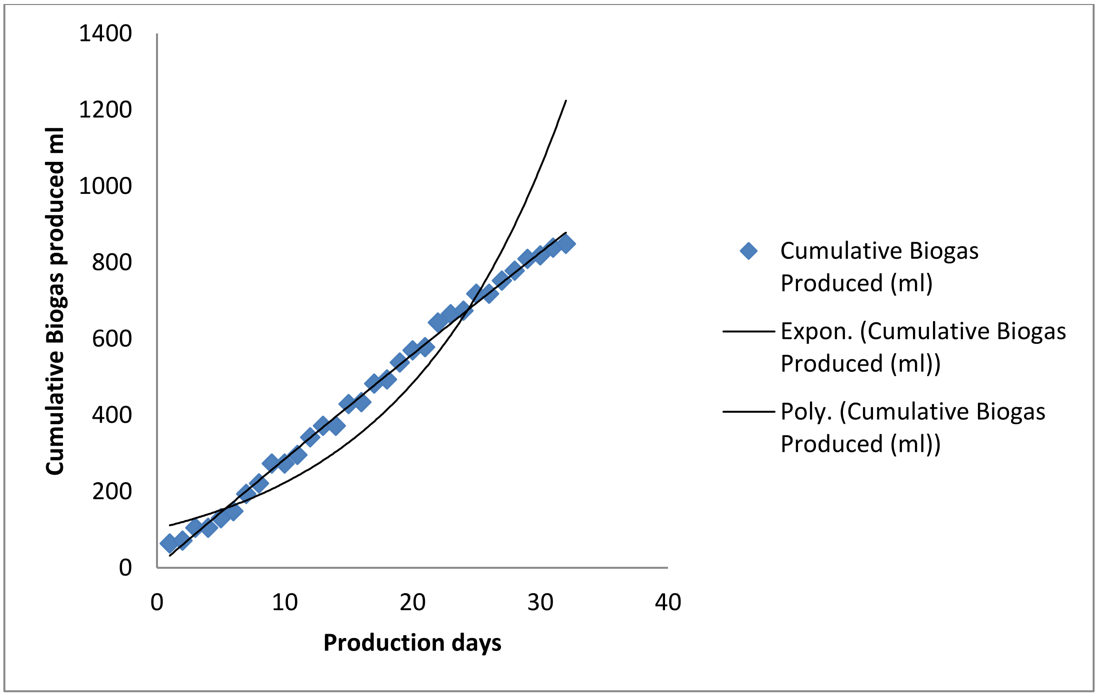

Fig.3: Cumulative Biogas produced from Digester B

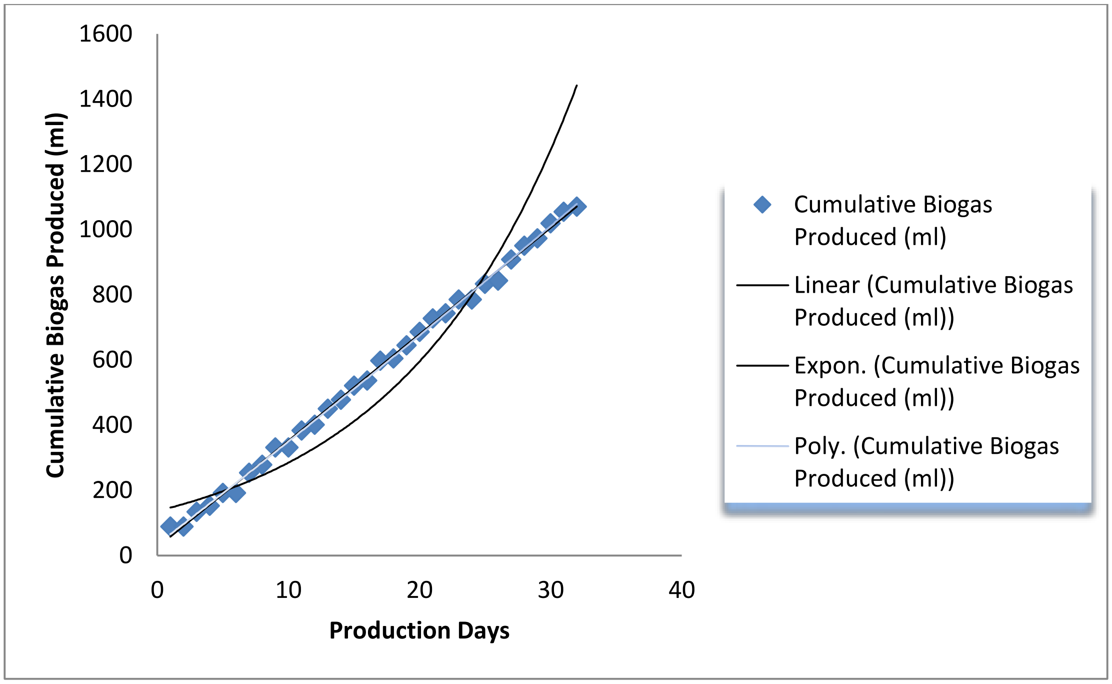

