INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS)
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue XI November 2024

Optimization of Methane Production Physical Pre-Treatment: A Comparative Study

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DOI: https://doi.org/10.51584/IJRIAS.2024.911045

Received: 06 November 2024; Accepted: 12 November 2024; Published: 18 December 2024

ABSTRACT

The increasing energy demands worldwide has resulted in tremendous carbon dioxide emissions (depletion of fossil fuels).In order to ameliorate the problem of depletion of fossil fuel, it is essential an alternative source of energy which impacted little on the environment be developed. For this study, biogas was considered as renewable energy sources that can be brought forth from different types of biomass. The pre-treatment of the organic waste dwell on grass and cow dung. Primary objectives included decreasing environmental pollution, improving good health, encouraging the use of simple technology in advancing organic waste digestion to create alternative energy source. Milling, pre-oven heating and sieving was employed in the physical pretreatment by which substrate size was reduced. This method was used in comparing the processes of mesophilic anaerobic co-digestion of cattle dung and grass. Evaluating biodegradability pretreated lignocellulosic biomass, 9-days batch anaerobic digestion experiments was used. The pretreatment method for grass resulted in 82% bio-methane yield with a cumulative CH_4 production increasing from 1.3 to 1.5 $nm^3CH_4/g/kg$.This enhancement was most likely due to the resistance of cellulose and hemicellulose molecules in the plant cell wall to degradation by bacteria. The pretreatment .method for cattle waste resulted in 90% higher bio-methane yield with a cumulative CH_4 production increasing from 2.8 to 3.0 $nm^3CH_4/g/kg$ This was attributed to pre-heating of the organic waste of cow dung cellulose and hemicellulose. The TS for the grass were 0.0452, 0.478 and 0.480 (+0.02) (w/w) and VS was 0.173, 0.0179, and 0.0156 (± 0.02) including high increased in pH and alkalinity to 7.9 respectively. In the result, it was established that both biomass achieved similar biomass solubilization.

Key words: cow dung, grass, methane, biomass, pretreatment. Anaerobic digester, cellulose, hemicellulose.

INTRODUCTION

This manuscripts look at waste reuse options and other alternative but primarily, it dwell on waste to energy conversion (see figure 1). However, these wastes be it industrial or organic can be turned into energy through processes like incineration, gasification, or anaerobic digestion. Renewable energy has become one of the best alternatives for sustainable energy development. Biogas, an energy source that is renewable which is also environmentally friendly, is generated via anaerobic digestion of biomass wastes (animal dung, plant residues, waste waters, municipal solid wastes, human and agro-industrial wastes etc). It primarily composed of methane (50 - 70%), CO_2 (20 - 40%) as well as other gases including CO, H_2S, NH_3, H_2, N_2, O_2 and water vapor etc. (Energy Commission, 1998).

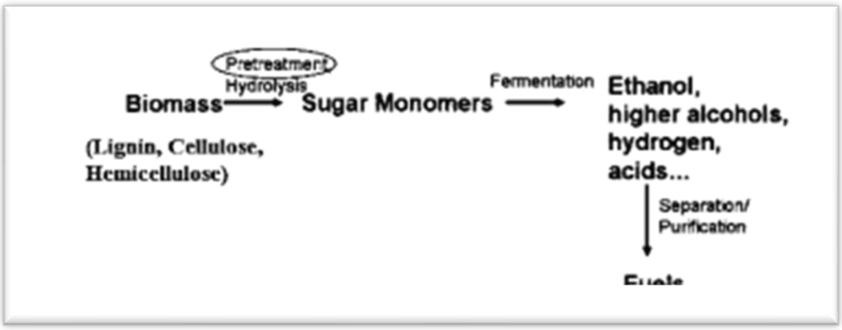

Fig 1.0 conversion of lignocellulosic biomass into methane.

AD is a synergistic process carried out by coordinated actions of various groups of microbes. This process made up of series of metabolic pathways, which can be classified into four steps: hydrolysis, fermentation, acetogenesis, and methanogenesis (Gerardi, 2003; Li et al., 2011; Montero et al., 2008). For example, milling pretreatment processes decrease the particle of the feedstock by breaking it cellular configuration so as to expose it cell tissues for hydrolysis (Fuerstenau and Abouzeid, 2002). Reduction of particle size not only improved enzymatic degradation rate, but also diminishes viscosity in reactor, hence enabling proper mixing and keeping away other unforeseeable problems like floating layers.

Also, the microcrystalline celluloses differ in particle size distribution (PSD) and, have critical implications for the hydrolysis rate and being utilized in the anaerobic process because cellulose, are degraded by the anaerobes through complex cellulose systems. However, most of the anaerobic cellulolytic species limit their complex celluloses specifically to the surface of the cell or the cell glycocalyx lattice yet does not discharge quantifiable measures of extracellular cellulose.

