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Parameters affecting biogas production from cow-dung and fruit/vegetable wastes: An empirical study

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Abstract
In order to enhance the performance of a biogas generation process and increase local production yield, certain operating parameters need to be controlled. This study investigated some parameters affecting biogas production from cow-dung and fruit/vegetable wastes. The factors studied were; temperature, pH and nutrient addition to the substrate. From the results obtained, mesophillic temperature of 25-35 °C, pH of 8 and the addition of nutrient - $CaCO_3$ and NH_3 in the ratio of 5g: l dm^3 are the conditions for best yield. With the following conditions, a gas volume of 1450 g (1.45 kg) was obtained on the 6^{th} day of anerobic digestion of cow dung co-digested with fruits/vegetable wastes. This proves that the production of cooking gas from plants and animal wastes is a feasible project and can be used to create wealth.

Keywords: Parameters, biogas production, cow-dung, Fruit/vegetable wastes

Introduction

Biogas is a gaseous fuel composed of methane and carbondioxide naturally produced by the decomposition of organic matter, usually in the absence of oxygen. It is a clean-burning, "green" fuel used for heating and cooking, transport and power generation (Ojikutu and Osokoya, 2014) [9]. Biogas usually contains about 55-65% methane, 30-35% carbon dioxide, and traces of hydrogen, nitrogen and other impurities.

Anaerobic digestion is a biological process through which bacteria break down organic matter such as animal manure, human dung, dead plants, agricultural and food wastes in the absence of oxygen. In other words, anaerobic generates energy as CH_4, CO_2 (used in green chemistry and fungi production) and a low-cost fertilizer without aerobic pathogens. The bio-methane can be used to increase the temperature of the digestion reactors thus, optimizing the process and reducing energy costs. Methane is safe if contained in a sealed environment. Biomethane combustion can substitute fossil fuels and biofuels, thus reducing, among others, polycyclic aromatic hydrocarbons, organometal/metalloids, radionuclides, smog and acid rain compounds.

The major advantage of the anaerobic digestion process is the production of biogas, a renewable energy source, which can be used as fuel for automobiles, for direct heating and for power generation (Deepanraj, Sivasubramanian and Jayaraj, 2015) [3]. The production of biogas, depending on the biomass feedstock used, helps in the reduction of fossil fuel usage and enables the lowering of carbon dioxide levels. Apart from biogas yield, anaerobic digestion liberates solid and liquid by-products which can be used as fertilizer or soil amendment.

The biogas produced during anaerobic digestion process is a blend of methane (CH_4: 55–65% by volume), carbon dioxide (CO_2:30–40% by volume), and traces of hydrogen sulphide (H_2S), hydrogen (H_2) (Deepanraj *et al.*, 2014) [4]. Due to the intricacy of the bioconversion processes, various factors like solid concentration, pH, temperature, mixing/agitation, C/N ratio, substrate composition, etc. affect the performance of an anaerobic digestion process. Many researchers have investigated the effects of these parameters on biogas production using various feedstock and reported their findings (Vanegas and Bartlett, 2013; Ghatak and Mahanta, 2014; Nyong, Abeng and Obeten, 2021; etc) [11, 5, 8]. This present research seeks to investigate parameters that affect the production of biogas via anerobic digestion of cow-dung co-metabolised with fruits and vegetable wastes. The parameters under review include temperature, pH and nutrient addition.

Methodology

The cow dung was collected at a local abattoir, the fruit and vegetable wastes were gotten from the market waste centre at Anantigha abattoir, Calabar South Local Government Area of Cross River State, Nigeria. The fruit and vegetable waste collected are: spoilt tomatoes, pawpaw, pineapple and banana peels, etc. Laboratory-scale anaerobic batch digesters made of plastic with a total volume of 2.5cm^3 were used in all the experiments. The cover of the digester was then connected to a tube where the gas would be collected into. The valve of this tube was in turn connected to a gas cylinder where the gas produced would be measured as well as stored.

A slurry, obtained by digesting with water, 100g of cow dung paste with 50g of paste from ground fruit and vegetable waste (FVW) was fed into a digester to fill up to about 75% of the digester volume, the mouse of the digesters was closed. This procedure was repeated in all digesters until all the parameters were measured. The biogas was collected in a tube and emptied into a gas cylinder of known weight. The change in weight of the cylinder was recorded as the volume of the gas obtained.

For the determination of the effect of temperature on biogas production, each reactors were maintained with different temperatures (30, 40, 50, 60 and 70 °C) using water bath. Five digesters were charged with equal quantities of cow-dung and FVW. The mixtures were allowed to remain under anaerobic condition for 30 days (to aid the formation of methanogenic bacteria) before readings were taken at daily intervals for 7 days. For the determination of the effect of pH on biogas generation rate, the digesters were buffered with buffer solutions (1 M sodium bicarbonate solution) of pH 5, 6, 7 and 8, 9 respectively. In the determination of the effect of nutrients addition, the digesters were, in addition to cow dung, fruits/vegetable wastes and water, charged with calcium carbonate ($CaCO_3$) and ammonia (NH_3) in the ratio of 5g: l dm^3; 4g: l dm^3; 3g: 1 dm^3; 2g: l dm^3 and lg: I dm^3 respectively in five digesters.

