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Biogas Production Potentials Of Cassava Peels Co-Digested With Yam Peels Using A Batch Reactor At Meshophilic Temperature

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ABSTRACT
Sustainable energy sources are considered to be a pre-requisite for the development of human and global prosperity. The mono-digestion of farm residues is considered to have a lower biogas potential than co-digestion. This study determined the effect of co-digesting peels of cassava and yam on biogas yield at mesophilic temperature. The substrates (cassava and yam peels) were collected from cassava and yam processing centre in Osogbo, Osun State. The chemical properties (dry matter, organic dry matter, total ash and protein) and amounts of substrates fed into the fermentation bottles were determined using Association of Official Analytical Chemists and German standard procedures, respectively. Cassava Peel (CP) and Yam Peel (YP) were co-digested at combinations 100%CP, 100%YP, 25%CP and 75%YP, 75%CP and 25%YP and finally 50%CP and 50%YP. Two digestion bottles were used for each of the combinations and the average yields were found at the end of the experiment. The digestion bottles were loaded into a thermostatic cabinet heater pre-set at mesophilic temperature (37°C). The gas produced was collected over scaled wet gas meters for 30 days. Fresh Mass Biogas Yields (FMBY), Fresh Mass Methane Yields (FMMY), Organic Dry Matter Biogas Yields (ODMBY) and Organic Dry Matter Methane Yields (ODMMY) were determined. Peels of cassava and yam have been established to have a very good biogas production potentials especially when co-digested at 75% C.P and 25% YP.
Key words: Biogas, co-digestion, cassava peel, yam peel, batch reactor, yields.

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I. INTRODUCTION

Energy is one of the most important factors for human development and global prosperity. The dependence on fossil fuels as primary energy source has led to global climate change, environmental degradation, and human health problems. Eighty percent (80%) of the world's energy consumption still originates from combusting fossil fuels [1]. Despite the huge percentage, it still falls short of the need of the fast population growth, and their burning substantially increases the Greenhouse Gas (GHG) concentrations contributing to global warming and climate change [2].

Biomass plays a key role in the transformation of energy system from fossil to renewable sources in order to mitigate climate change and enhance energy security which would translate to a low carbon economy. Biogas, among many other sources of biomass, is an interesting option with a large potential, offering many exciting possibilities to supplant fossil fuels and therefore reduce our dependence on them [3]. Biogas refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Hydrolysis, acidogenesis, acetogenesis, and methanogenesis are the four fundamental steps of anaerobic digestion in which large organic polymers that make up biomass are broken down into smaller molecules by chemicals and microorganisms to produce carbon dioxide, methane and other trace gases [4]. Table 1 shows the typical composition of biogas

Table 1: Typical Composition of Biogas

Constituents	%Composition
Methane ,CH_4	50-70
Carbon dioxide, CO_2	30-50
Hydrogen Sulphide, H_2S	0-1
Nitrogen, N_2	0-1
Hydrogen, H_2	0-1
Carbon monoxide CO	0-3
Oxygen	0-2

Source:[1]

Animal wastes and plant residues like rice straw, cassava peels, and maize cobs are all potential biomass for renewable energy productions [5]. Plant materials such as crop residues are more difficult to digest than animal wastes because of difficulty in achieving hydrolysis of cellulosic and lignocellulosic constituents [5]. Co-digestion with sewage sludge, animal manure or poultry litter is recommended in order to optimize the C/N ratio of agricultural residues. Agricultural wastes that are deemed for disposal can now be digested in a batch digester while the gas produced can be collected and passed through pipes to different sections of the farm where needed [1].

The peels of cassava and yam which are usually thrown away and piled up after a little of it is fed to the animals, rotten with foul smell as a result of fermentation and putrefaction processes by microbes thereby constituting a nuisance to the environment. Hence, a need to find solution to the wastes. The aim of the present work is to determine the biogas production potentials of peels of cassava and yam co-digested at different combinations using a batch reactor at mesophilic temperature.