Fig.4: Cumulative Biogas produced from Digester C

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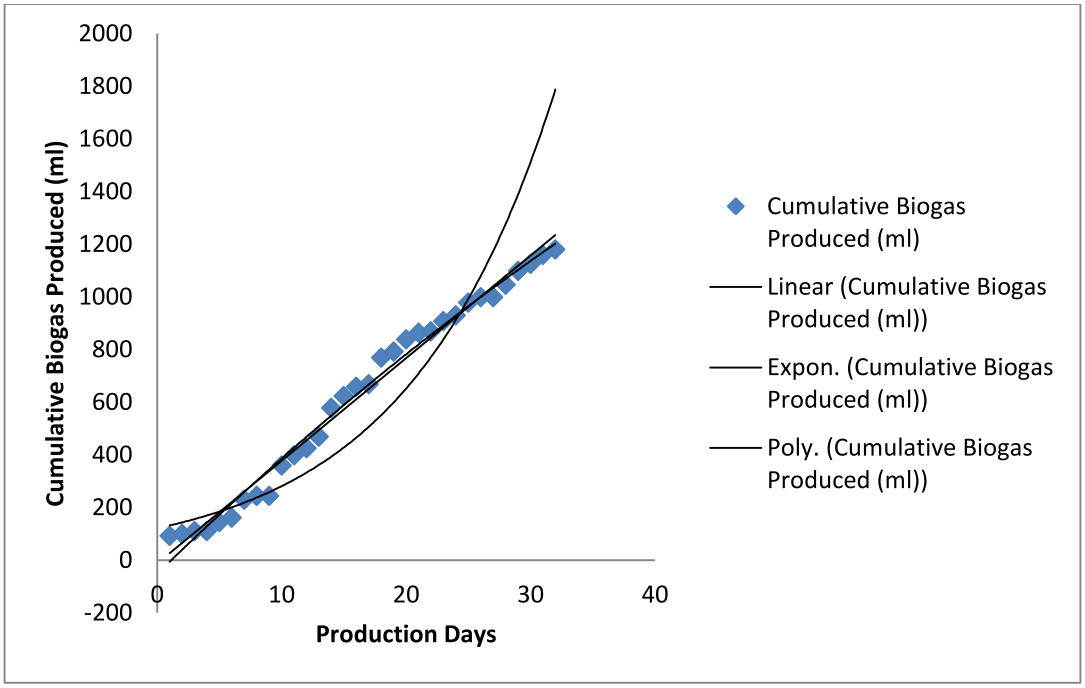

