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Full Length Research Article

BIOGAS PRODUCTION FROM POULTRY WASTE MODIFIED WITH SAWDUST

* [1]Ayedun H., [2]Adeyemo A.I., [1]Ayadi P.O.

[1]Department of Chemical Sciences, Olusegun Agagu University of Science and Technology, P. M. B 353, Okitipupa, Ondo State, Nigeria.
[2]Department of Biological Sciences, Olusegun Agagu University of Science and Technology, P. M. B 353, Okitipupa, Ondo State, Nigeria.

*Corresponding Author Email Address: ht.ayedun@oaustech.edu.ng Phone: +234-8032952831

ABSTRACT
The high demand for energy as a result of the increase in population and the need to keep our environments clean makes research on biogas from wastes very necessary. The study was conducted to use poultry wastes mixed with sawdust to generate gases that can be used for cooking. The poultry waste was mixed with saw dust in the ratio 4:0, 4:1, 2:1 and 1:1 over a period of 4 weeks. The gases collected were subjected to laboratory analysis using Gas Chromatography of Perkin Elmer model. Methane yields of $3.45 \times 10^{-3} m^3$, $3.05 \times 10^{-3} m^3$, $2.03 \times 10^{-3} m^3$ and $1.00 \times 10^{-3} m^3$ were generated respectively. The more saw dust added the less gas of interest produced. Analysis of residue showed concentrations of N, P, and K in the residue are 0.847 %, 0.28 %, and 2.09 % respectively which implies materials that can be incorporated in soil amendment. Removing saw dust from the environment to generate gas reduces environmental pollution caused by burning.

Keyword: Biogas, Delignification, Electricity, Heat, Poultry, Waste,

INTRODUCTION
The demand for energy consumption worldwide is estimated to double by 2035 (Rawat, *et al*., 2011). Fossil fuel is a finite resource which will be exhausted with time. The emission of greenhouse gases as a results of fossil fuel consumption is detrimental to human health (Seyitoğlu and Avcıoğlu, 2021). Renewable resources are the most preferred alternative to fossil fuel because they are environmentally friendly (Choi *et al*., 2020; Stagnaro *et al*., 2020). The world is embracing reliable and feasible renewable energy due to the depletion of fossil fuel and the negative effect on the environment (Sawle *et al*., 2018). The issues of climate change and environmental pollution are serious concerns that are attributed with the consumption of fossil fuels. The developed countries have already started intensive research to explore sustainable and renewable energy resources (Donkin *et al*., 2013).
Nigeria has abundant animals and birds that produced wastes which is thrown into open space, causing environmental pollution and health issues in the communities. Majority of Nigerians are dependent on traditional biomass such as firewood, charcoal, straw, crop residues, kerosene, electricity and liquefied natural gas, to meet their household energy needs. Most residents of both urban and rural area have, in recent time, embraced the use of gas but the surge in price caused a serious setback. Therefore, biogas production from wastes as energy source is sustainable alternative for the people (Samani *et al*., 2017). The rural community has great potential to utilize its resources but unfortunately, lack of technologies, research and development in the past have restricted the use of biogas plants.
Yadvika *et al*. (2007) discovered that anaerobic co-digesting of diverse feed stocks like dung (cattle swine) and fruit vegetable waste under mesophilic condition gives a chance of treating waste, which cannot be treated separately. Umar *et al*. (2013), investigated the biogas potentials from palm oil mill effluent and cattle manure as a single substrate as well as co-substrates. The digesters were operated at different mixing ratios. The results showed that biogas and its methane content production can be enhanced efficiently through co-digestion process. Biogas were produced from different fermentable materials by a small size model biogas plant (MdForhad *et al.,* 2013**)**.
Biogas produced from chicken and cattle wastes was used to generate energy of up to 21,000.00 kJ/m^3 (or 5, 019.12 Kcal/m^3) (Boysan *et al*., 2015). A good estimation of heat in calories, and electricity (kWh) that can be generated from a known amount of poultry waste is possible because a 1 m^3 of biogas is equivalent to 4.7 kWh of electricity and 0.66 diesel fuel (Seyitoğlu, and Avcıoğlu, 2021). It can be extended to number of heads of birds that produced known quantity of wastes. Fermentation accelerators were used in addition to fat and cow dung to obtain high quantity of biogas (Palacios *et al*., 2020). Biodigester of a capacity of 1 m^3 was used without agitation to obtain biogas (Culhane *et al*, 2015).
Okitipupa is an agriculturally based Local government where biomass wastes from timber and wood processing are generated in large quantities. Poultry wastes are also generated in substantial amount and disposed of land surfaces. All these can be harnessed into a useful source of renewable energy. The burning of saw dust and other solid wastes constitute air pollution. There is need to find a way of converting these wastes to a valuable resource. The objective of the study is to be able to estimate possible energy yield from biogas generated from these wastes thereby circumventing burning which is the usual practice in the area.