II. MATERIALS AND METHODS

Materials

Inoculum from previous biogas experiment was collected from a biogas plant in the Farm Power and Machinery laboratory of the Department Agricultural Engineering of Ladoke Akintola University of Technology, Ogbomoso, Nigeria. Substrates which were peels of cassava and yam were collected from Isale Osun Farm Settlement in Osogbo Local Government Area of Osun State, Nigeria where yam and cassava processing is their major occupation. The proximate analysis of the substrates was carried out.

Methods

The quantities of substrate loaded into the reactor bottles were determined in line with German Standard Procedure [6] using equation (1):

$$M_s = \frac{M_i C_i}{2 C_s} \quad (1)$$

Where:
M_s = Mass of substrate (g)
M_i = Mass of inoculum (g)
C_s = Concentration of substrate (%)
C_i = Concentration of Inoculum (%)

Twelve digestion vessels (A1, A2, B1, B2, C1, C2, D1, D2, E1, E2, F1 and F2) were set-up. Vessels A1 to E2 contained inoculum and substrate combinations while F1 and F2 contained only 800g of inoculum as control. All the reactors were charged with 800 g of inoculums each. The substrates (peels of cassava and yam) fed into the reactors were reduced to 1cm size to increase the rate of digestion. The experiment was replicated twice as described by Linke and Schelle [7] for batch reactor. A digital weighing scale was used to measure what was charged into each of the reactors. The digestion vessels labeled A1 and A2 were charged with 42.53g of cassava peel separately being a combination of 100% cassava peel and 0% yam peel. Vessels B1 and B2 were each charged with 21.8g yam peel representing a combination of 100% yam peel and 0% cassava peel. Another set of reactors labeled C1 and C2 were charged with 26.98g of substrates being a combination of 25% cassava peel and 75% yam peel. The fourth set of reactors labeled D1 and D2 were charged with 37.34g of substrates being a combination of 75% cassava peel and 25% yam peel. The last set of the reactors which were labeled E1 and E2 with 32.17g of substrates being a combination of 50% cassava peel and 50% yam peel. The reactors were closed immediately with the rubber cork already drilled and attached with a connector each.

The thermostatic cabinet was set to a constant temperature of about 37 ^{O}C (+ or - 2) and maintained throughout the experiment. All the reactors were well arranged in the thermostatic cabinet (plate 1). Twelve measuring cylinder were labeled as described above for the reactors and the graduated sampling gas tubes were inserted in each of the cylinders. The cylinders were then filled with the red liquid until the red liquid reached the zero point mark of the graduated gas bottles (plate 2). All the reactors were then connected to the gas sampling tube in the corresponding numbered cylinders with flexible pipes and the taps of the gas tube were properly and tightly closed to avoid leakage of gas. Flexible pipes were fixed to the other opening of the gas sampling tube for gas analysis.

The fermentation bottles were properly shaken each day in order to fully re-suspend the sediments and the scum layer [1] and the experiments were observed until the yield was less than 1% of the total yield. Equations 2 to 10 were used to calculate the biogas and methane yields under standard atmospheric conditions.

Plate 1: Thermostatic Cabinet with Digestion Bottles

Plate 2: Graduated gas sampling bottles inside measuring cylinder filled with red liquid

$$F = \frac{\left(P - P_{H_2O}\right) x\, T_O}{(t+273.15)\; x\; P_O} \qquad 2$$

Where:

T_O = 273.15°C (Normal Temperature)
t = Gas Temperature in °C
P_O = 1013.25 mbar (standard pressure)

P = Air pressure.

