Effect of Biogas Effluent generated from Domestic Wastes as Organic Fertilizer on Growth and Yield of Tomato (*Lycopersicum esculentum*)

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***Abstract*—Human activities results in waste, either at subsistence/household or commercial level; this has become a global problem that requires urgent solution. This work was aimed at reducing and eliminating the nuisance of these wastes by producing an alternative energy source (cooking gas) which will help in reducing environmental pollution and produce high grade fertilizer for crop production. The main objective of this study was to determine the effect of biogas effluent generated from organic wastes on tomato plants. Materials used for this study include: spinach sticks and plantain waste peels; poultry manure; 10 and 4 liters plastic Kegs, 100 and 70 liters plastic drum, 5mm gas hose, Gas valve, Gas pressure gauge. Parameters measured include: soil and effluent composition, growth rate (plant height, stem girth, number of leaf, canopy width, number of flowers, length of branches, number of branches, fruits weight and number of fruits). The slurry and NPK fertilizer used were determined using standard methods. It was observed that the slurry support the growth of tomato but with lesser fruit yield compared with NPK; highest number of substrate mixtures recorded the highest gas production and methane content, the effluent from plantain peel and poultry manure anaerobic digestion gave the highest nutritive values which perform better than the control and favorably with the chemical fertilizer (NPK) in terms of the number of flowers, fruits and fruit yield produced. The bio-digester is user-friendly, safe to operate, can be used for any domestic and agricultural wastes and can operate as batch or continuous flow process. The plants to which the effluent was applied first brought out flowers and fruits earlier than others. The fruits produced by these plants were also bigger than others. The research has also shown that the effluent resulting from the digestion of such substrate is of immense use in the production of tomato.**

Keywords—organic wastes, biogas, biogester, growth rate

I. INTRODUCTION

Energy plays a vital role in our day-to-day activities either in domestic or industrial applications. The current use of fossil fuels is rapidly depleting the natural reserves. The natural formation of coal and oil is a very slow process which takes ages. The dependence on oil has necessitated a search for alternative and renewable sources of energy, such as hydro-power, wind and solar energy and biogas. Biogas unit is the use of biological process, in the absence of oxygen, for the breakdown of organic matter into biogas and high quality fertilizer. Biogas as an alternative source of energy is renewable and considered one of the cheapest renewable energies in rural areas in developing countries. It is a combustible mixture of methane, carbondioxide and traces of water, hydrogen sulfide and halogens. And the process eliminates disease-causing organisms that cause disease in humans and animals. Any organic matter with the exception of mineral oil can be used as feedstock for anaerobic digestion to produce biogas (Ilori *et al.,* 2007). In many countries various cellulosic biomass (animals dung and crop residues) are available in large quantity which have a very good potential to cater to the energy demand and fertilizer, especially in the domestic applications. But, the high installation and maintenance costs [1], [2], [3]. Lack of technical base for maintenance and repair [4] and organizational difficulties has hindered its wide spread. However, in recent years a low-cost digester, made from polyethylene tubular film, has been promoted and used in many developing countries aimed at reducing the cost of making a digester by using local materials, simplifying installation, operation and maintenance [5], [6], [7], [8], [9], [10]..

