Aplinkos tyrimai, inžinerija ir vadyba, 2013. Nr. 4 (66), P.34-37 *ISSN 1392-1649 (print)*
Environmental Research, Engineering and Management, 2013. No. 4(66), P.34-37 *ISSN 2029-2139 (online)*
http://erem.ktu.lt

Biomethanation of Carpet Grass (*Axonopus fissifolius*)

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crossref http://dx.doi.org/10.5755/j01.erem.66.4.5228

(Received in September, 2013; accepted in December, 2013)

Axonopus fissifolius commonly called "carpet grass" was subjected to anaerobic digestion for 30 days. Anaerobic digestion was carried out in a batch-fed process at the ambient temperature of 27-29^{0}C. Biomethane measurements were obtained by measuring the volume displacement of a saturated filtered calcium hydroxide solution in a transparent calibrated vessel. 42.7g of fresh carpet grass clippings yielded 1.955 L of biomethane. Biomethane potential (BMP) of carpet grass for a 30 day anaerobic digestion was 0.05 m^3 CH_4 kg^{-1} TS. The rates of biomethane potentials for the first, second, third, fourth and fifth six-day intervals were 1.5mL g^{-1} TS (2.81%), 6.4mL g^{-1} TS (14.58%), 16.1mL g^{-1} TS (30.18%), 17.74mL g^{-1} TS (33.25%), and 10.23mL g^{-1} TS (19.81%) respectively. The total solids, volatile solids and pH of feedstock and digestate were 85.80% and 85.56%, 90.91% and 87.58%, 6.6 (27^{o}C) and 6.9 (27^{o}C) respectively. The relatively high biomethane potential of carpet grass at the ambient temperature presented in this paper depicts anaerobic digestion as a viable means of profitably treating grass waste for both sanitation and generating biomethane especially in the tropics where the ambient temperatures are usually favourable for optimum biomethanation for most part of the year, thus making the process affordable and less cumbersome.

Keywords: *Renewable energy, anaerobic digestion, grass waste, biogas*

1. Introduction

Biomass waste is the most common feedstock of biomethanation, with biomethanation itself being the most suitable and mature technology to convert biowaste to bioenergy (Yu *et al*. 2010). Biogas produced from biowaste is comparatively competitive, in terms of efficiency and cost, with other bioenergy forms (Edelmann *et al*. 2000; Chynoweth *et al*. 2001). This is basically due to the fact that biomass is the nature's preferred method of solar energy storage; thus providing a wide range of substrates for biomethanation- wood, food waste, energy crops and grass (Abu-Dahrieh *et al*. 2011).

Grasslands play an important role in global agriculture, covering about 69% (3.4 billion hectares) of the world's agricultural area or 26% of the total land area (FAOSTAT 2008). In the last two decades considerations on grassland use for bioenergy have considerably increased in Europe and North America (McLaughlin *et al*. 2002; Murphy and Power 2008). Grassland biomass is suitable for bioenergy production, and this has been corroborated by many researchers (Walsh *et al*. 2003; Thran 2005; Prochnow *et al*. 2008).

Considering limited availability of farmland and rising demand for agricultural products, biomass production for energy purposes on arable land will unfavourably compete with food production (Pick *et al*. 2012). Consequently, this study highlights the biomass potentials associated with "green waste" from residual grasslands currently not used for agricultural purposes: roadside edges, conservation grasslands, riparian stretches along ditches and streams and municipal green belts (public lawns, parks and sports fields). In Nigeria, these "green resources" are often times left overgrown and unkempt, and even when mowed the "green waste" is usually left *in situ* to rot. The grass studied in this work is carpet grass (*Axonopus fissifolius*). Harnessing herbaceous biomass as substrate for anaerobic digestion for biogas and biofertiliser production presents a profitable duo resource management/resource recovery platform – solid waste

management, biogas and biofertiliser recovery, not mentioning job creation and other allied benefits.

2. Methods

Sample collection and processing: Fresh grass clippings were collected immediately after mowing from a residential lawn in Owerri city (Nigeria).

Preparation of feedstock: About 42.7g of fresh carpet grass cuttings were seeped in 530mL untreated tap water. This was then inoculated with 10mL digestate from beef cattle gastro-intestinal content anaerobic digestion.

Experimental set-up: The feedstock preparation was placed in a batch reactor operated at the ambient temperature of 27-29^{o}C for a retention period of 30 days. The candle jar method described by Jensen and Trager (1977) was used to achieve anaerobiosis. The batch reactor was stirred manually by gently shaking or swirling it three to five times daily. Experiments were carried out in triplicates.