Worldwide, the race for energy demand and acquisition has resulted in enormous carbon dioxide emissions (depletion of fossil fuels). Hence, the need for an alternative source of energy consisting of lowest possible attainable effect on the environment. In this discourse, methane gas is one of the renewable energy sources whose production comes from different biomass types for example waste. Digestion involving anaerobic processes is a mature technology used to stabilize organic wastes while producing renewable energy under the form of biogas which can be used to generate heat and electricity or, after an upgrade, as a transportation fuel (Patinvoh et al., 2017). Additionally, to the creation of an environmentally friendly fuel, as biogas. AD has other advantages, Odors and greenhouse gases (GHG) emissions are reduced; furthermore, a nutrient rich digestate is obtained at the end of the AD process that serves alternatively as fertilizers in agricultural lands (Kumar et al., 2021). Anaerobic Digestion technology shows great potential and is considered highly promising in various fields, having the likelihood of converting biomass of various kinds into methane-rich biogas, a carbon neutral alternative to fossil fuel. However, several options of pretreatment that can be used in optimizing methane production. These can be classified as biological, physical, chemical or combination of these processes (Amin et al., 2017; Mustafa et al., 2018). Liu et al., (2019) stated that due to high energy demands including the emission of several adverse by-products and the need for special equipment, most pretreatment methods have limited applications. Pretreatment is vital and efficient in the transformation of biomass to bioethanol, and many other methods have been produced or created for biomass pretreatment. However, pretreatment approach are being split into groups like pretreatment without or with chemicals and fundamental pretreatment (Mata-Alvarez *et al.,* 2014). Pretreatment phase plays a vital role in altering biomass morphology to facilitate efficient methane production. The steps in pretreatment is a key constraint in the processing of biomass either for thermochemical or biochemical processes for the production of valuable chemicals and biofuels (Hassan *et al.,* 2016).

However, it is difficult in describing the most important pretreatment method due to some variables it depends on, like the type of feedstock and the actual product to be obtained from it. Nevertheless, one effective method for a given feedstock might not metaphor to an effective process for a different type of feedstock, though some methods of pretreatment may show some obvious gains. Zhu *et al.*, (2014) stated that pretreatment by physical means can be done by applying mechanical heating, microwave irradiation, refining, milling, ultrasound, thermal including, extruding, cavitation, dispersing etc.

Significance of Research

These research findings offers the following benefits to researchers, the public and relevant government agencies. The significance of this study includes: (i) How anaerobic digestion technology allows plant operator to reduce waste disposal cost. (ii) Assist in solving problems associated with biodigesters' like pumping and stirring, especially while solid wastes is being processed. (iii) The digestion process of the project presents a broad methodology for constructing, operating and monitoring the anaerobic digestion system. (iv) Provision of higher volumetric methane production.

Aim and Objectives of the Study

To investigate the difference in methane production at different physical pre-treatment levels. Specific

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue XI November 2024

objectives of the study are as follows:

1. To decrease environmental pollution using waste material as feedstock.

2. To increase good health and clean surrounding.

3. To produce a simple technology for organic waste digestion.

4. To produce biogas (methane) from the digestate, providing alternative heating and energy source.

METHODOLOGY

Through experiment, the utilization of organic fraction of MSW materials for the production of biogas as end product, improvement of soil condition and effective management of MSW for the improvement of health status and proper environmental hygiene, would be determined through partial stream digestion of these wastes (MSW). The study was divided into experimental and theoretical work. A simple local digester was constructed for the digestion and collection of digested organic fraction of the waste. Biological and chemical properties of the sample were determined at the biological lab and chemical lab of the institution (University of Cross River State, Calabar). The experiment was gear towards methane production at different physical pre-treatment levels. Feed stocks were gotten within Calabar metropolis, and experiment was conducted in University of Cross River State, Civil Engineering Hydraulics Laboratory.

Fig.2.0 Lccal Biodigester(anaerobic) after consturctiom.

Construction Process of Digester

Tools used**,** a drill, hack saw/saw for plastic, pipe range, a marker. However, materials used included 2 plastic barrel (of different size), PVC glove, PVC elbow pipe, one silicone/PVC glue, cronex teflon tape, tank fittings, PVC ball value, bulk head fitting (male and female adapter), binding wire, charcoal and nails.

Construction Steps

The construction steps involved cutting the top of the two plastic barrels. This was followed by cutting the PVC pipes connected with TEE joints and Elbow joints to form a stirrer. The stirrer was placed in the small barrel which was the gas collector barrel tied firmly with binding wire.

A 5cm hole was bored, higher from the bottom of the big barrel. Also, the inlet discharge connected the inlet discharge pipe with the male and female adapter. Furthermore, another 5cm hole was bored from top of the big barrel for slurry collection and this connected the slurry collection pipe. Another hole was bored but this time, it was 3cm from the bottom of the big barrel meant for discharge with a PVC ball valve connected to it. This was to be in opposite direction with the inlet pipe discharge. Finally, a hole was bored on the top center of the small barrel and connected to the gas line with a control valve on it (Figure 2).

Pretreatment on Grass and Cattle dung

Pretreatment of grass Lignocellulose biomass has a complex internal structure. It contains a number of main components (lignin cellulose, and hemicellulose) that have in turn also complex structures. Before going through anaerobic digestion the grass and the cow dung were suitably conditioned to accelerate and improve the process of degradation.

Physical pre-treatment in this context refers to techniques that do not rely on external substances like chemicals, water, or microorganisms for the pre-treatment process. Milling pretreatment was carried out on the grasses, to reduce the sizes of the substrate, to break open the cellular structure, and improve their bio accessibility to the cell tissues, by increasing the specific surface area of the biomass. This was then sieved for particle sizes of 10mm, 20mm, 30mm and 100mm. Particle size reduction not only increases the rate of enzymatic degradation, but also reduces viscosity in reactor thus making mixing easier and reduces the problems of floating layers.