Since ancient times, biogas is produced by the decay of vegetable and animal waste, and was early identified as a combustible “swamp gas” [11], [12]. The highly desirable fuel was obtained by fermentation of sewage as early as 1934 and was used for heating and initial combustion engine for pumping [13]. Attention is currently focused on biogas generation from organic waste i.e. animal manure and plant residues. Several large demonstration plants are functioning well and many small units are in daily use [14]. Presently, countries like China, India, Germany, Sweden, UK, Nepal, Pakistan, Switzerland etc have actualized this idea and doing well. As at 2005, more than 17 million family-sized low-technology digesters were used in China to provide biogas for cooking and lighting and well over 15 millions in India [15], while Germany at as 2006 had about 3 500 biogas plants. The use of biogas as vehicle fuel in Sweden started way back in the 1990s and has since led the world in biogas use for buses and other vehicles by 1996. More than 2000 high-rate anaerobic digesters are operated world-wide to treat organic polluted process waste water from beverage, food, meat, pulp and paper and milk industries [15]. In Africa, there are hundreds of biogas digesters installed already in countries like South Africa, Kenya, Tanzania, Rwandan, and Nigeria among others. Nigeria produces about 227,500 tons of fresh animal waste daily and since 1 kg of fresh animal waste produces about 0.03 m^3 biogas, a potential of about 6.8 million m^3 of biogas everyday from animal waste only is possible [16]. Also other raw materials available in Nigeria have been critically assessed for their possible use in biogas production by [16]. Vegetables and plantain constitute a major food crops in Nigeria and as a result, large amount of wastes are generated from the uneaten parts (sticks and peels). Biogas plants have huge potential to manage, produce a clean fuel and manure from these wastes.

Human activities results in waste, either at subsistence level (household) or commercial level such as industries, agriculture, hotels, institutions; this has become a global problem that requires urgent solution. Wastes are now seen as a means of solving social and economic problems. [17] developed a bio-digester for producing biogas from waste bio-materials to reduce and eliminate the menace and nuisance of these wastes and thus produce an alternative energy source (cooking gas) which will help in reducing environmental pollution. The biogas effluent produced also causes a tremendous accumulation of waste materials in the surroundings thus; this work was aimed at determination of the effect of biogas effluent generated from Domestic Wastes as Organic Manure for Tomato Plant.

II. MATERIALS AND METHODS

A. *Materials*

Materials used for this study were locally acquired, they include: spinach sticks (S) and plantain waste peels (Pl); poultry manure (P); 10 and 4 liters plastic Kegs, 100 and 70 liters plastic drum, 5mm gas hose, Gas valve, Gas pressure gauge, Tee gas connector, Gas needle nut, PVC tube pipe, PVC elbow pipe, back nut, nipple and reducer, PVC gum, Flexi tape, Ruler, Funnel, oven dryer, Digital vernier caliper, Digital K type thermometer, Digital weighing balance, Hygrometer, Pan. The constructed bio-digester is presented in Figure 1 [17]. A mix of spinach plant and poultry of 70:30, plantain peel and poultry manure of 70:30 and spinach plant, plantain peel and poultry manure of 35: 35: 30 were prepared at total solids, TS of 7, 8, and 9% for the biogas generation

B. *Determination of Effluent and Soil Composition*

Effluents were analyzed for Nitrogen, Phosphorus, Magnesium, Calcium, pH, Sodium and Potassium in the laboratory. Soil samples were obtained from the field used for the experiment and tested prior to and after planting to determine the levels of changes in Nitrogen, Phosphorus, Magnesium, Calcium, Aluminum, Organic Matter, Sodium, Hydrogen, ECEC, pH and Potassium content.

C. *Determination of Growth Rate*

Tomato seeds were obtained from Department of Plant Science, Obafemi Awolowo University, Ile-Ife Nigeria. The seeds were planted initially in a green house for 30 days in pre-nursery tray, and later a proper cup for 2 days for hardening process.

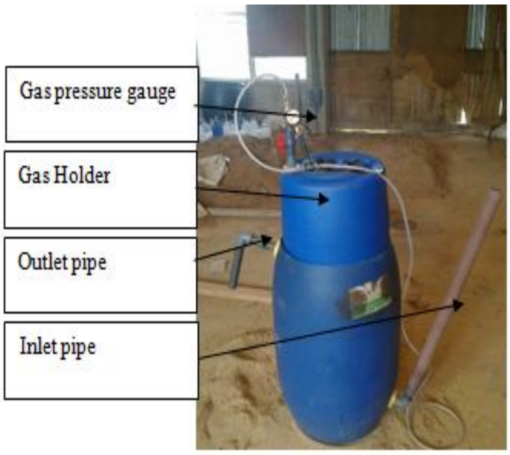

Plate 1: Constructed Bio-digester (Osunade *et al.* 2016)