Collection of gas samples: Using the modified method of Nda-Umar and Uzowuru (2011), biogas and biomethane samples were collected and measured daily. Biogas generation was measured by rapidly measuring the volume displacement of a clear solution of filtered saturated calcium hydroxide solution (2g/L) in a transparent calibrated vessel, when the gas sample was rapidly bubbled through it. The residual displacement after the gas had stood for 24 hours in the calcium hydroxide solution chamber was taken as the biomethane content.

Physicochemical analysis: The temperature was measured using a mercury thermometer (range, 0 – 110^{o}C) and pH determined with a Hanna Instrument pH meter (Model: H196107). Total solids (TS) and volatile solids (VS) were determined using standard procedures given by Pillai (2009).

Data analysis: Data generated were the averages of the triplicate readings from the experiments. Graphs were generated using the Microsoft Excel 2003 software.

3. Results and Discussion

Figure 1 shows daily readings of biogas yields and their biomethane contents. Though there were indications of biogas production from day 3, biogas reading was started from day 6. Daily biogas yield steadily increased from the ninth day to the sixteenth day of anaerobic digestion (AD) when it reached its maximum. The cumulative biogas and biomethane yields were 74.05mL g^{-1} TS and 59.83mL g^{-1} TS respectively, while the average biomethane content of biogas was 80.79%. The average daily yield of biogas and biomethane for 30 day AD was estimated to be 2.2mL g^{-1} day^{-1} TS and 1.78mL g^{-1} day^{-1} TS respectively. The rates of biomethane potentials for the first, second, third, fourth and fifth six-day intervals were 1.5mL g^{-1} TS (2.81%), 6.4mL g^{-1} TS (14.58%), 16.1mL g^{-1} TS (30.18%), 17.74mL g^{-1} TS (33.25%), and 10.23mL g^{-1} TS (19.81%) respectively. Using the schemes of the Biogas Project, LGED (http://api.ning.com), a 120 day AD of *Axonopus fissifolius* would give a cumulative yield of approximately 370.25mL g^{-1} TS and 299.15mL g^{-1} TS of biogas and biomethane respectively. This is similar to the figures given by Al Seadi *et al*. (2008) and Deublein and Steinhauser (2008). Disparity in actual yield is however bound to occur due to the type or species of crop/plant/grass used as substrate (De-Renzo 1997; Kumar 2012).

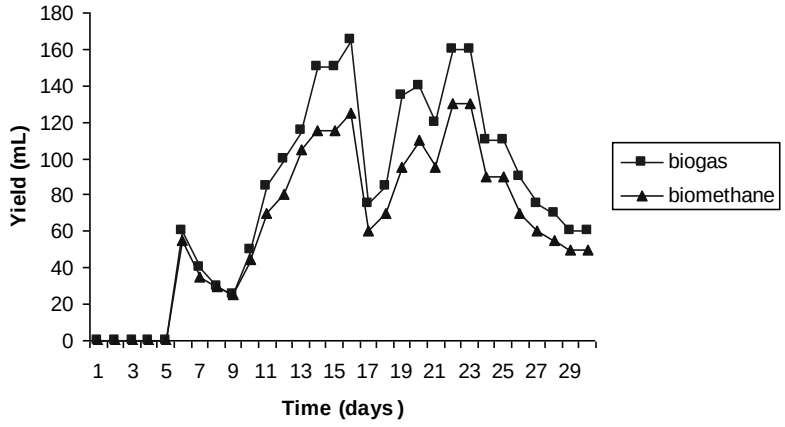

Fig. 1. Biogas/biomethane yielding rates of carpet grass (Axonopus fissifolius)

Documented evidence shows that biogas yield from grass is higher than that obtained from dairy cattle manure (Sidibe and Hashimoto 1990). While, according to Uzodinma and Ofoefule (2009), a mixture of grass and animal manure gives even higher biogas yields. Comparing the estimated biomethane potential (BMP) of carpet grass for a 120 day AD obtained here (0.35 m^3 CH_4 kg^{-1} TS) with BMPs from other plant substrates obtained by other workers as listed by Lehtomaki (2006); vetch-oat mixture (0.37 m^3 CH_4 kg^{-1} TS), carpet grass shows: a comparable BMP with Timothy-clover grass (0.34 m^3 CH_4 kg^{-1} TS), Red canary grass (0.33 m^3 CH_4 kg^{-1} TS); higher BMP than straw of oats (0.29 m^3 CH_4 kg^{-1} TS), lupine

