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Enhancement of Biogas Production Through The Co-Digestion of Animal Wastes to Address Energy Challenges

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Abstract: A thorough analysis and assessment of each individual feedstock type is necessary, as evidenced by the variety and abundance of potential feedstock for biogas generation. One valuable by product of anaerobic digestion of organic molecules is biogas. In order to improve biogas generation as an alternative to conventional energy resource use, the paper looks at binary and ternary combinations of different feedstock (cow, poultry, and horse waste). Because co-digestion has been shown to be an effective way to increase the generation of biogas. The digester was first built, after then sample was prepared. The water displacement method was used to quantify the amount of biogas produced. The largest daily volume of the biogas from cow and horse dung was 216 ml and was on the 18 th day, while the quantity of biogas produced from slurry containing cow dung and poultry dropping was 120ml, it occurred on 17 day. The largest quantity in the digester containing all the dung was 129ml on the 16 th day. An overview of biogas composition results shows that, methane content from the three reactor was between 58 to 64 "\ percent" which is higher than carbon dioxide with range between 30 to 38"\ percent". This signified the high calorific value of the biogas formed. The outcome showed how the feedstock could reduce carbon dioxide emissions and contribute to greater energy security.

Keywords: Biogas, Co-digestion, Cow dung, Horse dung, Poultry dropping

INTRODUCTION

Massive amounts of excrement are produced during cattle farming. If these dungs are not adequately managed, they cause environmental problems. Jan Baptist van Helmont (1580–1644) noted in 1630 that combustible gasses were created when organic material decomposed (Grando etal., 2017). Since then, scientists have thought that microbial conversion of organic waste and agricultural and food industry by-products is a practical way to boost resource efficiency and switch to renewable energy sources from fossil fuels. Over the past ten years, the use of anaerobic digestion (AD) as a waste management alternative has increased by about 25% annually (Silva et al., 2021). By generating biogas and preventing its build up in landfills, AD enables the utilization of this waste's energy potential. Furthermore, it is one of the other methods for producing renewable energy, which can help meet the growing need for energy and improve waste management techniques. According to Glivin et al. (2021), the International Energy Outlook (IEO) predicts that between 2012 and 2040, the world's main energy demand would rise to 48%. By 2040, 84% of energy will come from non-renewable sources, down from 91% in 1990. To meet the world's energy needs, renewable energy sources will continue to increase from 9% to 16%. According to global energy demand, non-renewable energy's proportion of electricity output will drop from 78% to 71% by 2040. Anaerobic digestion technology is therefore regarded as a workable way to switch to renewable energy sources from fossil fuels.

A key component of the shift to a resource-efficient and bio-based economy is biogas technology (Sica et al., 2023). Economic, social, health, and environmental benefits of the technology have been shown in both rural and developing areas. (Yasar et al., 2017). Biogas is a sustainable energy source that is most important to the growth of many nations since it can be produced close to human settlements and is very accessible (Roopnarain and Adeleke, 2017). While biogas has long been recognized globally, its widespread and widespread use has only been in the recent century, and particularly in the last three decades (Kougias and Angelidaki, 2018). More generally, it has been argued that biogas helps achieve 12 out of the 17 Sustainable Development Goals (SDGs) of the UN (Piadeh et al., 2024) The following are some uses for biogas: it can be burned to produce heat or electricity (Ampomah-Benefo et al., 2018), it can be liquefied into methanol and chemical feedstock; it can be compressed to be used as vehicle fuel, much like compressed natural gas (Scarlat et al., 2018); and it can be purified to be fed into gas distribution networks.