Physical pre-treatment methods used in this paper was only mechanical pretreatment. Lawn mower milling technique was applied as it continuously cut the grass into smaller particles. The rotary equipment used in the cutting process consisted of 4-6 mounted knives fixed on a solid rotor steel revolving at a speed of 500 - 600 RPM. However, the cow dung were pre-heated by oven drying them. It was then sieved to obtained different particle sizes. It was a tedious task and expensive because of energy consumption. This method reduces the polymerization degree, crystallization of cellulose and the feedstock particle size thereby increasing the bulk density by allowing the treatment of more concentrated feedstock and reducing the reactor volume. Chang et al., (2020) discussed the role of lignin in lignocellulosic biomass conversion. They stated that lignin has been seen as a recalcitrance component in biomass conversion. Additionally, the pre-treatment caused the disruption of the hydrogen bonds in the cellulose and also dissolving the hemicellulose of the organic waste.

Activation of the digester

A batch anaerobic digester was constructed for this research. The feedstock of cow dung, grass collected and processed was mixed with equal quantity of water, mixed properly and all unwanted particles removed from the mixture. It was a batching processes for the various particle sizes of 10mm, 20mm, 30mm and 100mm of grass and cow dung were processed discretely. For each batching operations as per each particle size, the digester was filled with either grass or cow dung mixture and the digester was then covered with the smaller barrel (gas collector) and stirred, by turning the smaller barrel clockwise or anticlockwise. The gas control valve was closed and leak off test conducted for possible leakages by running a soap test to check if there was a gas leakage. Air was let out of the system by opening the valve on the control barrel. However, with no leakages, the gas collector barrel was allowed to settle down. The gas control valve was locked and an additional weight was placed on the gas collector to control the pressure. Laboratory test were carried out for various parameter for each sample taken during specific batching operations.

For this project, waste sample like Cattle (dung) waste was collected from Nasarawa, 8 miles in Calabar and grass was gotten from the university of cross river state premises as a feedstock for the anaerobic digester. The choice of the sample types gotten was because of it abundance in the state especially the abattoir, the university environ and also primarily, aiding solid waste reduction in the state. Additionally, the ease to support the type of digester constructed for the project work was the availability of the physical components of the digester which were locally sourced. Organic wastes were collected in two 100kg bags, the substrate consist of cattle

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue XI November 2024

waste and grass.

Analysis of Samples

The relevant control parameters of AD processes included the following: hydraulic retention time, ph, temperature, VFA, COD, moisture content, total dissolve solid, Ammonia, etc. Sample slurry was prepared for each samples (Cow manure and grass) by diluting 5g each in 50ml of water, and analyzed using UV spectrophotometer.

Hydraulic retention Time

Biogas production through anaerobic digestion (AD) heavily depended on the retention time, (Gerardi, 2003), which is widely recognized as a key factor in the operational process parameters that control the transformation of VS into CH_4, as well as the microbial growth rate. For batch tests, the production rate of methane generally increases during the initial stage, and then gradually decreases afterward (Santosh et al., 2004). For evaluating the residence time, two types of performance indicators were commonly used in the biological process: (i) solids retention time (SRT): the time length indication for microbes (or solid wastes) to stay in a bioreactor, and (ii) hydraulic retention time (HRT).

Temperature

The fermentation and biogas production duration are primarily affected by temperature (ambient). Micro-organism population dynamics, growth rate including metabolism are dependent on the operating temperature. Hence, the AD process was diligently designed to meet methanogens sensitivity to temperature. According to the study conducted by Appels et al., (2008), it was discovered that a significant process failure could arise if the mixed liquor temperature of an anaerobic digester fluctuates by more than 1°C per day. In order to prevent localized temperature deviations, it was crucial to adequately stirred or mixed the digestate. According to Ogejo et al., (2009) the operating temperatures of, mesophilic, psychrophilic including thermophilic digestions are generally around 25°C, 35°C, and 55°C, respectively. Nevertheless, the production of biogas will almost ceased if the temperature of the digester is below 10°C. Balasubramaniyam et al., (2008) stated that mesophilic microorganisms at 20-45^{0}C temperature range produces methane while being active.

Ph Level

PH level of the digester needed to be preserved at 6.8–7.2 to ensure an efficient conversion of VFAs into CH_4 and CO_2 . Conversely, the AD process resulted in the continuous production of CO_2, and the amount of CO_2 generated also affect the pH of the digestate (Gerardi, 2003). During digestion, the two processes of acidification and methanogenesis required different PH level for optimal process control. The retention times of digestion affected the PH value whereas under the batch reactor acetogenesis occurred at a rapid pace. Acetogenesis had the potential of significant buildup of quantities of organics acids resulting in lower PH. Excessive generation of acid also inhibited methanogens because of their sensitivity to acid conditions.

Volatile Fatty Acids (VFAS)

The total content of VFAs was another critical factor, apart from the system pH, in the methane production via AD. During the process, acetogenesis and acidogenesis phases, catalytic decomposition of organic solids produces final and intermediates products like VFAs (Hassan et al., 2021; Rani and Nand, 2004).The concentration of VFAs was used as a key indicator for identifying the levels of the AD destabilization and the difficulty on methanogens growth.

