Biogas Production and Storage from Pig Dung Co-Digested With Pineapple Peel

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Abstract. Biomethanation potentials of pig dung co-digested with pineapple peels were investigated. Various blends of pig dung with pineapple peels were charged respectively into 50 kg prototype digesters labeled A to C. Digesters D and E were charged with only pineapple peels and pig dung respectively. Proximate and physico-chemical analyses were determined on the slurry using conventional methods. The wastes were subjected to anaerobic digestion for 35 days at mesophilic temperature range of 25 to 37°C. Relative humidity, ambient temperature, pH, slurry temperature and volume of gas were monitored and recorded on daily basis. Biogas yield increased progressively with higher pig dung blend. Onset of gas flammability was observed on the 5th day for blends of pig dung and pineapple peels, as well as for pineapple peels alone while for pig dung alone, it was observed on the 6th day. This was as a result of lower nitrogen contents of pineapple peels blends compared with that of pig dungs alone, a factor which favours early onset of flammability. Biogas generated from the mixture ranged from 65-71% CH₄, 28-34% CO₂, and traces of hydrogen sulphide and carbon (II) oxide. The biogas was subsequently stored in a gas cylinder using modified pressure system. This study is aimed at converting wastes such as pig dung and pineapple peels to useful energy and storing the gas produced in cylinders for easy accessibility.

Keywords: Biogas Production, pig dung, pineapple peels, Gas Flammability, Storage

1. Introduction
Rising crude oil prices together with environmental concerns led to the shift in focus towards alternative energy. In Nigeria, the urgent need for alternative and cheaper energy supplies is increasingly apparent now, considering the epileptic supply and distribution of both fossil fuel and electricity. The rural communities which rely on wood are not finding it easy due to cost and scarcity of wood. A major source of renewable energy is biogas. Other sources include wind, geothermal, hydro power and solar. Biogas is a derived un-fossilized, odourless and flammable gas of biological origin. It can be generated from biomass wastes. Municipal and agricultural wastes can be recycled to produce biogas. Unfortunately, most of these wastes are often recklessly disposed in such manner as to constitute health hazards. Biogas consists mainly of methane and carbon dioxide, resulting from the anaerobic digestion of various organic materials. The percentage of methane in biogas varies between 55 % and 80 % depending on the process...
and the type of organic matter. Biogas also contains very small quantity of other gases such as hydrogen sulphide, nitrogen, oxygen and water. Anaerobic digestion is a process in which microorganisms break down biodegradable materials in the absence of oxygen to produce bio-energy in the form of biogas. Co-digestion is the simultaneous digestion of mixture of two or more substrates. The use of co-substrates usually improves the yields from anaerobic digester due to positive synergisms established in the digestion medium and supply of missing nutrients by the co-substrate. The aim of this work is to compare the biogas production potentials of pig dungs co-digested with pineapple peels. The specific objectives include:

1. To determine the physicochemical and microbial characteristics of the slurry
2. To determine the potentials of the co-digestion of pig dungs and pineapple peels.
3. To store the gas produced.

Pig dung is dropping from pig. The runoff of pig dungs into lakes and rivers causes eutrophication. Producers around the world are coming under increasing pressure to limit the environmental impact of pig production. The most critical elements that contribute most to environmental pollution in pig production are nitrogen and phosphorus. Phosphorus causes eutrophication of river basins while nitrogen causes the emission of methane to the atmosphere and acidic rain. There are also concerns about zinc and copper, since the levels in the diet are often well above the animal’s requirement, especially zinc in piglet diets where it is added in attempt to reduce scouring and diarrhea and also copper in grower diet to promote growth.

Pineapple (Ananas comosus) is one of the most important fruits in the world and of the family Bromeliaceae. The increasing production of pineapple processed items results in massive waste generations. This is mainly due to selection and elimination of components unsuitable for human consumption. Besides, rough handling of fruits and exposure to adverse environmental conditions during transportation and storage can cause up to 55% of product waste. These wastes are usually prone to microbial spoilage thus limiting further exploitation. Reports have shown that 40-80% of pineapple fruit is discarded as waste having high biological oxygen demand and chemical oxygen demand values. Discarded fruits as well as the waste material can be utilized for further processes like fermentation and bioactive component extraction. Several efforts have been made to utilize pineapple wastes obtained from different sources. The conversion of complex organic compounds into methane and carbon dioxide requires different groups of microorganisms and is carried out in a sequence of four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. During the hydrolysis stage, organic substrate is converted into smaller components which are subsequently converted into volatile fatty acids (VFAs), ethanol, CO₂ and H₂ by acidogenic bacteria. Acetogenic bacteria then convert these fermentation products into acetic acid, CO₂ and H₂. Finally, methanogenic bacteria use hydrogen and acetate (most important substrate) to produce methane and carbon dioxide.