Although mono-digestion of substrate has been recognized as a significant cost-effective substitute, particularly as a renewable energy source, mono-digestion of manure typically leads to poor performance because of ammonia inhibition and nutrient imbalance (Yellezuome et al., 2022). Co-digestion is the most economical way to solve this issue (Hagos et al., 2017). It was shown that the approach yielded more methane overall than individual mono-digestions. Several feedstocks are combined and treated simultaneously as part of the co-digestion treatment method. Co-digestion can maximize sample digestion by utilizing bacterial diversity and nutrients found in various wastes (Karki et. al., 2021). Previous studies have focused on various AD processes, specifically those for the co-digestion of livestock manure with other organic residues, which hinder the negative impacts of livestock manure. Enhancement of system balance and output of methane through the synergistic effects of fostering a more diverse microbial community (Zhao et al., 2024), better nutrient balance, dilution of heavy metals as well as toxic compounds, and safe and better quality digestate for agricultural applications are the main advantages of co-digestion (Wang et al., 2023). Although co-digestion of cow manure produces more biogas, there is still opportunity for development, according to a review of scholarly papers on the subject. Therefore, greater effort is required to combine or co-digest animal wastes in order to produce biogas successfully. Thus, by co-digesting cow dung with horse and poultry droppings, the study sought to explain laboratory studies on methane potential.

EXPERIMENTAL PROCEDURE

This study focuses only on building a biodigester and assessing different feedstock (cow dung, chicken droppings, and horse dung) for producing biogas. Following collection and preparation, the samples were sent to a laboratory for prompt examination.

MATERIALS AND METHOD

Thermometer, delivery tube, 250 ml measuring cylinder, vessel, timber object, plastic container, hand glove, sack, polythene bag, oven, weighing balance, crucible, and digesters are among the supplies we utilized for this project. In a laboratory, three digesters were built. Each digester was constructed using 5.34-liter plastic containers. Using a soldering iron, a hole for the gas delivery system was created on top of the digester. The gas produced leaves the digester through the hole, which is attached to one end of the measuring cylinder, which functions as the gas measurement device. To keep light from harming microorganisms that are vulnerable to it, the finished construction was covered with black plastic bags to block out light. Light does not destroy methanogens, but it significantly reduces methanation.

SAMPLE COLLECTION AND PREPARATION

Three substrates were used in this study: cow dung, chicken droppings, and horse dung. In the research area, these manures represent the most prevalent type of agricultural waste. For the experiment, the manure was gathered from various farms, sealed in airtight bags, and brought to the lab. The cow dung and horse dung were combined in a 1:1 ratio after any unwanted material had been removed. A final slurry was then created by adding water to the mixture in a 1:1 ratio. This slurry was then put into the digester through the inlet chamber. As soon as the digester was 80% full, the slurry addition was stopped. Finally, the digester was sealed and stored for further digestion. For the remaining samples, the procedure was repeated. Notably, the slurry was shook every day at 1:00 pm before to taking readings in order to speed up the gas production. The delivery tube lacks the function of a tap to regulate the flow of gas, and the components were not chemically treated before to use.

METHODS OF MEASUREMENT

The fresh manures were characterized using a variety of methods. The daily generation of biogas was obtained using water displacement. A Biogas samples were obtained using a gas bag, and the composition of the biogas generated was measured using a gas analyzer. A pH meter was then inserted through a tiny hole to determine the pH value.

RESULTS AND DISCUSSION

The digester was fed with cow, horse dung and poultry dropping. The results obtained are given and interpreted in the subsection.

RESULTS OF CO-DIGESTION ON BIOGAS PRODUCTION

The results of our previous experimental study of cow, horse, and poultry manure indicate that using chicken droppings (PD) and horse dung (HD) as biogas feedstock was somewhat less effective than using cattle dung. Conversely, the optimum substrate for co-digestion with horse (HD) and chicken droppings (PD) is believed to be cow dung (CD). Anaerobic digestion of a single substrate fails because of low-quality inorganic compounds and unpredictable raw material qualities (Mothe et al. 2021). According to Ihoeghian et al., (2022) co-digestion produces a better yield of biogas than individual mono-digestion. Figure 1 displayed the results of the biogas production from the co-digestion of cow dung (CD) and horse dung (HD), cow dung (CD) and poultry dropping (PD), and cow with horse and poultry dropping under the same conditions. The majority of experimental trials show no overlap, as shown in figure 1, showing distinct biogas outputs. On the first day of the original biogas studies, there was no biogas produced. The gas begins to evolve on day two. During the third week of retention, a high methane output was noted.