Fig.5: Cumulative Biogas produced from Digester D

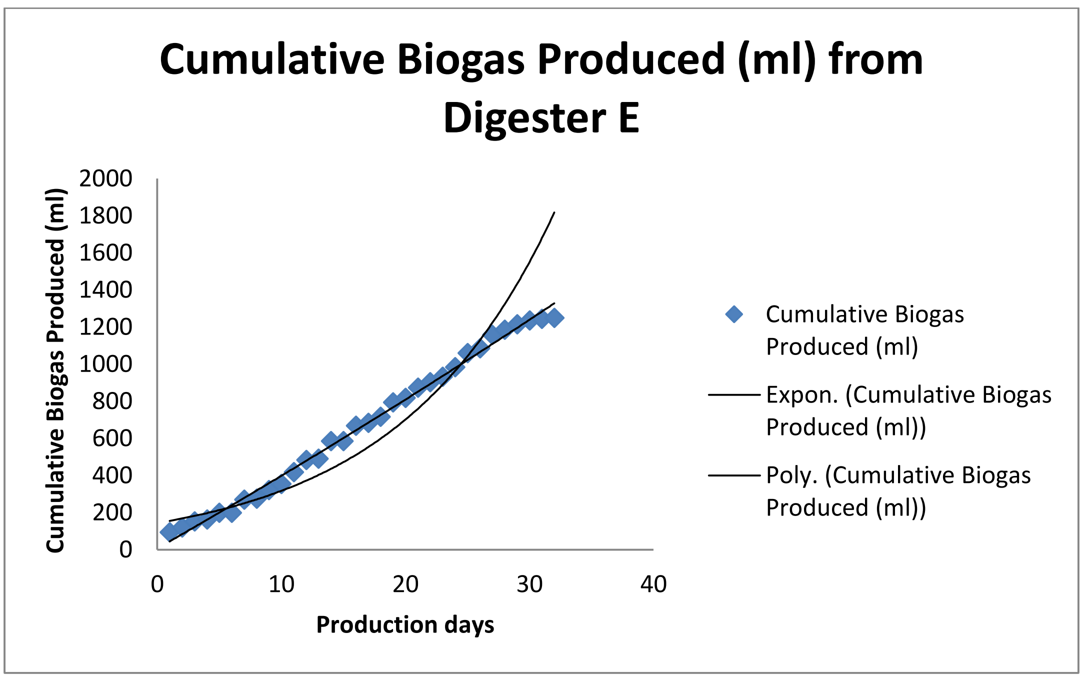

Fig.6: Cumulative Biogas produced from Digester E

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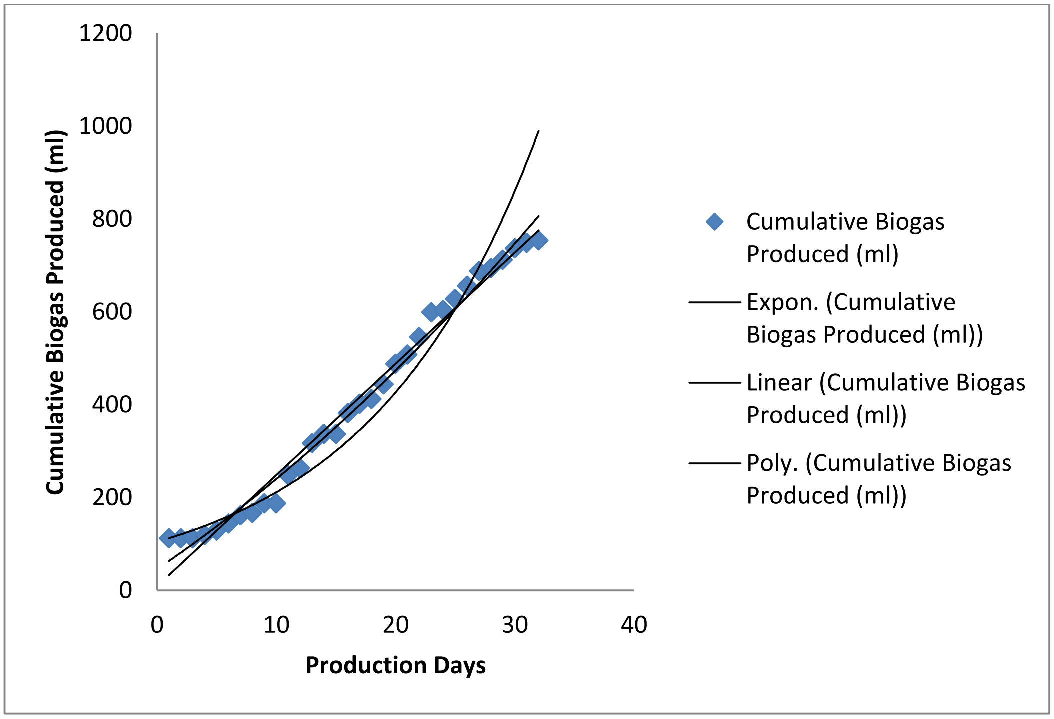