They were transplanted to the field and planted at a spacing of 60cm x 30cm. Fertilizer application was carried out weekly until flowering stage. The slurry with the highest Nitrogen percentage and NPK 15:15:15 fertilizer was used to plant. A concrete planting basin of 120m x 60m was used for the field planting. The following plant growth parameters was monitored and recorded weekly; plant height, stem girth, number of leaf, canopy width, number of flowers, length of branches, number of branches, fruits weight and number of fruits. The data collected was analyzed using descriptive and inferential statistics to check their growth performance.

D. Determination of Slurry and NPK Quantities Applied

This was determined using the Nitrogen value of the slurry and NPK on the required nitrogen for the crop using:

$$TN = \frac{R_N \, x \, 100}{N_S}, \qquad (1)$$

if TN = 10,000m^2 then,

$$Qs = \frac{T_N \, x \, A_M{}^2}{10000} \qquad (2)$$

Where: RN is the Required nitrogen value per hectare, TN is the calculated nitrogen per hectare, Ns is the average nitrogen value of slurry/NPK, Qs is the quantity to apply and Am^2 is the planting area.

E. Statistical Analysis

The data collected was subjected to a one – way analysis of variance (ANOVA) to determine the effects of the digester temperature, ambient temperature and pH on biogas generated on the various levels of treatments. Duncan's multiple range tests was used to establish the differences among treatments. The statistical analysis was performed using the Statistical Analysis System [18] software.

III. RESULTS AND DISCUSSION

The result of waste characteristic, effluent composition and the soil composition test is presented in Tables 1 – 3 while the physico-chemical properties of the tomato fruits is presented in Table 4

Table 1: Wastes Characteristics

Samples	Moisture content	Ash percentage	Carbon content	Nitrogen content	C/N ratio
Spinach stalk	94.96	1.72	54.6	0.7	78
Plantain peel	82.75	2.36	54.24	0.67	80.96
Poultry manure	74.59		36.87	3.3	11.17

Table 2: Effluent Composition

Type	pH	% Total N	P (ppm)	Na^+ Cmol/kg	K^+ Cmol/kg	Ca^{2+} Cmol/kg	Mg^{2+} Cmol/kg
S:P 7%	8	0.5286	42.68	0.17	2.05	8	0.92
S:P 8%	6.9	0.0898	31.43	0.15	1.8	3.4	0.46
S:P 9%	6.7	1.28	31.08	0.18	1.86	6	0.46
Pl:P 7%	5.7	1.6808	142.4	0.16	1.92	2.8	0.92
Pl:P 8%	5.5	0.4311	378.3	0.16	2.05	3.4	0.46
Pl:P 9%	5.5	0.9652	333.68	0.15	1.8	2.2	0.23
S:Pl:P 7%	6.2	1.4696	60.53	0.17	1.83	2.6	0.69
S:Pl:P 8%	6.3	0.5733	53.54	0.12	1.67	4	3.4
S:Pl:P 9%	6	1.0213	50.83	0.14	1.8	2.4	2.76

Table 3: The soil composition

S/N	K+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	ECEC	P	N%	pH	OM
1	0.77	0.22	7.3	0.88	1.2	5.9	16.27	3.817	0.65	7.1	3.689
2	0.78	0.21	7.5	0.91	1.3	5.2	16.39	3.876	0.66	7.3	3.781
3	0.76	0.22	7.0	0.85	1.5	5.6	16.22	3.888	0.63	7.0	3.668
Ave	0.77	0.22	7.3	0.88	1.33	5.9	16.29	3.861	0.63	7.1	3.713
S. D.	0.01	0.0058	0.252	0.03	0.153	0.2	0.087	0.038	0.03	0.153	0.06

Table 4: Physico-Chemical Properties of Tomato Fruits

Parameters	Slurry	NPK	Control
Moisture content (%)	91.62	91.25	92.89
Ash (%)	0.71	0.68	0.53
Crude fibre (%)	1.13	2.79	2.30
Ether extract (%)	0.36	0.42	0.46
Crude protein (%)	4.81	5.91	4.38
	Drying		

Weight before (g)	1094	1000	1118
Weight after (g)	246	168	208
	Number of fruits at second harvest		
Nos	26	9	15

Please note: the second harvest was done after week 9, i.e. between week 10 – 12, in which no treatments (NPK and slurry) were applied during these periods.