\[
\begin{align*}
C₆H₁₂O₆ + 2H₂O & \rightarrow 2C₂H₅COOH + 2CO₂ + 4H₂ \\
C₆H₁₂O₆ & \rightarrow 2C₂H₅CH₂OH + 2CO₂
\end{align*}
\]
\[ \text{C}_6\text{H}_{12}\text{O}_6 + 2\text{H}_2 \rightarrow 2\text{CH}_3\text{CH}_2\text{COOH} + 2\text{H}_2\text{O} \]

**Scheme 1.** Conversion of glucose to intermediary products.

The products from the acidogenic phase serve as substrate for other bacteria. Acetogenic bacteria can get the energy necessary for their survival and growth, only at very low hydrogen concentration. Acetogenic and methane-producing microorganisms must therefore live in symbiosis. Methanogenic organisms can survive only with higher hydrogen partial pressure. They constantly remove the products of metabolism of the acetogenic bacteria from the substrate and so keep the partial pressure of hydrogen at a low level suitable for the acetogenic bacteria.

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{COOH} + 2\text{H}_2\text{O} &\rightarrow \text{CH}_3\text{COOH} + 3\text{H}_2 + \text{CO}_2 \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + 2\text{H}_2\text{O} &\rightarrow 2\text{CH}_3\text{COOH} + 2\text{H}_2 \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} + 2\text{H}_2\text{O} &\rightarrow 2\text{CH}_3\text{COOH} + 2\text{H}_2 \\
\end{align*}
\]

**Scheme 2.** Volatile fatty acid degradation.

In the fourth stage, the methane formation takes place under strictly anaerobic conditions. The methanogenic bacteria are able to grow directly on \( \text{H}_2/\text{CO}_2 \), acetate and other one-carbon compounds, such as formate and methanol. The hydrogenotrophic methanogens use hydrogen to convert carbon dioxide to methane. By converting carbon dioxide to methane, these organisms help to maintain a low partial hydrogen pressure in an anaerobic digester that is required for acetogenic bacteria.

\[ \text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \]

The acetotrophic methanogens or acetoclastic bacteria “split” acetate into methane and carbon dioxide. Some hydrogenotrophic methanogens use carbon monoxide to produce methane.

\[
\begin{align*}
4\text{CH}_3\text{COOH} &\rightarrow 4\text{CH}_4 + 4\text{CO}_2 \\
4\text{CO} + 2\text{H}_2\text{O} &\rightarrow \text{CH}_4 + 3\text{CO}_2 \\
\end{align*}
\]

Factors that affect the biogas production include: Temperature, nutrients, pH, C/N ratio, Retention time.

**2. Materials and Method**

The pineapple waste used for this study was collected from pineapple dump site around Ogige market at Nsukka, Enugu State, while pig dung was collected from a pig farm at Orba road in Nsukka, Enugu State, Nigeria. Equipment used for this study include metal prototype digesters of 50 L capacity constructed at the National Centre for Energy Research and Development, University of Nigeria, Nsukka, Ohaus Weighing balance (0.001g accuracy, model AR 3130, Made in England), graduated transparent plastic bucket, Thermometer, Thermo-Hygrometer (Model BH 6212, made in Japan), Jenway pH meter (model 3510), hose pipe and Biogas burner, Vecstar Furnace, Memmert Oven and Gas analyzer. Proximate analysis was carried out on the samples. The analysis provided information on the usability of the samples as well as their nutrient content. Other analyses include: volatile solids, total solids, relative humidity, and carbon content. Microbial analysis was carried out on the slurry as well. Standard methods were...
employed in these determinations. Batch operation was used considering the size of the digester. Digester A was charged with 2.82 kg of pig dung, 6.58 kg pineapple peels, and 28.1 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 5.8. Digester B was charged with 4.7 kg of pig dung, 4.7 kg pineapple peels, and 28.1 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 6.2. Digester C was charged with 6.58 kg of pig dung, 2.82 kg pineapple peels, and 28.1 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 6.6. Digester D was charged with 9.4 kg pineapple peels and 28.1 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 5.2. Digester E was charged with 9.4 kg pig dung and 28.1 L of water in the ratio of 1:3 (waste to water) and its pH at the point of charging was 6.9. This quantity (waste and water) constitutes 75% of the whole digester while the 25% space left was for the biogas. The digesters were adequately stirred and sealed to ensure they were air tight in order to encourage effective anaerobic digestion and prevent the escape of the gas generated. Gas production in the digesters measured in liter/total mass of slurry was obtained by the downward displacement of water by the gas using a trough and a calibrated transparent bucket. Gas flammability was monitored with the aid of a biogas burner. Digestion lasted for 35 days.

