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Short Communication

Experimental Investigation of Biogas Production from Cow Dung in an Anaerobic Batch Digester at Mesophilic Conditions

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P A P E R I N F O

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A B S T R A C T

This paper presents the experimental investigation of biogas production from cow dung as an alternative for fossil fuels for energy consumption. This was carried out using an 18 Liters capacity plastic keg prototype biogas plant, constructed to investigate the anaerobic digestion for generation of biogas. Batch experiment was operated and daily gas yield from the plant was monitored for duration of 30 days. The digester was charged with these wastes in the ratio of 1:1, of waste to water, respectively. The mesophilic temperature ranges attained within the testing period were 20 – 35 °C. The Biogas production from cow dung fluctuates from the first day to the thirtieth day between 0 and 340 ml. The pH of cow dung gradually reduced due to acid former and methanogenes within the 30 days retention period.

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INTRODUCTION

Biogas refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source and in many cases exerts a very small carbon footprint [1]. Biogas may be produced by anaerobic digestion with anaerobic organisms, which digest material inside a closed system (air-tight tanks with different configurations) [2]. Biogas is produced as landfill gas (LFG), which is produced by the breakdown of biodegradable waste inside a landfill due to biochemical reactions occurred inside microorganisms.

Biogas is primarily methane (CH_4) and carbon dioxide (CO_2). It may have small amounts of hydrogen sulfide (H_2S), moisture and siloxanes. The gases: methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel. It can also be used in a gas engine to convert the energy in the gas into electricity and heat [3] and even for internal combustion engines. Biogas can be compressed, the same way natural gas is compressed. When it becomes bio-methane, biogas can be cleaned and upgraded to natural gas standards. Biogas is considered to be a renewable resource because its production-and-use cycle is continuous. Also, it generates no net carbon dioxide. A biogas plant can be fed with energy crops such as maize silage or biodegradable wastes including sewage sludge and food waste.

The dangers of biogas are mostly similar to those of natural gas, but with an additional risk from the toxicity of its hydrogen sulfide fraction. Biogas can be explosive when mixed in the ratio of one part biogas to 8-20 parts air. Thus, special safety precautions have to be taken for entering an empty biogas digester for maintenance work. It is important that a biogas system never has negative pressure as this could cause an explosion. Negative gas pressure can occur if too much gas is removed or leaked. Frequent smell checks must be performed on a biogas system. If biogas is smelled anywhere windows and doors should be opened immediately. If there is a fire the gas should be shut off at the gate valve of the biogas system [4].

BIOGAS FROM COWS DUNG

Manure can be an alternative energy source for livestock farmers. An anaerobic digester partially converts manure to energy in the form of biogas that contains methane (see Figure 1). In the digester, bacteria decompose organic materials in the absence of air with the release of methane and carbon dioxide. Figure 2 shows the patway of breaking downthe organic mater in a digester. Acid-forming bacteria liquefy the volatile solids to simple fatty acids. The methane-forming bacteria then convert these volatile acids to

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methane and carbon dioxide. Rapid digestion and efficient biogas production usually occur within limited ranges of temperature. Also, the procedure is influenced by the composition of the raw material.

Optimum gas production occurs in two temperature ranges. Mesophilic bacteria flourish in temperatures around 35°C, and thermophilic bacteria in the range of 49°C-60°C. , Figure 3 illustrates the temeperature ranges of mesophils and thermophils. The biogas production decreases when the bacteria are subjected to temperatures outside of these ranges. Thermophilic bacteria produce somewhat more biogas. However, the biogas is not worth the energy needed to raise the digester temperature from 35°C to 49°C [5].