A. Growth and Yield Parameters at Harvest (15 Weeks After Planting WAP)

Means from the analysis of Variance (ANOVA) of the traits at harvest showed that, the mean squares of fruit yield and other growth parameter at harvest of tomato evaluated under different fertilizer treatments had significant effect on the fruit weight, number of leaf and length of branches. However, the treatments had no significant effect on parameters like, plant height, stem girth, canopy width, number of branches, number of flowers and number of fruits. Least significant difference (LSD) of plant height, stem girth, canopy width, number of leaf number of branches, length of branches, number of flowers, number of fruits and fruit weight were obtained as: 43.1, 0.2, 28.1, 13.8, 12.5, 14.4, 8.7, 8.7, 20.7 and 246.1, respectively as presented in Tables 5 and 6.

The slurry and control (SC), slurry and NPK (SN) and between NPK and control (NC). The NPK had the highest mean value of 140.9 and the lowest for the slurry with a value of 117.6. However, the NS and NC had significant effect with mean differences of 0.3 and 0.2 respectively. But CS showed no significant for the stem girth. The mean values also showed that control had the highest canopy cover (82.2cm), while NPK treatment had the least (75.0cm) mean. The number leaf mean values indicated that, the SC and SN were significant with mean difference of 30.9 and 21.1 respectively. The NC was however not significant. The mean values of C, N and S for the number of branches are as follows 48.8, 39.4 and 38.1. But, the S:N, S:C and N:C treatments effect was not significant. In addition, the length of branches with means difference of 18.3, 28.4 and 10.1 for SC, SN and NC, respectively, showed that the effect of SC and SN was significant and NC not significant. The SN had the highest difference mean value of 28.4. The number of flowers means values showed that all SN, SC and NC effects were not significant. With the highest mean value from NPK with 6.3, slurry, 5.3 and the lowest control with 4.0. And from the mean values for number of fruits, 7.3, 33.3 and 17 (C, N, and S), only N: C was significant with mean difference of 26. The NS and CS were not significant with difference mean values of 16.3 and 9.7, respectively. The result of the mean values of the fruit weight also showed that only N: C was significant, while S: N and S: C effect was not the significant. Their mean values are 63.3 for C, 241.6 for S and 474.9 and N.

B. The pattern of growth and yield parameters

Plant height, stem girth and canopy increased as the plant matures(Figures1 – 3). The number of leaves also increased as the plant matures. This was also reported by [19] that the plant height and number of leaves increases as the plant matures. However, the number of the leaves reduces at a time (Figure 4) which may be due to the yellow curl leaf virus attack on the plant. The number and length of branches also showed an increase to a maximum as the plant matures and later slows down again (Figures 5-6) so that the graph obtained by plotting them against time gave a sigmoid curve. The tomato plants growth patterns showed an initial slow growth in the nursery and the accelerated (linear or polynomial) growth as observed in the green house after transplanting. The number of flowers, number of fruit and fruit weight per treatments are presented on Figures7-9. Although, there was no significant difference for the number of flowers among the treatments, higher value was recorded for the slurry while the control gave the least value. The highest values were recorded for NPK treatment. The higher number of fruit from the slurry compared to control agreed with [20] where tomatoes yield was increased by application of slurry from anaerobic digestion (AD). The slurry had better effect on the fruit enlargement compared with the control as reported by [21], that slurry had better performance on fruits enlargement. The general low yield obtained from the tomato might be due to the virus disease and non-development of flowers into fruits as about 20% of the flowers developed into fruits. Most of the flowers were dried up and fell off, while some forms tiny fruits which shriveled up and fall off without further development. This may be due to their genetic composition. [22] discovered that only 50% of the flowers produced developed into fruits. The poor fruit set may also be a result of high temperatures and rainfall that are not conducive for good fruit set. This was supported by [23] who reported that high temperatures affect fruits setting in tomato.