Fig.7: Cumulative Biogas produced from Digester F

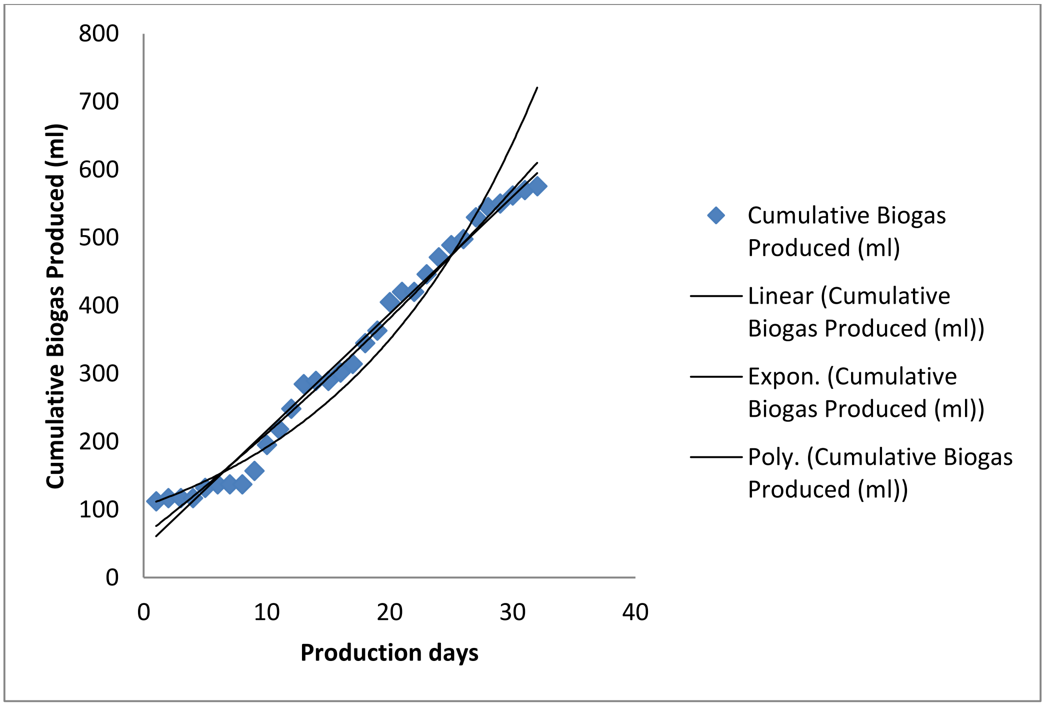

Fig.8: Cumulative Biogas produced from Digester G

Table 2: Models of the relationship between the cumulative Biogas produced and the production days for the various Digester