The composition of manure varies according to feed rations and different farm management practices. This depends on the type and weight of animals, the feed ration, and the degree of confinement. A digester can process other farm wastes, such as milk-room waste water, straw, corn husks, grass, and leaves, with or instead of dairy animal manure. Regardless of the material used, biogas production proceeds most efficiently when the raw materials fed to the digester have a certain *pH* and carbon-to-nitrogen ratio (*C/N*). Bacteria flourish in slurry with a *pH* around 7.0. Carbon is the major chemical element in manure, and the bacteria digest the carbon with the release of biogas. However, in order to derive their energy from carbon, the bacteria required nitrogen to be available in the raw material. The ratio of carbon to nitrogen in the raw material is crucial to efficient digestion. It is possible to adjust the *C/N* ratio of a digester by adding material to complement the material already in the digester [6]. All materials in contact with the manure or biogas should be corrosion resistant. All pipes and gas-lines should be made large enough to provide access for cleaning devices.

The main components of a farm-size digester system are:

(i) A slurry handling system, including slurry preparation area, dung pump or other loading method, and effluent tank.

(ii) One or more digester chambers.

(iii) Housing for the heating, agitation, and hydraulic equipment.

All safety measures should be carefully considered. Biogas is combustible and has the potential to suffocate. When the biogas is mixed with air in a concentration of 6% to 15%, the gas becomes explosive.

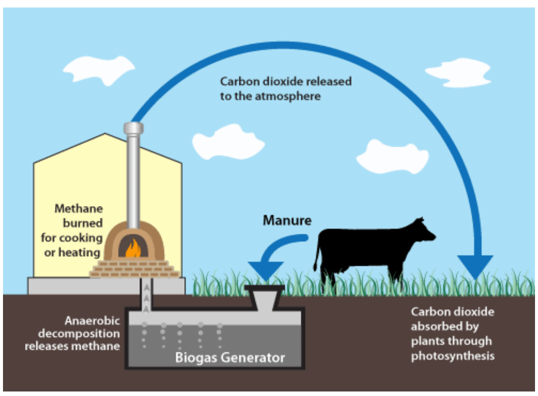

Figure 1. Biogas from livestock manure in an anaerobic digester

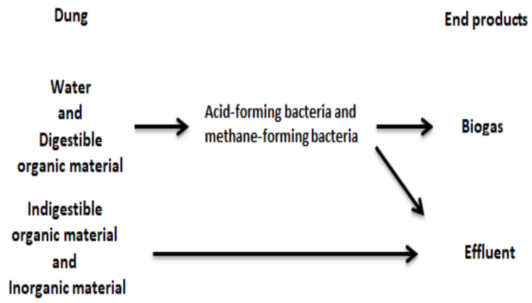

Figure 2. Breakdown procedure of manure in an anaerobic digester

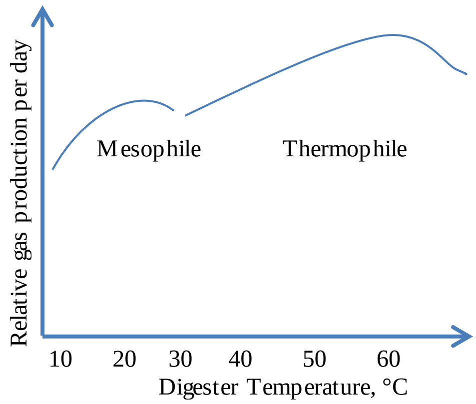

Figure 3. Temperature effect on biogas production rate

LITERATURE SURVEY

Many researches considered the biogas production from animal manure. Cu´ellar and Webber [7] estimated that livestock agriculture produces over one billion tons of manure annually on a renewable basis in the United States. They calculated the biogas energy potential using values for the amount of biogas energy that can be produced per animal unit (defined as 1000 pounds) per day and the number of animal units in the States. They assessed that the 95 million animal units in the country could produce nearly 1 quad of renewable energy per year, amounting to approximately 1% of the U.S. total energy consumption. Moreover, they mentioned that converting the biogas into electricity using standard microturbines could produce 88±20 billion *kWh*, or 2.4±0.6% of annual electricity consumption in the USA. Also, they highlighted that replacing coal and manure *GHG* (greenhouse gas) emissions with the emissions from biogas would produce a net potential *GHG* emissions reduction of 99±59 million metric tons or 3.9±2.3% of the annual *GHG* emissions from electricity generation in the States.