Table 5: Mean squares of fruit yield and other growth parameter at harvest of tomato evaluated under different fertilizer treatments in the green house of Obafemi Awolowo University, Ile-Ife in 2012.

Source	DF	Fruit yield (g)	Stem girth (cm)	Plant height c(m)	Number of leaf	Number of branches	Length of branches	Number of flowers	Number of fruits	Canopy width (cm)
Treatment	2	127799*	0.0377ns	532.3ns	748.3**	102.4ns	624.6*	4.11ns	518.1ns	44.2ns
Replicate	2	5970.6ns	0.0182ns	1920.7ns	517.8*	104ns	106.5ns	3.44ns	16.8ns	209.4ns
Error	4	11786	0.0055	6.6	37.2	30.5	40.3	14.61	83.4	153.9
Corrected Total	8									

Table 6: Mean values of fruit yield and other growth parameter at harvest of tomato evaluated under different fertilizer treatments in the green house of Obafemi Awolowo University, Ile-Ife in 2012.

Treatment	Plant height	Stem girth	Canopy width	No of leaf	No of branches	Length of branches	No of flowers	No of fruits	Fruit weight
C3	118.2	1.5	82.2	106.8	48.8	92.0	4.0	7.3	63.3
N2	140.9	1.7	75.0	116.6	39.4	102.1	6.3	33.3	474.9
S1	117.6	1.4	76.4	85.7	38.1	73.7	5.3	17.0	241.6
Grand mean	125.6	1.5	77.9	103.0	42.1	89.3	5.2	19.2	259.9
`LSD	43.1	0.2	28.1	13.8	12.5	14.4	8.7	20.7	246.1

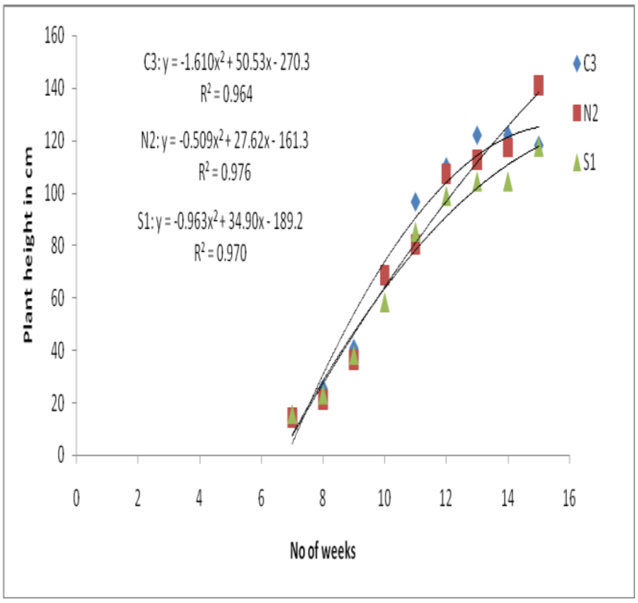

Figure 1: The effect of the three treatments on the rate of increase in plant heights