Chemical Oxygen Demand (COD)

In anaerobic treatment, the fundamental concept revolves around harnessing the power of anaerobic bacteria in transforming organic pollutants or Chemical Oxygen Demand (COD) into biogas within an environment devoid of oxygen. This conversion process entails the utilization of COD, which is ultimately converted into Biogas, composed primarily of Methane (CH_4) and Carbon Dioxide (CO_2). Organic matter with low energy content produces less methane than OM with high energy content. However, these energy content of organic matter can be estimated using Chemical Oxygen Demand (COD). Organic matter content of a pollutant was measured indirectly, and in the process of aerobic digestion, the measurement of oxygen required for digestion was closely observed.

$$OM + O_2 \rightarrow CO_2 + H_2O + Energy \quad (1)$$

The amount of oxygen (O_2) needed for the conversion OM to CO_2 and H_2O is the Chemical oxygen demand.

Moisture content

This involve removing the water from the product by drying (oven), and measuring the amount by weighing. For the dry sample, the quantity of water was then divided by the dry weight.

Total Dissolved solid

In the measurement of the total solid (TS) which indicates the overall solid content in an anaerobic digestion and volatile solids (VS) which represent the organic fraction of total solids, the anaerobic fresh active digestate and substrate was determined after the sample had been properly homogenized. A portion of the well mixed biomass sample was transferred to the weighted empty crucibles using a spatula while the fresh active digestate was poured into the crucible and the weight of wet samples plus the empty crucible weight, weighed again and data recorded. The biomass sample was then kept in an oven and dry at 105^{o}C for 24 hours. The biomass sample was then placed in a desiccator to cool in about one hour and weighed to the nearest sensitivity of 0.1mg. The total solids (TS) and volatile solids (VS) were determined as:

% total solid (TS) = $\frac{w_3 - w_1}{w_2 - w_1}$ (2)

W_3 is the substrate or digestate sample weight after drying in an oven at 105^{o}C measured in (g)

W_1 is the empty weight of the crucible measured in (g)

W_2 is the measured weight of crucible with a fresh active digestate, % Volatile solids (VS) = $\frac{w_3 - w_4}{w_2 - w_1}$ (3)

W_4 is the measured weight of crucible and a fresh active digestate or substrate after the heating at 550^{o}C measured in (g).

Volume of Gas Produce

The volume of gas that would be produced was dependent on the degradability of the waste sample and also the available nutrient present for the microbial consumption. The amount of gas production was monitored daily and recorded daily by taking the rise in height of the gas collector. This was calculated analytically using the equation below.

$$V = \frac{\lambda d^2}{4 * h} \quad (4)$$

Where V= volume

D = Diameter of barrel

λ = 3.147 [constant]

h = height of barrel

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue XI November 2024

Total Solids Content (Tsc)/Organic Loading Rate (Olr)

Low solid (LS) anaerobic digestion (AD) systems contain less than 10% TS, medium solids (MS) about 15-20% and high solid (HS) process achieved better methane yield (Jing et al., 2014). The organic loading rate was the amount of measure of the biological conversion capacity of the AD system. Feeding the system above the sustainable OLR resulted in low biogas yields. Due to accumulation of inhibiting substances such as fatty acid in the digested slurry, as was the case, feeding frequency to the system was reduced. OLR was actually a relevant as a control parameter in the continuous systems.

Construction process of Reactor

A Simple local digester (Batch Reactor) or a biogas plant was constructed for the digestion and collection of digested organic fraction of the waste. Biological and physical properties of the samples were determined at the laboratories of the Cross River State water board and the University of Cross River State (UNICROSS) microbiological department. Before experimental testing, the types of digesters employed, feed stocks, breaking down of organic substrates and degree of particle size reduction were all carefully considered as this could posed problem or become a bottleneck.

RESULTS AND DISCUSSION

The outcome of two different substrate biomass characterizations are shown below in table 1 and table 2.

Table 1. Grass Waste Batch Testing

Grass	TS	VS	COD	NH_4	Alkalinity	PH	Moisture	Conductivity	TDS	CH_4(N m^3/kg)
Day 3	0.316	1.040	51	6.8	33.6	7.7	0.0195	418.2	250.92	1.3
Day 6	0.306	1.038	52.2	6.6	33.1	6.9	0.0191	417.0	200.01	1.4
Day 9	0.412	1.020	53.6	7.0	34.04	7.3	0.0183	300.0	230.56	1.5