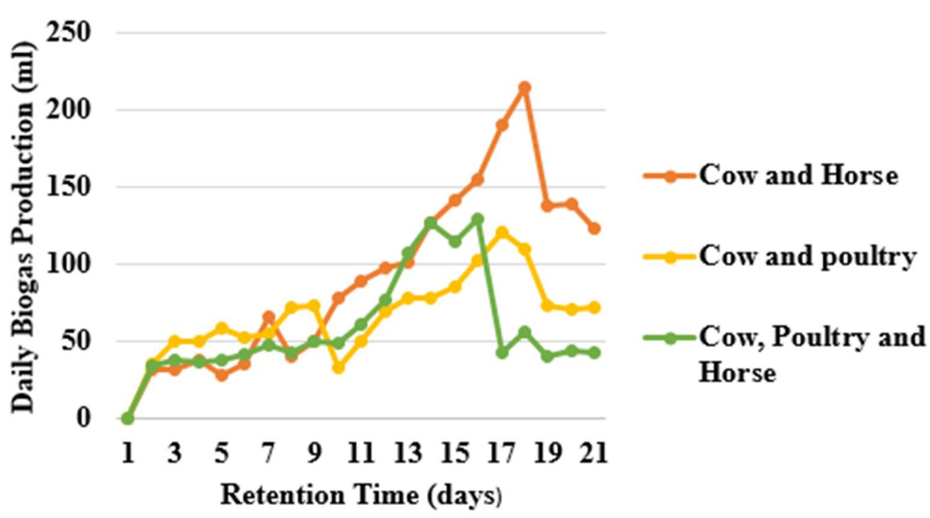

Figure 1: Graph of Daily Biogas Production from Co-digestion

When CD and HD are digested together, more biogas is produced than when HD and PD are digested separately. Consequently, combining two or more feedstock would complement their respective advantages and may result in improved digestion, growth of microorganisms, and increased biogas production. From the 10 th to 21 day, the co-digestion of CD and HD, is higher than CD and PD, CD, PD and HD. The largest daily volume of the biogas from CD and HD was 216ml and was on the 18th day, while the quantity of biogas produced from slurry containing CD and PD was 120ml, it occurred on 17 day. The largest quantity in the digester containing all the dung was 129ml on the 16 th day (Figure 1). The development of increased biogas in CD and PD suggests that the biomass utilized contains a high concentration of these microbes, as the organic elements present are broken down into easily degradable lignocellulosic and proteinaceous molecules (Silva et al., 2021).

RESULTS OF CUMULATIVE BIOGAS PRODUCTION

In Figure 2, the Cumulative Biogas Production from co-digestion was displayed. It is evident that the kind of mixture in the slurry affects the amount of biogas produced. Although it is steadily increasing, the biogas production for all digesters is comparatively quite modest during the first week. This phase may be explained by the large buildup of long chain volatile fatty acid (VFAs) and correlates to a low degradation of the slurry. On the fourteenth day, the curve starts to display a varied amount of biogas from each reactor. Reactors with CD and HD produced the highest biogas yield, followed by digesters with CD and PD. The digester that produced the least amount of cumulative biogas had CD, PD, and HD. According to Ameen et. al., (2021) co-digesting the microbial biomass with cow dung, chicken manure, and pig manure produced the highest methane outputs.