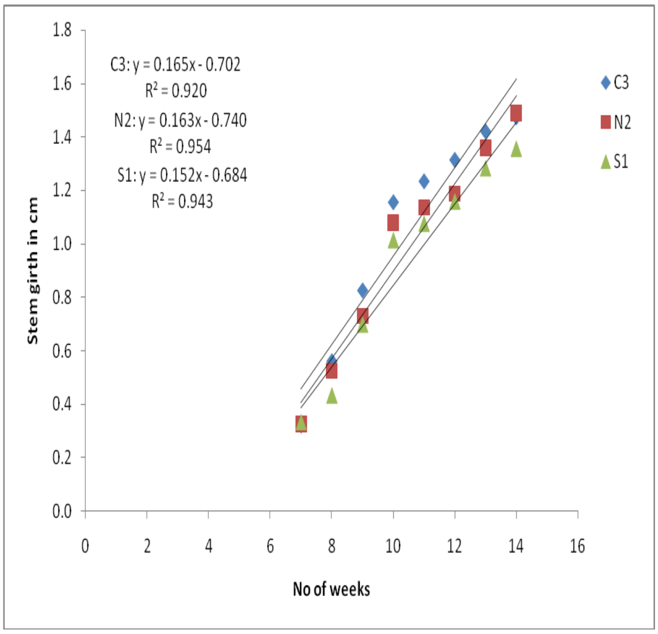

Figure 2: The effect of the three treatments on the rate of increase in stem girth

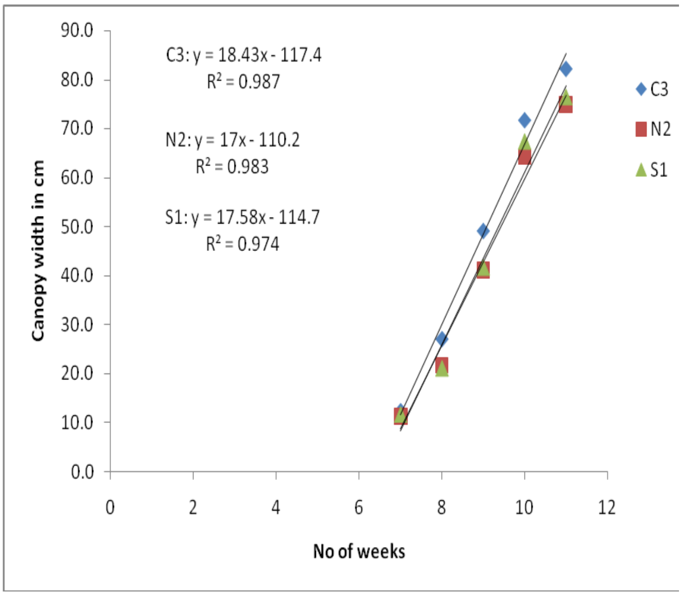

Figure 3: The effect of the three treatments on the rate of increase in canopy width

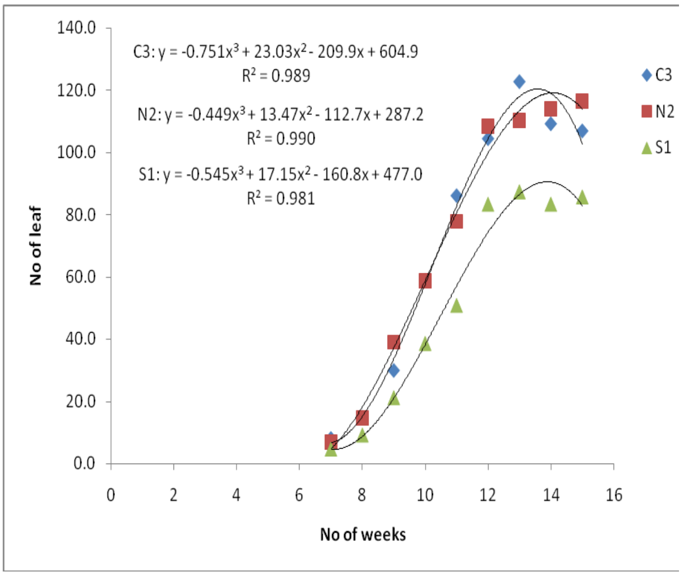

Figure 4: The effect of the three treatments on therate of increase in number of leaf

In summary, the slurry support the growth of tomato but with lesser fruit yield compared with NPK. The findings in this study were in agreement with those reported by [24], that, the biogas slurry promote the growth of tomato plant, however, decrease tomato yield.