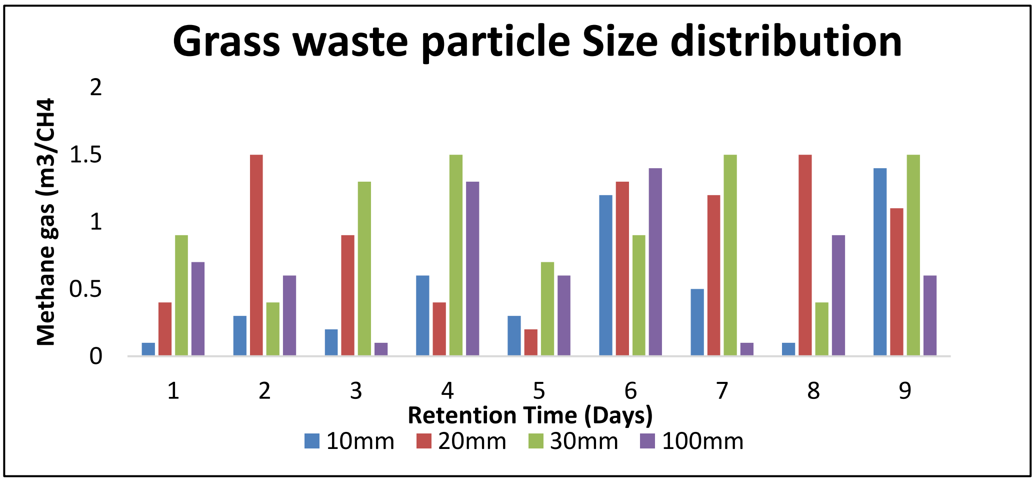

Fig. 3 Grass Waste particle size distribution/methane productions

In summary, for description of the methane gas production, a difference in the production output level in terms of biogas for the grass type of substrate used with a maximum value was recorded for the particle size of 20 mm. This was followed by that of particle size of 10mm, however a poor yield for the particle of 100mm sizes was also observed depreciating to a level approximately 30% less than the 10mm of particle size. Pre-treatment was applied to the cow-dung to better the performance process of the reactor and to increase biogas yield. Three physical pre-treatment methods applicable to cattle manure, included pre-heating, drying and sieving. Dry sample of cattle waste was sieved into different particle as shown below in Figure 4.

Table 2. Cattle Waste Batch Testing

Cattle	TS	VS	COD	NH_4	Alkalinity	PH	Moisture	Conductivity	TDS	CH_4(N m^3/kg)
Day 3	0.045	0.017	54	72	30	7.9	0.0287	315.4	189.24	2.8
Day 6	0.478	1.038	55	72.5	32	7.8	0.0289	315.4	189.98	3.0
Day 9	0.480	0.0156	55	73.2	33	7.9	0.0290	315.4	190.0	3.0

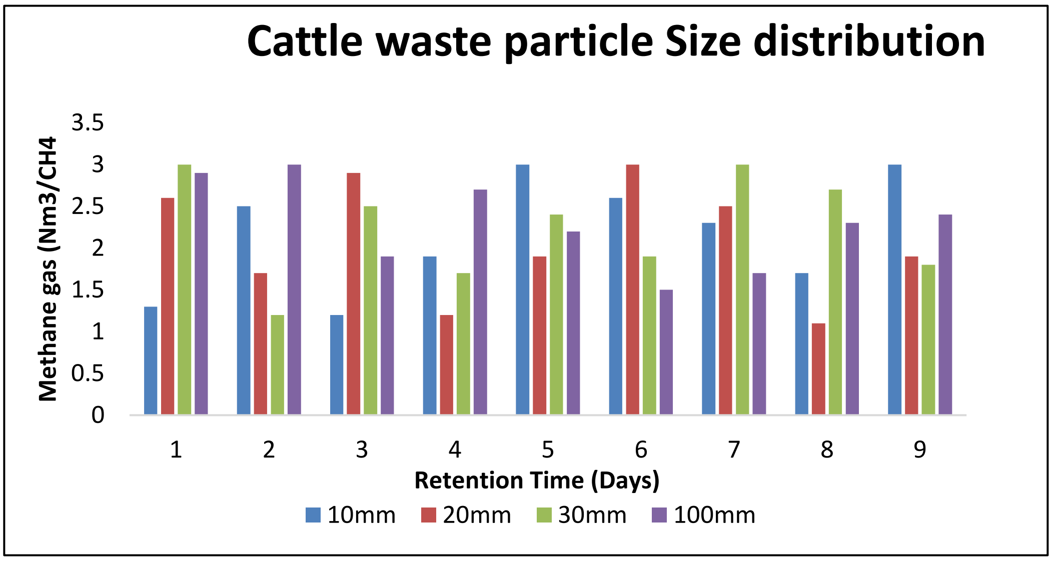

Fig 4. Cattle waste particle size Distribution/methane production

For the Cattle waste, dry sample was used in other to achieved different particle sizes. Results for methane production as shown in the bar chart methane distribution (figure 4), shows that 30mm and 100mm had very high methane production.

Biochemical Methane Potential

The Biochemical Methane Potential Analysis (BMP) was a straight forward process that involves combining a substrate sample with an anaerobic micro-organism, a medium of nutrient, and allowing it to incubate for a period of 9 days. This analysis was designed to bring about the methane production potential of a given substrate. The amount of methane (CH_4) generated during the incubation period was quantified or measured. There were several ways of interpreting results from BMP test. The simplest interpretation was the Specific Yield of Methane or the quantity of CH_4 produced in terms of per mass of VS being added. Another metric to be considered was the wet mass of methane potential, which was carried out by calculating the quantity of CH_4 produced in relation to the mass of the wet sample. Volumetric Potential of Methane was the amount of CH_4 produced divided by the substrate volume added.