3. Results and Discussion
Nutritional and physical properties of the samples are shown in tables 1 and 2 below

| Digesters | Protein (%) | Fat Content (%) | Ash Content (%) | Fibre Content (%) | Moisture Content (%) |
|-----------|-------------|-----------------|-----------------|-------------------|---------------------|
| A         | 2.26        | 1.09            | 7.08            | 2.64              | 82.09               |
| B         | 2.72        | 0.94            | 9.66            | 2.66              | 80.40               |
| C         | 3.18        | 0.87            | 12.38           | 2.68              | 78.73               |
| D         | 1.58        | 1.26            | 3.10            | 2.60              | 84.62               |
| E         | 3.86        | 0.70            | 16.36           | 2.72              | 76.21               |

A = 30:70 (Pig dung: Pineapple Waste), B = 50:50 (Pig dung: Pineapple Waste), C = 70:30 (Pig dung: Pineapple Waste), D = Pineapple waste only, E = Pig Dung waste only.

| Digesters | Total Solid (%) | Volatile Solid (%) | Carbon Content (%) | Nitrogen Content (%) | Carbon:Nitrogen (C:N ratio) |
|-----------|-----------------|--------------------|-------------------|----------------------|---------------------------|
| A         | 69.61           | 53.30              | 13.73             | 0.36                 | 38.14                     |
| B         | 70.50           | 54.30              | 13.41             | 0.44                 | 30.48                     |
| C         | 71.43           | 55.31              | 13.09             | 0.51                 | 25.67                     |
| D         | 68.24           | 51.86              | 14.22             | 0.25                 | 56.88                     |
| E         | 72.8            | 56.78              | 12.60             | 0.62                 | 20.32                     |
A = 30:70 (Pig dung: Pineapple Waste), B = 50:50 (Pig dung: Pineapple Waste), C = 70:30 (Pig dung: Pineapple Waste), D = Pineapple waste only, E = Pig Dung waste only.

Table 3: TOTAL VIABLE MICROBIAL POPULATION (cfu / ml)

| DAYS | DIGESTER A | DIGESTER B | DIGESTER C | DIGESTER D | DIGESTER E |
|------|------------|------------|------------|------------|------------|
| 0    | 1.8x10^5   | 3.0x10^4   | 3.6x10^4   | 9.0x10^4   | 5.2x10^5   |
| 7    | 2.5x10^4   | 3.8x10^4   | 4.3x10^4   | 1.5x10^4   | 6.0x10^4   |
| 14   | 3.4x10^4   | 4.2x10^4   | 5.5x10^4   | 2.2x10^4   | 6.8x10^4   |
| 21   | 1.8x10^5   | 2.5x10^5   | 3.2x10^5   | 1.0x10^5   | 4.2x10^5   |
| 28   | 1.0x10^7   | 1.5x10^7   | 2.0x10^7   | 5.0x10^5   | 2.8x10^7   |
| 35   | 3.2x10^7   | 4.8x10^7   | 6.0x10^7   | 1.6x10^7   | 7.2x10^7   |

Table 4: LOGARITHM OF TOTAL VIABLE MICROBIAL POPULATION

| DAYS | DIGESTER A | DIGESTER B | DIGESTER C | DIGESTER D | DIGESTER E |
|------|------------|------------|------------|------------|------------|
| 0    | 2.993      | 3.214      | 3.294      | 2.691      | 3.453      |
| 7    | 3.135      | 3.317      | 3.371      | 2.913      | 3.515      |
| 14   | 3.269      | 3.360      | 3.478      | 3.080      | 3.570      |
| 21   | 3.427      | 3.569      | 3.677      | 3.171      | 3.794      |
| 28   | 3.171      | 3.348      | 3.473      | 2.870      | 3.619      |
| 35   | 2.808      | 2.984      | 3.081      | 2.507      | 3.160      |
Figure 1: LOGARITHM OF TOTAL Viable Microbial Population Vs DAYS