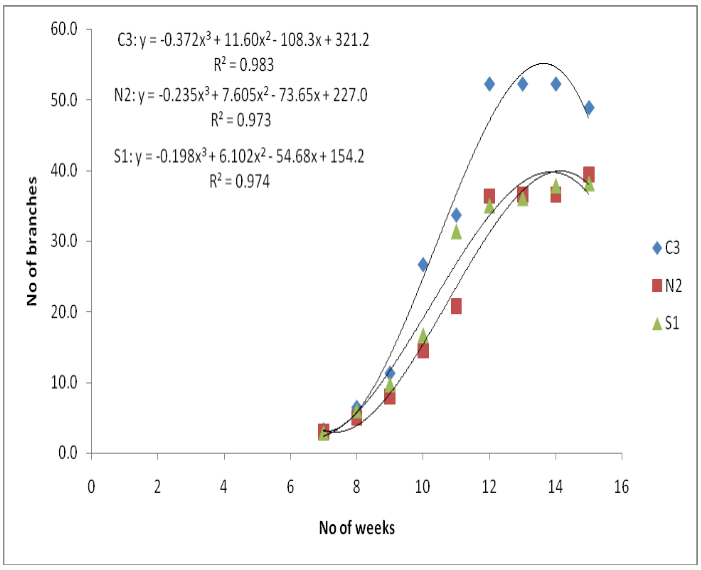

Figure 5: The effect of the three treatments on the rate of increase in number of branches

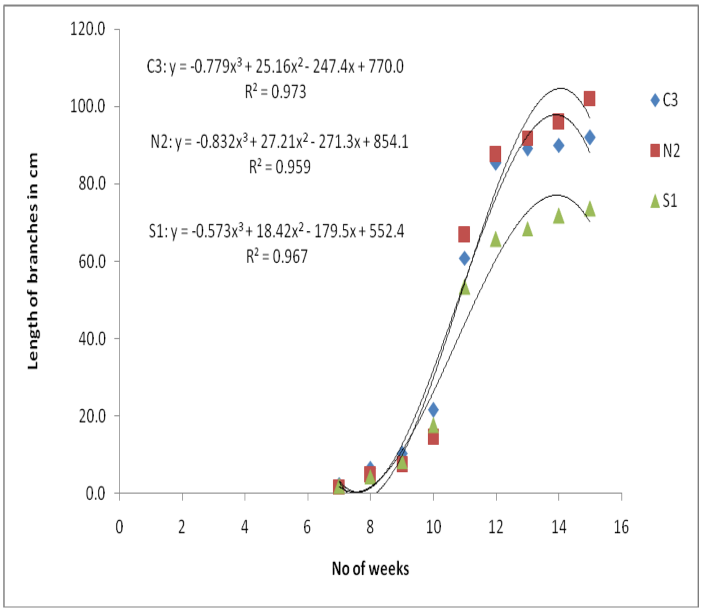

Figure 6: The effect of the three treatments on the rate of increase in length of branches

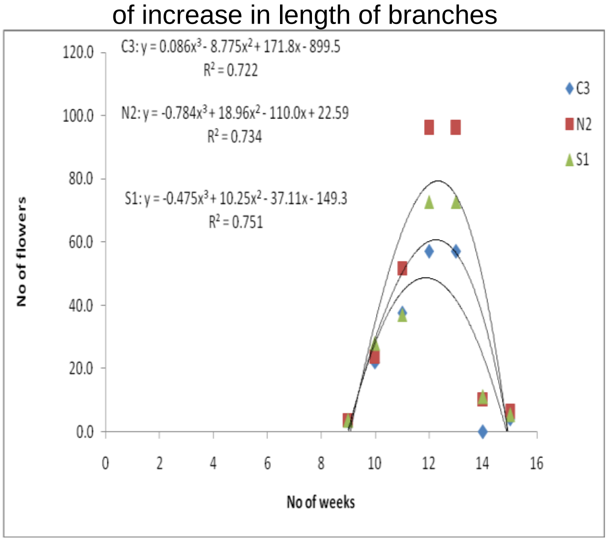

Figure 7:The effect of the three treatments on the rate of increase in number of flowers