Ahn et al. [8] evaluated the performance of anaerobic digestion of animal manure–switchgrass mixture under dry (15% total solid (*TS*)) and thermophilic conditions (55*°C*). They digested three different mixtures of animal manure (swine, poultry, and dairy) and switchgrass using batch-operated 1-*L* reactors. The swine manure test units showed 52.9%. They mentioned that over the 62 days digestion, the swine manure test units yielded the highest amount of methane 0.337 $L\ CH_4/g\ VS$ (volatile solids), while the dairy and poultry manure test units showed very poor methane yield 0.028 $L\ CH_4/g\ VS$ and 0.002 $L\ CH_4/g\ VS$, respectively.

They confirmed that although dairy and poultry manure performed poorly, they may still have high potential as biomass for dry anaerobic digestion if appropriate designs are developed to prevent significant volatile fatty acid (*VFA*) accumulation and *pH* drop.

Guo [9], in his research aimed to assess environmental benefits from manure treatment perspective, energy perspective and agricultural perspective of entire biogas system and to analyze whether biogas system implemented is a good choice to achieve the sustainability in China. He collected the basic data through investigation of household biogas project in western China and livestock farm-based biogas project in east. He stated that both energy substitution and agricultural land acceptable capacity are to be considered as constraint conditions of largescale biogas system development.

Abubakar and Ismail [10] investigated the effectiveness of cow dung for biogas production and presented the performance characteristics of the anaerobic digestion in batch and semi continuous operations. They mentioned that the cow dung digestion reaches 47% *VS* reduction and approximately 48.5% chemical oxygen demand (*COD*) removal with biogas yield of 0.15 *L biogas/kg VS added*. Moreover, they confirmed that, despite large variations in pollutants concentrations, they achieved an improved performance of anaerobic digestion of the biodegradable fraction of cow dung.

Nasir et al. [11] focused on the potential of anaerobic digestion (*AD*) for biogas production from livestock manure wastes and compares the operating and performance data for various anaerobic process configurations. They indicated that variety of different operational conditions, various reactor configurations such as batch reactors, continuously stirred tank reactor (*CSTR*), plug flow reactor (*PFR*), up-flow anaerobic sludge blanket (*UASB*), anaerobic sequencing batch reactor (*ASBR*), temperature phased anaerobic digestion (*TPAD*), and continuous one- and two-stage systems, present a suitable technology for the *AD* of livestock manure waste. Also, they mentioned that the main performance indicators are biogas and methane yield, degradation of *VS*, higher loading, and process stability with a short retention time.

As stated in the final report of his project [12], Moller aimed to provide a precise determination of biogas potentials and the methane production of manure from a wide range of animal categories and how it is influenced by pre-treatment. In his work, the manure samples were digested in triplicate in batch assays for 90 days with monitoring of methane loss at different temperatures. His tests illustrated that the type of feedstuff used for animals is an important factor. Also, it was indicated that increasing the digestion time increases the biogas production especially for cow manure.

Soufi and Saleh [13] studied the resources of biomass and energy that can be extracted from livestock manure and agricultural waste in Iran. They stated that the use of biogas technology leads to reduce methane emissions, since the arrival of livestock manure into biogas units prevents the spontaneous fermentation of livestock manure and the entry of the resulting methane into the atmosphere and consequently the warming of the planet. Also, they demonstrated that, applying the usual amounts of biogas efficiency from livestock manure, agricultural waste, municipal waste and urban wastewater and food industries, the resulting biogas will have plenty of energy.

Recebli et al. [14] studied experimentally a model biogas production unit which had 0.5 m^3 fermentation tank capacities of a breeding farm in the Urla district of Izmir/Turkey with 70 cattle and 1400 chicken. Animal wastes (poultry manure and bovine animals manure) were anaerobically fermented in the tank.