Table 5: Cumulative Biogas Yield

| Sample                  | VOLUME (L) |
|-------------------------|------------|
| A(30:70)                | 177.9      |
| B(50:50)                | 184.8      |
| C(70:30)                | 217.5      |
| D(PINEAPPLE PEELS)      | 133.1      |
| E(PIG DUNGS)            | 233.2      |

Fig. 2: Cumulative biogas yield
Fig. 3. Daily volume of gas produced.

The results of the volume of biogas produced, total viable count, as well as the microbial growth as the digestion progressed are as presented in Tables 1 to 5. The digestion was highly dependent on daily ambient temperature changes which ranged from 25 to 37 °C. Increase in temperature increased the rate of biogas production and vice versa. The blends with pig dung (Digesters A to C) as well as pineapple peels alone (digester D) all produced flammable gas on 5th day. The pig dung alone produced flammable gas on the 6th day. The pH of the pineapple peels alone (sample D) was between 4.8 and 5.8 throughout the digestion period. This pH was unfavourable for microbial growth and it adversely affected the volume of biogas produced. The same pH problem also affected the rate of production of gas by sample A whose pH ranged from 5.0 to 6.1. For samples B, C and E with pH ranges 6.5 to 7.6, 7.0 to 7.6 and 7.6 to 8.3, the volume of gas produced drastically improved. Ofomatah and Obasi (2017) reported that biogas production would always continue as the digester slurry pH is maintained between 6.6 to 7.6 with optimum range between 7.0 and 7.2. Below 6.2, the bacteria become inactive since the methanogens are very sensitive to pH changes and do not survive at low or high pH. The addition of different wastes in biogas production (co-digestion) is meant to improve biogas production. Blending of wastes in this way can lead to improved digestion process and enhancement of biogas production through synergistic effect. These benefits could be possible as a result of the presence of the required nutrients or reduction of substances that can inhibit bioconversion. The cumulative volume of biogas produced increased progressively from samples A to C as a result of the blending with pig dung. This shows that pig dung (sample E) was a good inoculum for biogas production with pineapple waste.
Table 6: Gas Composition.

| Gas composition | CO₂ (%) | CO (ppm) | CH₄ (%) |
|-----------------|---------|----------|---------|
| A               | 33      | 537      | 66      |
| B               | 32      | 476      | 67      |
| C               | 30      | 472      | 69      |
| D               | 34      | 610      | 65      |
| E               | 28      | 469      | 71      |

Biogas consists mainly of methane (50-80%), CO₂ (20-50%) and traces of hydrogen sulphide (H₂S), carbon (II) oxide (CO), hydrogen (H₂) and nitrogen (N₂). The relative percentages of these gases in biogas depend on the type of waste and the management of the digestion process¹². The results obtained as shown in Table 6 was within the quality range for biogas and agree with other reports by researchers¹³,¹⁴.

**Biogas Storage**

The gas produced was stored with the aid of the modified pressure system as shown below.

![Storage of flammable gas using modified pressure system.](image)

The flammable biogas was stored in a cylinder and kept for use. The biogas stored in this container was able to come out of the cylinder and burn with a blue flame. Previous efforts at storage were mainly with balloons and tubes. Eze (2000) reported that biogas could be stored in balloon for three months¹³.

**Statistical Analysis**

Paired samples statistics was used in comparing the volumes of biogas produced by various samples. The results showed that there are significant differences in the volumes of biogas produced by samples C and E when compared with other samples since P was < 0.05.

**4. Conclusion**

From this study, it was discovered that the volume of biogas produced by pineapple peels can be greatly increased by adding adjunct like pig dung. The quality of flammable biogas produced was quite high containing up to 60% methane. The percentage of each of these components in biogas...
depends on the type of waste used for the production and the management of the digestion process. In this work, flammable biogas produced was stored with ease. The stored gas was used to raise the temperature of one litre of water from 30°C to 100°C within three minutes in the laboratory. The use of pineapple waste and other environmental pollutants in the production of biogas will go a long way in contributing to the national energy need and environmental quality by ridding our cities of such nuisance which litter the streets and cities and constitute potential sources of both terrible and dangerous pathogenic microorganisms.

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