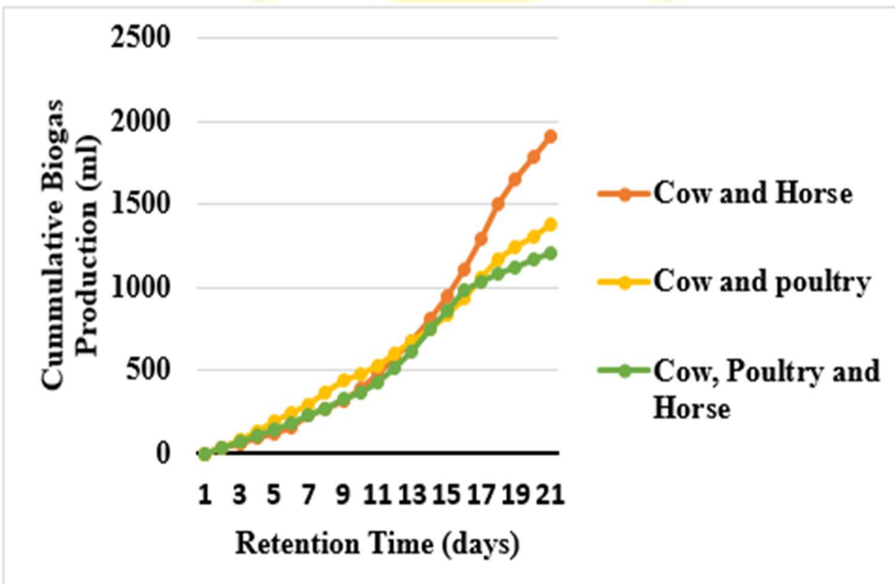

Figure 2: Graph of Cumulative Biogas Production from Co-digestion

RESULTS OF BIOGAS COMPOSITIONS

The particular composition of the biogas varies depending on the substrate. According to Ahmed et al. (2024), methane is a crucial metric for evaluating the effectiveness of anaerobic digestion. The findings of an investigation of the average gas produced during a 21-day period are displayed in Figure 3. Figure 3. The three reactors' methane levels varied from 58 to 64%, while their carbon dioxide percentages ranged from 30 to 38%. According to a report by Jameel et al. (2024), the percentage composition of biogas is 30–50% carbon dioxide and 50–70% methane.

According to Sher et al. (2024), the composition of biogas indicates that carbon dioxide makes up 40–50% and methane 50–60%. The percentage composition of biogas affects its calorific value. This results proved the substantial calorific value of the biogas and lower greenhouse gas emissions.

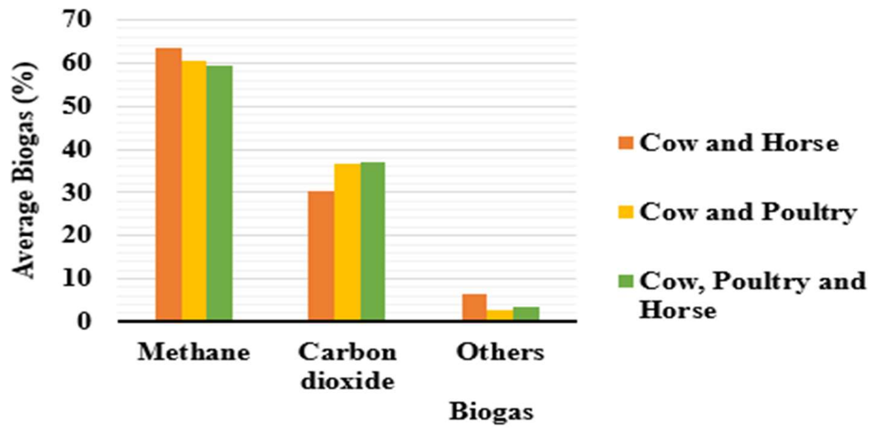

Figure 3: Average Biogas Composition

CONCLUSION

The increasing demand for using biomass as a key energy source in new or existing applications using biochemical conversion technologies is what spurred this study. Additionally, Nigeria produces more animal excrement than is needed for fertilizer, which has a negative effect on the environment and people. This study examined the potential for volumetric gas productivity, process economics, and environmental benefits of co-digesting cow dung with chicken dropping, cow dung with horse dropping, and ultimately, cow dung with horse dropping. A blend of cow and horse manure has the maximum potential for producing biogas (216 ml), with a cumulative biogas yield of 1906 ml over 21 retention times. The results thus shown the viability of co-digesting substrates in a mesophilic environment to produce more biogas. As a result, using biogas technology necessitates careful feedstock analysis. Our findings suggest that using biogas generation, especially from a combination of cow and horse dung, might produce valuable and renewable by products while lowering greenhouse gas emissions and manure odors.

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