MATERIALS AND METHODS
Materials used were fresh poultry waste and saw dusts. The fresh poultry wastes are collected from Agric Reality Farm at Maclean village off Aye road, Okitipupa (Latitude 5.125°N Longitude 4.008°E and Latitude 8.042°N Longitude 6.011°E), Ondo State, Nigeria. The saw dusts were collected from saw mill factory located in Ayeka area, Okitipupa, Ondo State.
The fresh poultry wastes were collected using sterile polythene bags immediately they were passed out from the chicken and each sample was labelled appropriately with a serial number, location mark and group mark in which the sample falls. The samples were transported immediately to the laboratory for analysis within 1 hour of sample collection (Marchioro *et al*., 2018).
Inoculum: inoculum was collected from a standardized mesophilic acclimated inoculum from a lab-scale according to the methodology described by Steinmetz *et al*. (2016).

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Pretreatment of saw dust: The saw dusts were dried and milled to reduce the particle size (0.5mm). Delignification was done by boiling the saw dust in 1.5M NaOH for 2 hours. It was cooled to room temperature (25 °C), filtered washed with 1L of hot distilled water. The saw dusts were dried in an oven for 48 hours at 45 °C milled into powder (Pramasari *et al*., 2021; Lourenço *et al*., 2021).

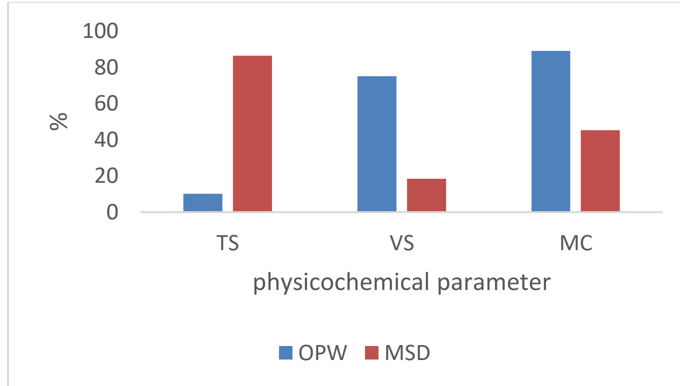
Slurry preparation: The modified method used by Ahamed *et al*. (2016), was adopted for calculation. The slurry of total weight 2 kg was prepared by weighing 500g of poultry wastes and 140g of treated saw dust while1360g of water was added. The poultry wastes, saw dust and water represented 25 %, 7% and 68% of the total slurry respectively to achieve 4:1 of waste to sawdust ratio. The weight was adjusted by weighing 250g and 500g of sawdust to 500g of poultry wastes to obtained 2:1 and 1:1 used for the experiment.

Digestion and biogas generation: The batch digester was set up, with inoculum introduced while the connection was tightly fitted to prevent air leakage. The material remained in the digester throughout the entire digestion period, no new fresh substrate was added and no digest residue was removed during the process. The methane yield was calculated from % volume recorded. The assumption adopted was that, at standard temperature and pressure, 1g of oxygen demand take 400mL (0.4 m^3 required 1kg of oxygen demand) of methane (Hamilton, 2022).

Analysis of the gas and the residues: Gas Chromatography – Mass Spectrometry (GC-MS) (Perkin Elmer) was used to determine different components of gases produced with a thermal conductivity detector (TCD). Atomic Absorption Spectroscopy (AAS) (Bulk Scientific model) was used for the determination of metals in the residue. Heavy metal contents (Cd, Mn, Ni, Zn, Cu, Fe) in the biogas residues were determined using Atomic Absorption Spectroscopy (AAS) according to method of APHA (1998).

Calculation:
Assumption: The amount of heat provided by 1 m^3 of biogas is equivalent to 4.7 kWh of electricity (Seyitoğlu, and Avcıoğlu, 2021). 1 m^3 biogas has 60% methane content and equivalent of 22 MJm^{-3} of energy (Yağlı and Koç, 2019). The estimated biogas energy was calculated by multiplying cubic meter of methane produced with 4.7 kWh and 22 MJm^{-3} for electrical and heat energy respectively.

RESULTS AND DISCUSSION
The % Total Solid in ordinary poultry wastes (OPW) and modified saw dust (MSD) are 10.12 % and 86.5 % respectively (Figure 1). Similarly, the % volatile solid (VS) are 75.2 % and 18.4 % respectively (Figure 1). However, the moisture contents are 89.20 % and 45.34 % respectively.