Physical Pre-treatment was employed on grass and other biomass feedstock to enhance surface area and facilitate digestion. Impressively high biogas yields have been observed through the implementation of these techniques, resulting in biogas production increases, ranging from 25 to 60% (Figure 5). When it comes to pre-treatments in mechanical processes, it is possible to adapt machinery from other industries with some modifications or adjustments. However, it was observed that, this machinery was very delicate and susceptible to damage from inert materials like stones or metals. Additionally, mechanical methods are high energy demanding and have high maintenance costs.

The pretreatment method for grass resulted in an 82% higher bio-methane yield with a cumulative CH_4 production increasing from 1.3 to 1.5 nm^3CH_4/g/kg (Figure 6).This enhancement was most likely due to the higher accessibility of cellulose and hemicellulose to the bacteria after the pretreatment.

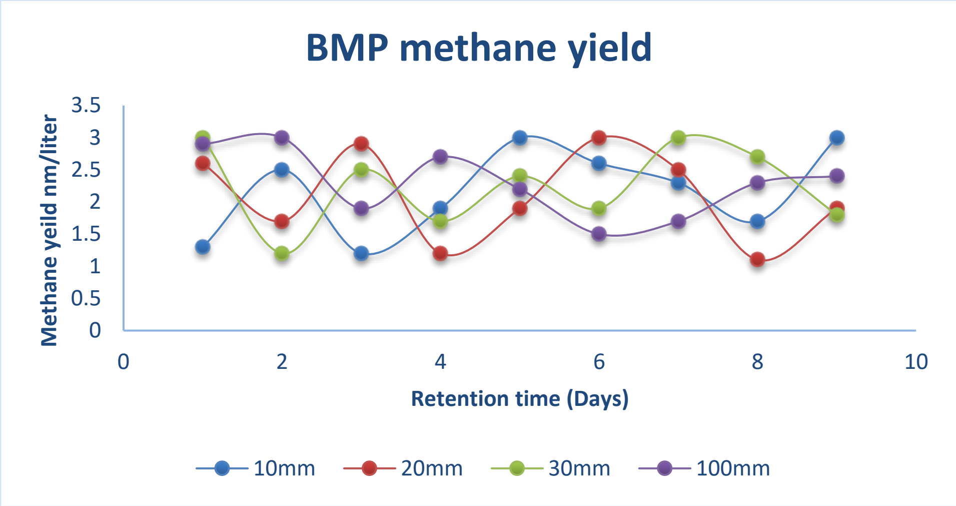

Fig 5. BMP Methane Yield

Fig 6. Methane Yield from Grass Waste

The TS was 0.316, 0.306 and 0.412 (± 0.04) (w/w), and VS was 0.0173, 0.0179 and 0.0156 (± 0.03) respectively. The advantages of Physical pre-treatment of grass brought about reduced cellulose crystallinity and particle size. Biomass handling was easier, since existing machinery improves fluidity in digester and also increases surface area. However, the disadvantages was that physical pre-treatment requires high energy demand, high maintenance cost including sensitivity to inert materials and it yield only about + 25-60% of biogas.

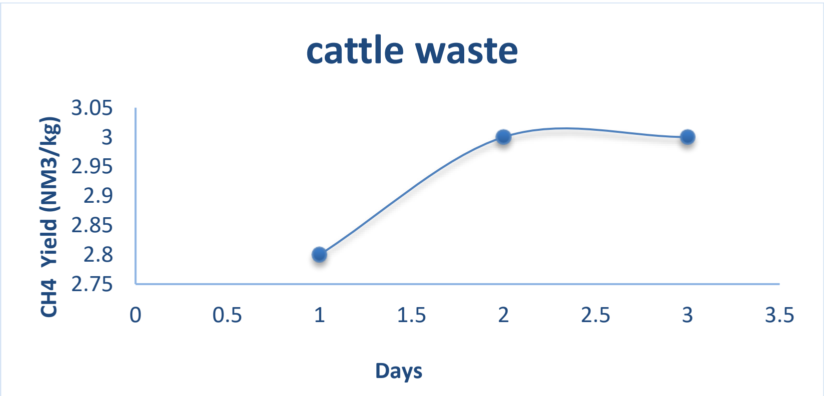

Fig 7. Methane Yield from Cattle Waste

The pre-treatment method for cattle waste resulted in a 90% higher bio-methane yield with a cumulative CH_4 production increasing from 2.8 to 3.0 $nm^3CH_{4/}g/kg$ (Figure 7). The result shows the benefit of co-digestion effect (i.e., substrate properties improvement) was on reaction rate primarily and also specifically during the early incubation period. The acceleration mentioned above was especially noticeable when co-digesting mixtures of high cattle waste. Also, suggesting that the microbial growth including enzyme production were promoted due to the mixing with more readily utilizable co-substrates. This facilitated the hydrolysis of biodegradable organic matter in the cattle waste slowly. The TS resulted in 0.0452, 0.478 and 0.480 (+0.02) (w/w) and VS was 0.173, 0.0179 and 0.0156 ((± 0.02) respectively.

The research work has shown the comparing between the simulated results and the experimental data for different degradability, it reveals that large particles degrades slowly while the smaller fraction is more degradable. This demonstrates a kind of bi-modal distribution with a lower and upper bound of degradability. Hence, suggesting that the smaller particle sizes may be one step towards more efficient conversion.