Water vapour pressure (P_{H_2O}) is dependent on the gas temperature and amounts to 23.4 mbar for 20 °C. Equation 3 describes the water vapour pressure as a function of temperature and depicts the range between 15 and 30 °C.

$$P(H_2O) = y_o + a.e^{b.t} \qquad 3$$

Where:

y_o = -4.3905;
a = 9.762 and b = 0.0521

The normalized biogas volume is given as

Biogas [Nml] = Biogas [ml] x F 4

Normalized by the quantity of biogas released, the total gas that took off the control batch is as follows:

Biogas [Nml] = (Biogas [Nml] – Control [Nml]) 5

On weight basis, mass of biogas released in standard litres/kg FM fresh mass can be calculated as follows:

1 standard ml/g FM = 1 standard litres/kg FM = $1m^3$/t FM

$$\text{Mass of biogas yield} = \sum \frac{Biogas\ [Nml]}{Mass\ [g]} \qquad 6$$

oDM biogas produced was as a result of the percentage of volatile solid (VS) that was available in the substrate.

oDM biogas yield =
$$\sum \frac{Biogas\ [Nml]}{Mass\ [g]} \qquad 7$$

$CH_{4corr.}$ =
$$\frac{CH4\ [vol] x\ 100}{(Mass\ [g] + CO2\ [vol\ \%])} \qquad 8$$

Methane yield on Fresh Mass basis (FM) =
$$\frac{Fresh\ mass\ biogas\ yield\ x\ CH4corr.}{100} \qquad 9$$

Methane yield on Organic Dry Matter basis (oDM) =

$$\frac{oDM\ biogas\ yield\ \ x\ CH4corr.}{100} \qquad 10$$

III. RESULTS AND DISCUSSION

Table 2 shows the chemical and thermal properties of the substrates used for the experiment. The biogas and methane yields of fresh mass and organic dry matter of the selected substrates for the five different combinations are as shown in Figures 1-4. It was observed that cumulative gas yields increased with time.

Table 2: Chemical and Thermal Properties of Substrates

Parameter (%)	Cassava Peel	Yam peel
Dry matter	30.16	65.16
Organic Dry matter	62.43	56.32
C/N ratio	29.1	25.3
Crude lipid	0.63	1.30
Moisture content	8.06	10.26
Protein %	10.6	3.62
Potassium g/kg	1.173	0.988
Phosphorus (mg/kg)	2.876	2.056
Crude fibre	10.5	8.025
pH	6.7	7.3
Conductivity (µS/cm)	10.482	8.967
Nitrogen	1.792	0.849
Ammonia	0.813	0.923
Total Ash %	1.7839	0.9694