Results and Discussion

Table 1 shows the volume of biogas obtained at different temperatures for 7 days. The temperature ranged from 30, 40 50, 60 and 70^{o}C. The result showed that room temperature (30^{o}C) favoured the conversion of cow manure to methane. Perhaps the methanogenic bacteria are mesophillic in nature and become inhibited at high temperatures. This could be the reason why very small volume of gas is obtained from the digester controlled at 70^{o}C. Peak biogas generation was observed at room temperature on the 5th day.

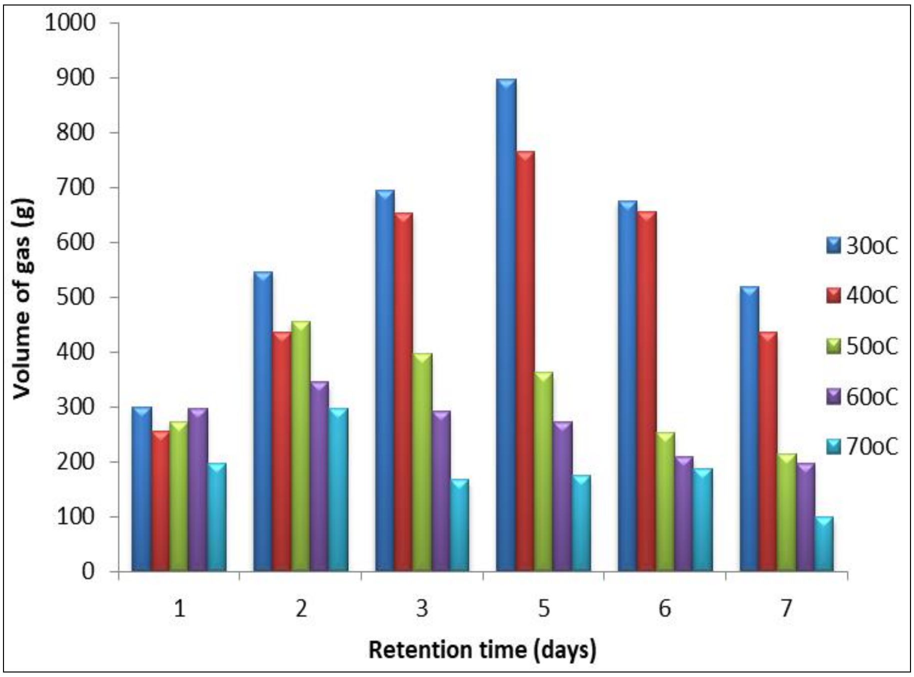

Fig 1: Effect of temperature on biogas production

This correlates with the findings of Anika, Akin-Osaniye, Asikong and Edet (2019) [1] who also reported high biogas volumes obtained at mesophillic temperatures between 28°C to 30°C. they concluded that the digestion temperatures within this range are favourable to the mesophilic bacteria populations.

Figure 2 shows the daily biogas production over 7 days retention period for the substrate with different pH respectively. Results reveal that the biogas gas production was higher during the first 3 days of gas collection, and decreased gradually till the seventh day. However, the volumes of gas collected were higher in digesters with pH 8 and 9. A maximum gas yield of 1290 g was obtained for pH 8 on the 6th day, followed by 1119 g for pH 9. Compared to pH 8 and 9, pH 5, 6 and 7 produced lower biogas production and degradation efficiency. The results show that pH of the substrate has a significant effect on biogas production because it affects the activity of bacteria to destroy organic matter into biogas. A low pH in the digester inhibits the activity of microorganisms involved in the digestion process particularly methanogenic bacteria.