(0.29 m^3 CH_4 kg^{-1} TS), and willow (0.28 m^3 CH_4 kg^{-1} TS), straw of rapeseed (0.22 m^3 CH_4 kg^{-1} TS); and lower BMP than sugar beet (0.4 m^3 CH_4 kg^{-1} TS). The proximity of the biogas and biomethane graphs in Figure 1 indicates high quality biogas (an average methane content of about 80.79%). The total solids, volatile solids and pH of feedstock and digestate measured were 85.80% and 85.56%, 90.91% and 87.58%, 6.6 (27^0C) and 6.9 (27^0C) respectively. There was a low total solids and volatile solids removal which according to Francois *et al*. (2006) implies a relatively slow rate of biodegradation. The high ligno-cellulose content of "green biomass" and relatively limited anaerobic microbes available to digest lingo-cellulose during AD (McDonald *et al*. 1991) may have been responsible for the low total solids and volatile solids removal after anaerobic digestion; ligno-cellulose is recalcitrant to microbial attack during anaerobic digestion (Fan *et al*. 1981).

4. Conclusions

From the results obtained in this work, 42.7g of fresh carpet grass clippings yielded 1.955 L of biomethane in a 30 day batch anaerobic digestion. Thus using the schemes of the "Biogas Project of LGED," 1 ton of fresh carpet grass clippings will yield about 121.6 m^3 biomethane in a 120 days batch AD. If a single acre of carpet grass yields approximately 3 tons of clippings per annum, and 1 hectare is about 2.47 acres, it implies that one hectare of carpet grass lawn (about the size of a soccer pitch) will produce 7.41 tons grass clippings per annum. This means carpet grass will give an estimated biomethane potential of about 901.056 m^3 CH_4 ha^{-1} yr^{-1}. These figures highlight the massive potential of carpet grass as a sustainable renewable energy resource. Anaerobic digestion is hence shown to be a profitable means of managing grass waste in particular and green waste by extension. The benefits of anaerobic digestion of carpet grass are seen to go beyond sanitation, but also in the generation of valuable resources, namely biogas and biofertiliser (digestate). An economically viable treatment method that will facilitate the digestion of the ligno-cellulose content of carpet grass thereby making available more volatile solids for biomethanation would further improve both biogas yield and total solids reduction; thus improving the economic viability of the entire AD process.

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Paprastosios klosnės (*Axonopus fissifolius*) metanizavimas

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(gauta 2013 m. spalio mėn.; atiduota spaudai 2013 m. gruodžio mėn.)

Axonopus fissifolius, įprastai vadinamai paprastąja klosne arba „kilimine žole“, buvo taikomas 30 parų anaerobinis apdorojimas. Anaerobinio pūdymo procesas buvo vykdomas serijinio padavimo sąlygomis, aplinkos temperatūrai esant 27–29 ^{0}C. Biometano matavimai buvo atliekami filtruoto sočiojo kalcio hidroksido tirpalo, laikomo skaidrioje kalibruotoje kolboje, apimties poslinkiui nustatyti. Iš 42,7 g šviežios susmulkintos paprastosios klosnės buvo gauta 1,955 l biometano. Per 30 dienų anaerobinio apdorojimo metu išgautas paprastosios klosnės biometano potencialas (BMP) buvo 0,05 m^3 CH_4 kg^{-1} KD. Biometano potencialo normos pirmą, antrą, trečią, ketvirtą, penktą ir šeštą dienomis buvo atitinkamai 1,5 ml g^{-1} KD (2,81 proc.), 6,4 ml g^{-1} KD (14,58 proc.), 16,1 ml g^{-1} KD (30,18 proc.), 17,74 ml g^{-1} KD (33,25 proc.) ir 10,23ml g^{-1} KD (19,81 proc.). Pramoninių žaliavų ir pūdymo liekanų kietosios bei lakiosios dalelės ir pH buvo atitinkamai 85,80 proc. ir 85,56 proc., 90,91 proc. ir 87,58 proc, 6,6 (27 ^{o}C) ir 6,9 (27 ^{o}C). Gautas santykinai aukštas paprastosios klosnės biometano potencialas pasirinktoje aplinkos temperatūroje parodė, jog anaerobinis žolės atliekų pūdymas gali būti perspektyvi priemonė tvarkant šios rūšies atliekas – išlaikomos puikios sanitarinės sąlygos, taip pat yra išgaunamas biometanas. Toks biodujų išgavimas galėtų būti ypač pelningas tropikuose, kur aplinkos temperatūra įprastai visus metus yra tokia, kokios reikia optimaliai biometanacijai, dėl ko procesas dar lengviau prieinamas ir mažiau sudėtingas.