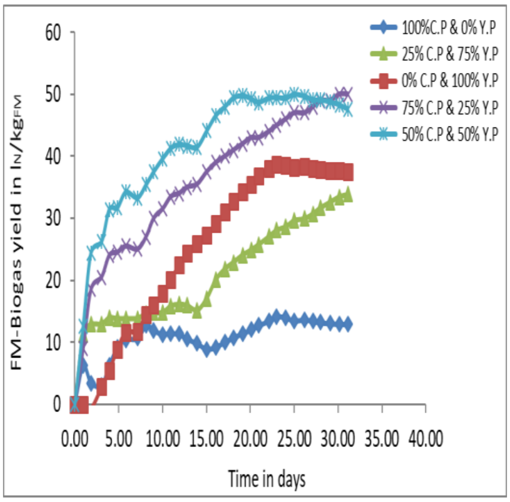

Figure 1: The Fresh Mass Biogas Yield

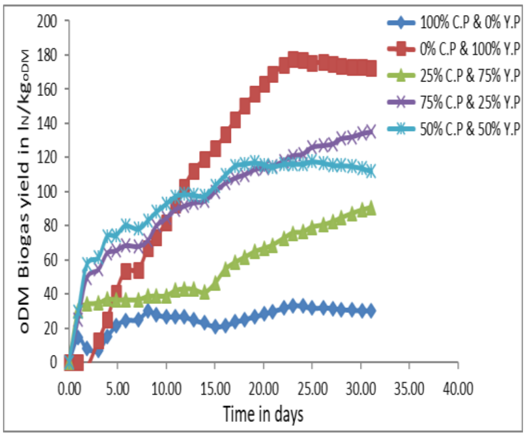

Figure 2: Organic Dry Matter Biogas Yield

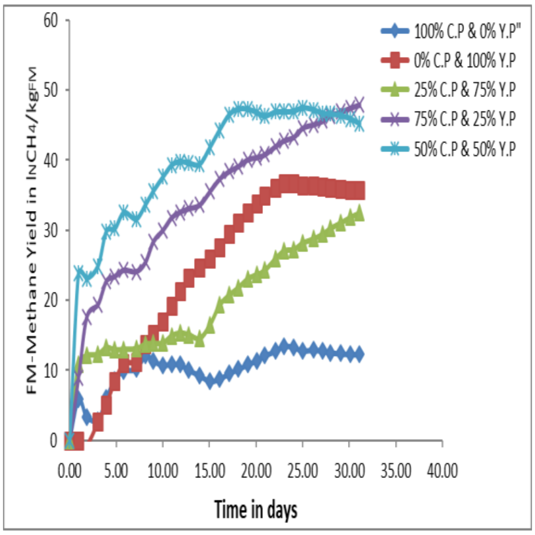

Figure 3: Fresh Mass Methane Yield

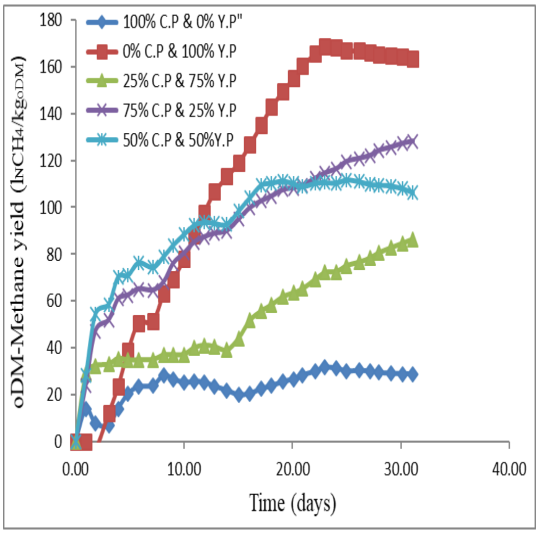

Figure 4: Organic Dry Matter Methane Yield (ODMMY)

The Fresh Mass Biogas Yield (FMBY)

Figure 1 shows the fresh mass biogas yield of all the combinations. It shows a good increase in the fresh mass biogas yield. 100% CP produced the lowest fresh mass biogas yield producing 12.9 l_N/kg_{FM} at the end of the retention period but when co-digested with yam peel at combination 75% C.P & 25% Y.P and 50% C.P & 50% Y.P produced an incredibly high fresh mass biogas producing 50 l_N/kg_{FM} and 47.6 l_N/kg_{FM} respectively at the end of the retention period. This is in line with the conclusion of Adelekan and Bamgboye [8]. A constant increase in yields was observed from the first day of loading the feedstock. However, towards the close of the retention time, a sharp decrease was noticed indicating a decline in FMBY production. This is in line with findings of Ojikutu and Osokoya [9]. Mix ratio 25% C.P & 75% Y.P gave a low production compared to the former combinations producing 33.85 l_N/kg_{FM} at the termination period, a little lower in production to 100% Y.P with 37.53 l_N/kg_{FM} at the end of the 30 days retention time. This could be the result of the production of volatile fatty acids by the micro-organisms which hinders the releasing of the biogas as previously published [10]. The results further showed that co-digestion of samples with two substrates mixed at certain ratio (50% C.P & 50% Y.P and 75% C.P & 25% Y.P) produced more than certain two or substrates mix ratio. This is in agreement with previous findings [11]. As earlier reported [11], it might be due to the attribution of the positive synergetic effect of the co-digestion of C.P and Y.P in providing more balanced nutrients and decreased effect of toxic compounds It has been established that more than one kind of substrate could establish positive synergism in the digester [4]. The rapid initial biogas production observed in 50% C.P & 50% Y.P and 75% C.P & 25% Y.P as previously suggested [11] could also be due to availability of readily bio-degradable organic matter in the substrate and the presence of high content of the methanogens.

IV. CONCLUSION

Peels of cassava and yam have been established to have a very good biogas production potentials especially when co-digested at 75% C.P and 25% YP. This combination is highly desirable in biogas and methane productions. The selected substrates have better proximate composition and biogas production potentials.

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