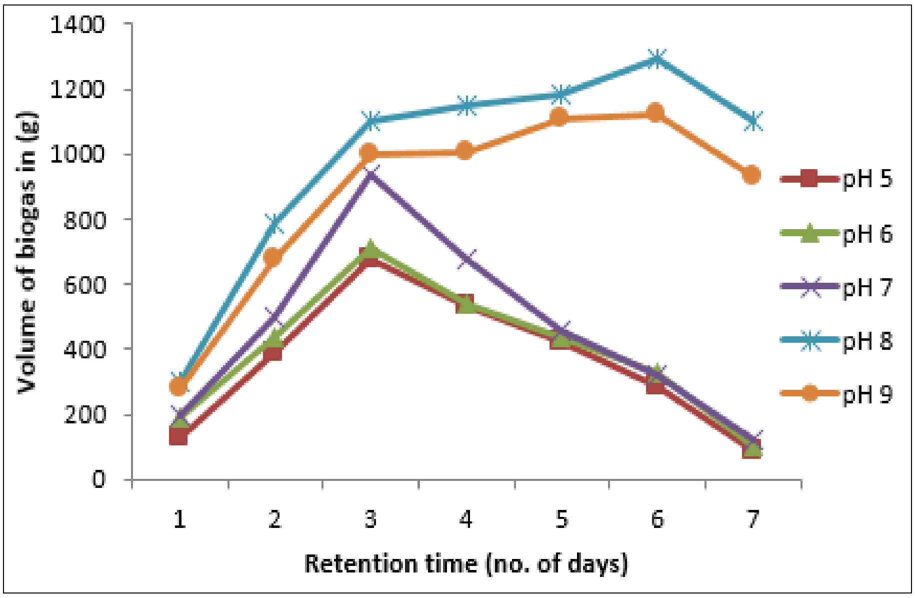

Fig 2: Effect of pH on biogas production

This result competes slightly with the findings of Jayaraj, Deepanraj and Sivasubramanian (2013) [7] who reported a high biogas yield of 500 ml with pH 7 and a retention time of 6 days. pH is an influential factor that affects anaerobic digestion process of biogas generation (Ciobla *et al*, 2012) [2]. It was observed that the volume of gas produced daily dropped with respect to pH. This could have been as a result of the production of volatile fatty acids such as propionic and butyric acid by acid forming bacteria while acting on the substrates in the digesters. pH value of 8 appears to be the most favourable pH for the production of biogas from cow dung co-digested with fruit/vegetable wastes as observed in this study.

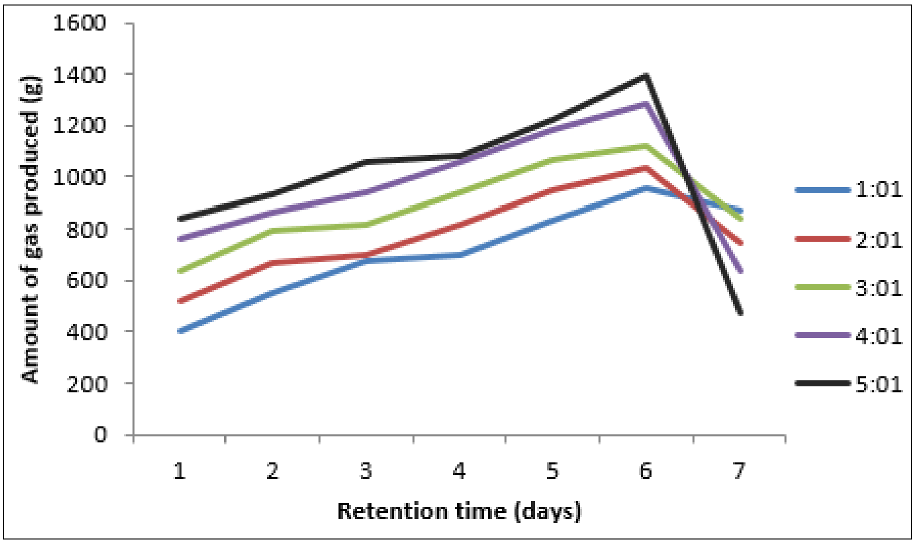

Fig 3: Effect of nutrient addition on biogas production ($CaCO_3$ and NH_3 in the ratio of 5g: l dm^3; 4g: l dm^3; 3g: 1 dm^3; 2g: l dm^3 and lg: I dm^3)

In the determination of the effect of nutrients addition, the digesters were, in addition to cow dung, fruits/vegetable wastes and water, charged with calcium carbonate ($CaCO_3$) and ammonia (NH_3) in the ratio of 5g: l dm^3; 4g: l dm^3; 3g: 1 dm^3; 2g: l dm^3 and lg: I dm^3 respectively in five digesters. Results show that upon nutrient addition, increased volume of biogas was recorded daily. The addition of calcium carbonate and ammonia tend to improve biogas production rates. The highest biogas yield was obtained on the 6th day with the nutrient ratio of 5:1. This results agrees with the findings of Sambo, Garba and Danshehu (1995) [10] who also reported high yields of biogas from cow manure when additional nutrient was added to the slurry.

Conclusion

The power of organic wastes and their inert capabilities to generate biogas is of great economic value if fully harnessed and is of practical relevance especially in waste management. The results of this study has gone a long way in ascertaining the energy production capabilities of fruit wastes as well as reveal some conditions for high yields. Therefore the excellent biodegradability potential displayed by cow dung and fruits/ vegetable wastes is of great importance in waste management and the energy transition vision of Nigeria.

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