Key: TS – Total Solid, VS – Volatile Solid, MC – Moisture Content, OPW – Ordinary Poultry Wastes, MSD – Modified Saw Dust
Figure 1: The percentage of physicochemical parameters in ordinary Poultry Waste (PW) co-digested with saw dust (SD)

The % volume of methane produced throughout the reaction ranged between 19.35 % to 65.2 % with the mean value of (46.25±18.3) % (Table 1). Jurgutis *et al*. (2020), reported higher % of methane after the micro-organisms used has adapted to total ammonium nitrogen and constant organic loading rate and retention time.

Table 1: Range of % volume of gas formed at pH 5.5 - 7.0 and Temperature 28^{0}C

Gaseous products (% Volume)	Minimum	Maximum	Mean ± SD
CH_4	19.35	65.2	46.25±18.3
NH_3	0.012	0.042	0.025 ± 0.01
CO	0.12	2.42	0.979± 0.95
H_2S	0.032	0.32	0.138±0.10
CO_2	8.77	35.97	23.93±11.3

The % ammonia produced ranged between 0.012 % to 0.042 % with the mean value of (0.025±0.01) %. The % carbon monoxide by volume range between 0.012 % to 2.42 % with a mean value of (0.979±0.95) %. The % hydrogen sulphide produced ranged between 0.032 % to 0.32 % with a mean value of (0.138±0.1) %. The % carbon dioxide produced ranged between 8.77 % to 35.97 % with a mean value of (23.93±0.01) %. Otaraku and Ogedengbe (2013) reported a % methane content range higher than the results obtained from the present study when biogas was produced from chicken droppings co-digested with *Cymbopogon citratus*.

Table 2: Variation of % volume of gas formed at various combination ratios (4:0; 4:1; 2:1 and 1:1) Poultry wastes: saw dust (n =3)

Poultry wastes : Saw dust	Methane CH_4	Ammonia NH_3	Carbon monoxide CO	Hydrogen sulphide H_2S	Carbon dioxide CO_2
4:0	63.37±2.67c	0.037±0.01c	1.328±0.097b	0.2597±0.055c	33.39±0.681c
4:1	60.91±1.27c	0.0143±0.002a	2.3±0.166c	0.192±0.039b	35.19±0.702d
2:1	40.68±0.424b	0.0297±0.002b	0.153±0.009a	0.0607±0.004a	17.96±0.437b

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1:1	20.043±0.769a	0.0187±0.002a	0.1367±0.015a	0.0373±0.005a	9.18±0.481a

Note: data with the same letter down the column are not significantly different using Duncan Multiple Range Test

The poultry wastes were mixed at different ratio with palm wastes as shown in Table 2. Reducing the quantity of poultry wastes used for biogas production decreases the quantity of methane produced. This trend is in agreement with previous study (Speight and Radovanovic, 2020). The % methane was significantly higher when 100% poultry wastes was used while modified poultry wastes yielded less methane gas (Table 2). The gases formed are the waste products of the respiration of decomposer microorganisms and the composition of the gases depends on the substance that is being decomposed (Weiland, 2010).

With the exception of the first preparation without saw dust other slurry was prepared such that the total weight of the slurry was 2 kg. With the assumption of Hamilton, (2022), that 1 kg of oxygen demand (OD) take 400 mL of methane and 1kg OD remove 0.4m^3 of methane produced. Twenty-five percent (25 %) poultry waste with 7 % saw dust and 68 % of water yielded 3.45 x 10^{-3}m^3 of methane (Table 3).

Table 3: Mass of slurry with quantity of materials used and methane yield

Poultry waste (g)	Saw dust (g)	Poultry waste: saw dust	Water (g)	Methane yield m^3 (x10-3)	Calculated Heat energy MJm^{-3}	Calculated Electrical energy kWhr-
500	0	4:0	500	3.45	0.0759	0.0162
500	140	4:1	1360	3.05	0.0671	0.0143
500	250	2:1	1350	2.03	0.0447	0.0095
500	500	1:1	1000	1.0	0.022	0.0047

Twenty-five percent (25 %) poultry wastes with 12.5 % saw dust and 62.5 % of water yielded 2.05 x 10^{-3}m^3 of methane. Twenty-five percent (25 %) poultry wastes with 25 % saw dust and 50 % of water yielded 1.0 x 10^{-3}m^3 of methane. Estimated heat energy generated for each ratio combination are 0.0759 MJm^{-3}, 0.0671 MJm^{-3}, 0.0447 MJm^{-3}, and 0.0671 MJm^{-3} respectively. Similarly, the estimated electrical energy generated for each ratio combination are 0.0162 kWh, 0. 0143 kWh, 0. 0095 kWh, and 0. 0047 kWh respectively. Consider the highest value of methane gas generated from the present study and extrapolate to twelve months of a year, the heat energy of 0.9108 MJm^{-3} and 0.1944 kWh of electricity will be generated annually. Kumaş and Akyüza, (2021), reported an annual thermal energy of 1133 x103 GJ and 234.62 GWh of electrical energy generated from animal manure.