	Type	Equation	R-squared
	Linear	$y = 13.196x + 18.542$	$R^2 = 0.9889$
Digester A	Exponential	$y = 63.328e^{0.0688x}$	$R^2 = 0.9161$
	Polynomial	$y = 0.0609x^2 + 11.185x + 9.939$	$R^2 = 0.9904$
	Linear	$y = 27.312x + 10.592$	$R^2 = 0.996$
Digester B	Exponential	$y = 102.97e^{0.0774x}$	$R^2 = 0.902$
	Polynomial	$y = -0.0379x^2 + 28.563x + 3.5005$	$R^2 = 0.9962$
	Linear	$y = 32.69x + 24.639$	$R^2 = 0.998$
Digester C	Exponential	$y = 136.11e^{0.0738x}$	$R^2 = 0.9103$
	Polynomial	$y = 0.0493x^2 + 31.063x + 3.864$	$R^2 = 0.9981$
	Linear	$y = 38.972x - 12.656$	$R^2 = 0.9851$
Digester D	Exponential	$y = 121.17e^{0.0841x}$	$R^2 = 0.896$
	Polynomial	$y = -0.207x^2 + 45.802x - 51.361$	$R^2 = 0.987$
	Linear	$y = 41.382x - 11.427$	$R^2 = 0.9934$
Digester E	Exponential	$y = 143.49e^{0.0793x}$	$R^2 = 0.926$
	Polynomial	$y = 0.097x^2 + 38.18x + 6.7188$	$R^2 = 0.9938$
	Linear	$y = 23.972x + 8.7641$	$R^2 = 0.9836$
Digester F	Exponential	$y = 104.85e^{0.0702x}$	$R^2 = 0.9634$
	Polynomial	$y = 0.1978x^2 + 17.444x + 5.754$	$R^2 = 0.9882$
	Linear	$y = 17.241x + 43.423$	$R^2 = 0.9836$
Digester G	Exponential	$y = 105.09e^{0.0602x}$	$R^2 = 0.9584$
	Polynomial	$y = 0.0971x^2 + 14.038x + 1.578$	$R^2 = 0.9857$

Figures 2 to 8 show the plot of cumulative biogas produced on different days up to 32days.The figures show a trend which suggests that the quantity of biogas produced increased as the number of days increased.This is in agreement with the finding of Federica et al.(2019).

Table 2 shows the model relationship between the cumulative biogas produced and the production days.From the table, Digester A which comprises water hyacinth and Cow dung has the following regression coefficients, R^2 = 0.9889, 0.9191 and 0.9904 representing linear, exponential and polynomial models respectively.From the models the polynomial model has the best fit with R^2 value of 0.9904, followed by the linear model with $R^2 = 0.9889$. For Digester B the regression coefficient, R^2were 0.996, 0.902, and 0.9962 for the linear, exponential and the polynomial models respectively.From these values, the polynomial model fits the data better.Therefore, for Digester B it can be represented by y = $-0.0379x^2 + 28.563x + 3.5005$. For Digester C, coefficient of regression, R^2

of 0.998, 0.9103, and 0.9981 were determined.From the models,the polynomial fits it better with R^2 of 0.9981 with equation given by y = $0.0493x^2 + 31.063x + 3.864$. Digester D had regression coefficients, R^2 of 0.9851, 0.896, and 0.987 for linear, exponential and polynomial models respectively, From the models, polynomial fits it better with R^2 of 0.987 with equation given by y = $-0.207x^2 + 45.802x - 51.361$. Digester E has a coefficients of determination R^2

of 0.9934, 0.926, and 0.9938for the three cases.The polynomial model fits the data better with $R^2$of 0.9938 and equation given by y = $0.097x^2 + 38.18x + 6.7188$. Digester F has coefficients of determination, R^2 of 0.9836, 0.9634, and 0.9882 for the linear, exponential and polynomial models respectively.The polynomialmodel fits it better with R^2 of 0.9882 and model equation given by y = $0.1978x^2 + 17.444x + 5.754$.

Digester G has coefficient of determination R^2 of 0.9836, 0.9584, and 0.9857 for the three cases respectively.From the models, the polynomial fits it better with R^2 of 0.9857 and the model equation given by y = $0.0971x^2 + 14.038x + 1.578$. For all the Digesters, the polynomial model best describes them. it, therefore, means that the polynomial model can be used to correctly predict the cumulative biogas production on any given day.

IV. CONCLUSION

The polynomial model best describes all the digesters that were studied. It can be used to accurately predict the cumulative biogas production at any given time.Also, in absence of the polynomial model, a linear model could be used but with a little degree of inaccuracy.

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