The average results of the pH, total alkalinity (TA) from both substrate biomass for Grass waste and cattle waste obtained during the batch testing, provided process stability of bioreactors, during biodegradation as seen in Table 1 and Table 2 respectively. The results clearly show a relatively stable pH in the reactors with time. However, this could be possibly seen as suggesting the volatile fatty acids (VFAs) accumulation in the bioreactors. Considering data obtained, the decrease in pH on the third day from 7.7 to 6.9 and to7.3 for Grass and Cattle waste the pH profile in the digester reveals that the pH fluctuates between 7.8 and 7.9 indicating that the bioreactor was in a stable operating mode and above 7.9 the digester was unstable, due to volatile fatty acid (VFA) accumulation and possibly ammonia. Also, in addition the average data for the pH of grass was 7.3 and cattle manure was 7.9. In conclusion one can say for milling pretreatment of grass and cattle waste, cattle waste yield more biogas and a relatively high pH more than the grass waste (see figure 8).

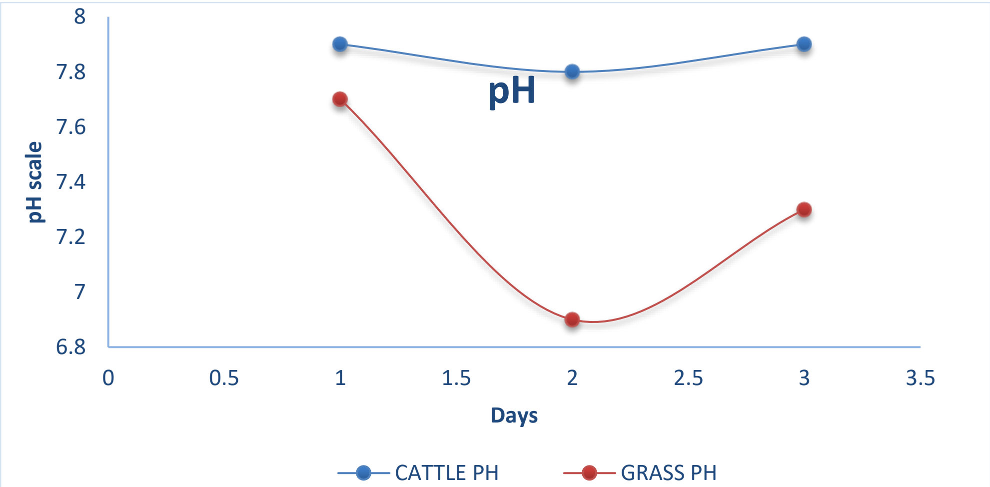

Fig 8. Chart showing the pH of both grass and cattle waste for a retention time of 3- 9 days.

CONCLUSIONS

Physical pretreatments resulted in reducing the feedstock particle sizes, hence disrupting the structure of lignocellulosic in the biomass. However, from the study, preheating resulted in the production of higher percentage of methane than the cutting and milling of the substrates. Despite the fact that mechanical methods are normally related to high energy requirements, they are still considered very promising in improving the energy balance and alternative energy source.

All the methods share the drawback of requiring high energy. The machinery used for grass pretreatment was initially designed for other purposes, so a thorough analysis was necessary to maximize the efficiency of each piece of equipment.

The difference in the kinetics of the feedstock at the different particle size was related to the available surface area. Smaller particle sizes have a larger specific (m^2/kg) surface area which increases the availability of reactive substrate for processing by micro-organisms during the digestion processes. Further, the chemical component of the feedstock plays a key role in the difference in kinetic reactions of the particle sizes. For example, a substrate with higher lignin content tense to have a protective barrier that prevents the digestibility or biodegradability of cellulose material that is found present in the lignocellulosic biomass because of the bond holding the molecules which are hindered by structural, compositional and physicochemical factors.

Therefore, the motive behind this research work was to investigate differences in methane production at different physical pretreatment levels of the digestate through experimental analysis. Findings on this study, shows that the digester should be fed twice a day during operation rather than once a day. When a new amount of substrate biomass is introduced into the digester this helps in decreasing the shock. This maintains digester stability while also increasing the rate of bio-methanation.

RECOMMENDATIONS

1. For chemical and biological treatments, new compounds and enzymes can be studied to increase the effectiveness and also reduce the toxicity and the pre-treatment time. Parameters of pretreatment may be specified using multi- objective optimization technique, so that a high biogas yield can be produced with a positive energy balance.

2. For a greater development of biomethane and biogas production, it is important to establish a new legal framework in which these AD and upgrading technologies are sponsored as they contribute to energy system decarbonization and circular economy.

3. Regular inspection of bio-digester should be carried out for possible maintenance.

List of Abbreviations

AD: Anaerobic Digestion

GHG: Green House Gases

VS: Volatile Solid

VFA: Volatile Fatty Acid

CH_4: Methane

OM: Organic Matter

OLR: Organic Loading Rate

BMP: Biochemical Methane Potential

MSW: Municipal Solid Waste

Availability of Data and Material

Data is in the custody of the corresponding author and is available on written request.

Competing Interest

Not applicable.

Funding

Not applicable

Authors' Contribution

Not applicable.

ACKNOWLEDGEMENT

Not applicable.