No visible changes are recorded in the pressure gauge until 20th day after incubation. With 100 % poultry (4:0), the pressure recorded are 0.9 Nm^2, 1.3 Nm^2, 1.5 Nm^2, and 2.0 Nm^2 for day 20, 25, 30 and 35 respectively (Figure 2).

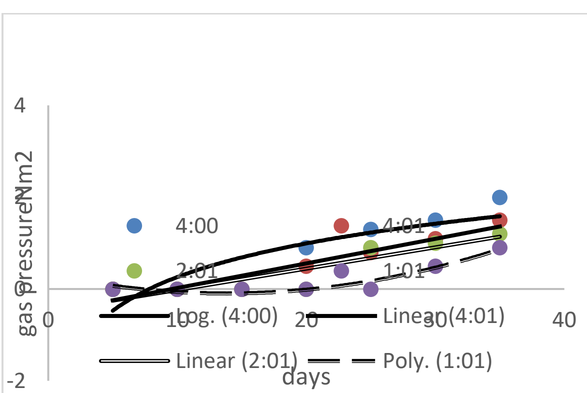

Figure 2: A graph of pressure monitored at different days for different preparations for poultry wastes

When poultry wastes with saw dust in the ratio 4: 1 was used, the pressure recorded are 0.5 Nm^2, 0.8 Nm^2, 1.1 Nm^2, and 1.5 Nm^2 for the days respectively. With the poultry waste and saw dust in the ratio 2:1, the pressure recorded are Nil, 0.9 Nm^2, 1.0 Nm^2, and 1.2Nm^2 for the days respectively. Finally, with poultry waste and saw dust in the ratio 1: 1, the pressure recorded are nil, nil, 0.5 Nm^2, and 0.9 Nm^2 for the days respectively.

The average concentration of N, P, K and Mg in the residue are 0.847 %, 0.28 %, 2.09 %, and 0.4767 mg/kg respectively (Table 4). Liang *et al.* (2021) recorded 0.059 %, 0.05% and 0.052% for N, P and K respectively for animal wastes fermentation residue. Marchioro *et al.* (2018), reported higher value of N, P, and K with solid state anaerobic digestion of poultry litters.

The concentration of Ni determined in the digest residue ranged between 0.17 to 0.2018 ppm with the mean value of 0.1919 ppm while that of Mn ranged between 0.312 to 0.8137 ppm with the mean value of 0.59 ppm.

Table 4: The result of elemental analysis of the residue.

Elements	1	2	3	Mean
N (%)	0.97	0.85	0.72	0.847
P(%)	0.38	0.27	0.19	0.28
K (%)	2.26	2.11	1.92	2.0967
Mg (%)	0.59	0.46	0.38	0.4767
Ni(ppm)	0.2018	0.204	0.17	0.1919
Mn(ppm)	0.8137	0.645	0.312	0.59
Zn(ppm)	0.6209	0.543	0.322	0.495
Fe(ppm)	129.8063	120.7	98.1	116.2
Cu(ppm)	0.8674	0.619	0.573	0.686
Cd (ppm)	0.0113	0.002	0.001	0.0048

Zinc concentration ranged between 0.322 to 0.6209 ppm with the

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mean value of 0.495 ppm while Fe concentration ranged between 98.1 to 129.806 ppm with the mean value of 116.2 ppm. Copper concentration ranged between 0.573 to 0.8674 ppm with the mean value of 0.686 ppm while Cd concentration ranged between 0.001 to 0.0113 ppm with the mean value of 0.0048 ppm. It was reported that the presence of Ni, Mn and Fe can enhance biogas formation in the batch anaerobic digester (Ye *et al,* 2012). This could have been responsible for the biogas formed in the present study. Metals such as Ni and Fe, helps to stimulate bacterial activities which leads to proper digestion of substrates while the presence Cu and Zn may induce inhibitory effect on the performance of the anaerobic digestion process due to their toxic effect to the anaerobic bacteria (Basililko *et al.,* 2001).

Conclusion

The present work, showed that co-digestion of poultry wastes with saw dust can produce biogas. The volume of biogas produced is less when mixed with saw dust than digesting poultry wastes only using anaerobic batch digester under laboratory conditions. Pre-treatment of saw dust before co-digestion with poultry wastes is necessary to allow microorganisms to degrade the cellulose. The present study suggests biogas as a possible source of heat and electrical energy. Biogas production from poultry wastes is a sustainable way of removing poultry wastes and saw dust from our environment.

Conflict of Interest: There is no conflict of interest

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