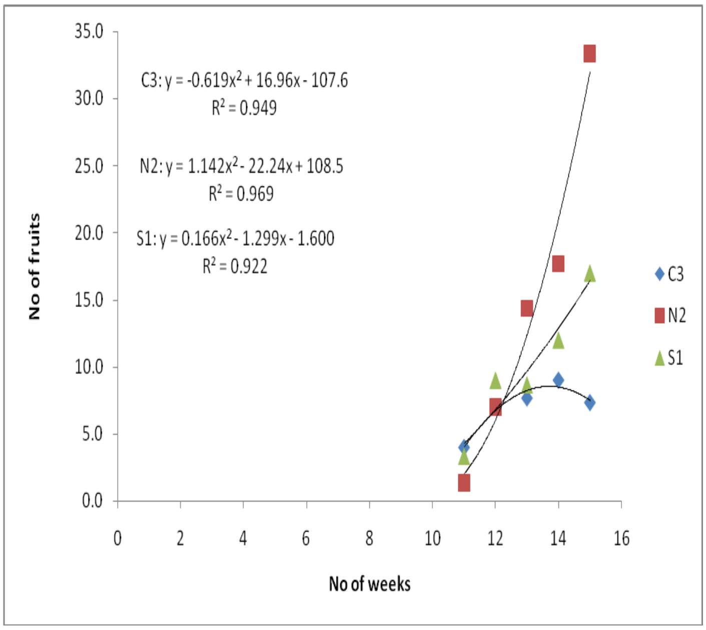

Figure 8: The effect of the three treatments on the rate of increase in number of fruits

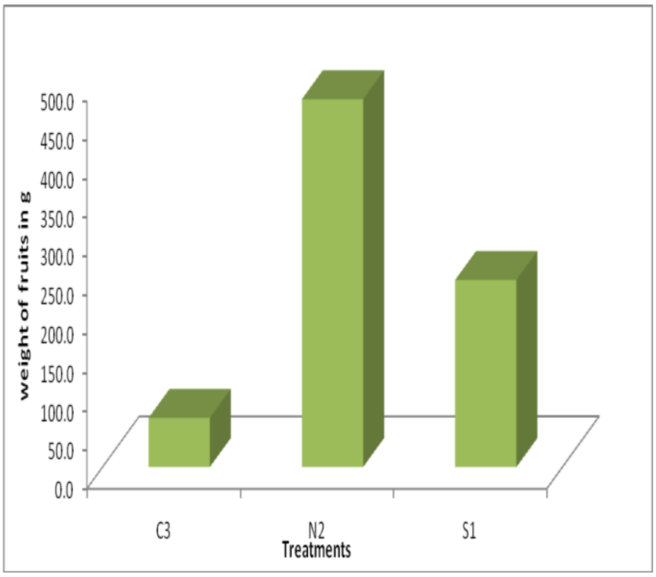

Figure 9:The fruit weights of the three treatments

IV. CONCLUSIONS

Experiments were conducted to know the biogas potential from domestic wastes and the effect of its effluent on growth and yield of tomato. The data collected from the experimental results were subjected to analysis in order to draw out useful information. From the analysis carried out the following conclusion can be drawn.

1. The highest number of substrate mixtures recorded the highest gas production and methane content.
2. The effluent from plantain peel and poultry manure anaerobic digestion gave the highest nutritive values which perform better than the control and favorably with the chemical fertilizer (NPK); and its fruits bigger than the NPK one.
3. The biodigester is:
   a. Safe to operate
   b. It can also be used for any domestic and agricultural wastes.
   c. It can operate as batch or continuous flow process.
   d. It is user friendliness and

Hygiene and operational cleanliness.

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