REFERENCES

1. Ali, H. Hamzah, M. H. Man, H. C. Jamali, N. S. Siajam, S. I. and Ismail, M. H (2023). Effect of
2. Organic Loading on Anaerobic Digestion of Cow Dung: Methane Production and Study. Heliyon, Volume 9 (6).
3. Amin, F. R.., Habiba, K., Zhang, H. Rahman, S. Zhang, R. Liu, G. Chen, C(2017) Pretreatment Methods of Lignocellulosic Biomass for Anaerobic Digestion. AMB Express Journal Article Number 72(7):1-12.DOI:10.1186/S13568-017-0375-4.
4. Appels, L. Baeyens, J. Degreve, J. Dewil, R.(2008) Principles and Potential of the Anaerobic Digestion of waste-Activated Sludge. Progress in Energy and Combustion Journal.34 (6):pp. 755-781. DOI:10.1016/j.pecs.2008.06.002.
5. Balasubramaniyam, U. Zisengwe, L. S. Meriggi, E. Buysman (2008). Biogas Production in Climates with Long Cold Winters. Wageningen University.
6. Chang, Y., Xianzhi, M., Yunqiao, P. and Authur, J. R. (2020). The Critical Role of Ligninocllulosic Biomass Conversion and Recent Pre-Treatment Strategies. Bioresources Technology Journal, April, 2020, Vol. 301, Issues 1, pages 122784.
7. Energy Commission of Nigeria (ECN). https://energy.gov.ng
8. Fuerstenau, D. and Abouzeid, A. Z. (2002). The energy Efficiency of Ball Milling in Comminution. International Journal of Mineral Processing. Vol. 67, Issues 1-4, pages 161-185.
9. Gerardi, M. H (2003). The Microbiology of Anaerobic Digesters. John Wiley and Sons Inc. Hoboken. http://dx. Doi.org/10.1002/0471468967.
10. Hassan, G. K. Jones, R.J. Nicolau, J. M. Dinsdale, R.Abo-Aly, M. M. El-Gohary, F. A and Guwy, A (2021). Increasing 2-Bio-(H_2 and CH_4) Production from Food Waste by Combining Two Stage Anaerobic Digestion and Electrodialysis for Continuous Volatile Fatty Acid Removal. Waste Management Journal. Volume, 129 pp:20-25.
11. Jancovici. Com/wp-content/uploads/2016/04/world_energy_1998 pdf.
12. Jing, Y. Bin, D. Jingwei, J and Xiaohu, D (2014). Effect of Increasing Total Solid Contents on Anaerobic Digestion of Food Waste under Mesophilic Condition: Performance and Microbial Characteristics Analysis. https://doi.org/10.137/journal.pone. 0102548. t001.
13. Kumar, M. Dutta, S. Luo, G. Zhang, S. Show, P. L. Sawarkar, A. D. Singh, L. and Tsang, D. C. W. (2021). A Critical Review on Biochair for Enhancing Biogas Production from Anaerobic Digestion of Food Waste and Sludge. Journal of Cleaner Production, 305, 127143 (doi:10.1016/j-jclepoo.2021-127143)
14. Liu, T. Zhou, X. Zifu, L. Wong, X. Sun, J (2019) Effect of Liquid Digestate Pretreatment on Biogas Production for Anaerobic Digestion of wheat Straw. Journal of Bioresources Technology. Volume 280, pages 345-351.
15. Mata Alvarez, J., Dosta, J., Romero-Guiza, M, S., Almansa, X. F., Peces, M. and Astals, S. (2014). A Critical Review on Anaerobic Co-Digestion Achievement between 2010 and 2013. Renewable and Sustainable Energy Review Journal. Volume 36, pages 412-427. DOI:10.1016/jrser. 2024.04.039.
16. Montero, B., Gacia-Morales, J. L., Sales, D., and Solera, R. (2008) Evolution of Microorganisms in Thermophilic-Dry Anaerobic Digestion. Bioresources Technology Journal, Volume 99, Issue 8, pages 233- 243.
17. Mustafa, A. M. Chen, X. Liu, H. Sheng, K. (2018). Effect of Ammonia Concentration on Hythane (H2 and CH_2) Production in two phase Anaerobic Digestion. https:www.science direct. Com/ science/article/pii/5036031991332483.
18. Ogejo, J. A. Wen, Z. Ignosh, J. Bendfeldt, E. Collins, E. R (2009). Biomethane Technology. Virginia Cooperative Extension, 444(881): 1-11.
19. Patinvoh, R. J. Osadolor, O. A. Chandolias, K. Harvath, I. S. and Taherzadeh (2017) Innovative Pretreatment Strategies for Biogas Production. Journal of Bioresources Technology. Volume 224, pp: 13-24.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue XI November 2024

20. Rani, D. Nand, K (2004).Ensilage of Pineapple Processing Waste for Methane Generation. Journal of Waste Management.
21. Santosh, T. Sreekrishman, T. R. Kohli, S. Rena, V (2004). Enhancement of Biogas Production from Solid Substrate using Different Techniques-A Review. Journal of Bioresourses Technology. Volume 95, pp:1-10.
22. Zhu, N., Li, Q., Guo, X., Zhang, H., and Deng, Y. (2014). Sequential Extraction of Anaerobic Digistate Sludge for Determination of Partitioning of Heavy Metals. Ecotoxicology and Environmental Safety. Vol.102, pages 18-24.