They carried out two processes; firstly, 350 *kg* bovine animal manure blend (175 *kg* manure + 175 *kg* water) filled to the tank and the process occurred, secondly, 375 *kg* poultry manure blend (50 *kg* manure + 325 *kg* water) was filled to the tank and the processes done. Their results showed that daily 6.33 m^3 and 0.83 m^3 biogas productions were obtained from fermentation of bovine animal manure and poultry animal manure. They confirmed that by using biogas as a fuel to the heating or energy systems instead of natural gas about $0.35 $/m^3$ energy cost is saved.

Based on the above literature review, it is clear that, due to the importance of the present subject, investigation of biogas production from cow dung is needed for the students' level. It is also worth saying that the cow dung is generally available in the Arab counties. Thus, it should be used as a raw material for biogas production.

EXPERIMENTAL SET-UP AND PROCEDURE

Experimental set-up was made to investigate the production of biogas from the anaerobic digestion of cow dung. The digester made of plastic cylindrical tank of 18 liters capacity was used for set-up. The photograph of experimental the set-up is shown in Figure 4. The digester was connected with displacement tank and water collector. Plastic pipes were used to connect the digesters and the displacement tanks. The gas produced in the digester passed through the pipe to the displacement tank. Another plastic pipe was used to take the displaced water from the displacement tank to the water collector which fitted air tight in the displacement tank and inserted up to bottom part of it. Digestion was done at ambient temperature. During the investigation the volume of the produced gas was measured with the help of water displacement method, considering the volume of the produced biogas was equivalent to the displaced water in the water collector. The digesters were operated in batch style and fed manually. At the time of experiments, these were ensured that the digesters were completely gas tautened.

Figure 4. Photograph of the experimental setup

RESULTS

In this research work, substrates with percentage total solid (TS) is 18.7 %. five kilograms of cow dung was used in the experiment was conducted within mesophilic temperature range of 20°C - 35°C and hydraulic retention time of thirty (30) days.

Figure 5 show the volume biogas produced from cow dung within the retention period 30 days. For biogas produced in cow dung, biogas was not produced for the first 8 days because it takes more time for cow dung to decompose after which gas is being produced. This is predicted because non growth of methanogenic bacteria. This can also be traced to the fact that most cows feed on fibrous materials and microorganisms required a longer etention time to degrade fibrous materials. Production of gas from cow dung started on day 9 of the retention period by producing average biogas of 30 ml, thereafter increases to 100 ml on day 10 and reduces to 50 ml on day 12. At day 13, the biogas produced was 160 ml in which decreases back to 45 ml on the next day and increases thereafter until it reached the peak on day 22 with 340 ml biogas production after which it begins to reduce till the completion of the retention period.

Figure 6 illustrates the pH of cow dung within the 30 days retention period. The pH for cow dung fluctuates from the first day to the tenth day between 5 and 7.4, after which is begins to decrease gradually for the remaining days of the retention period. As it was observed in the first few days, the pH of cow dung decreases due to high volatile fatty acid (VFA).

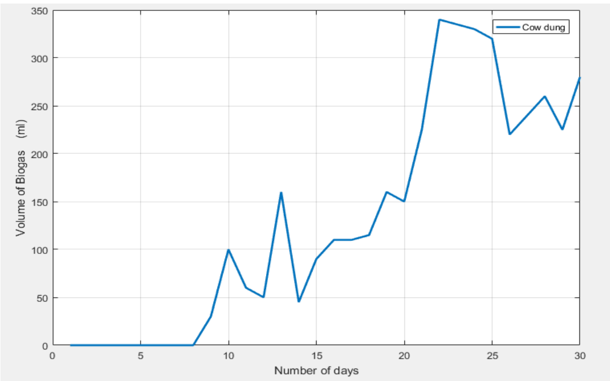

Figure 5. Volume of biogas against number of days

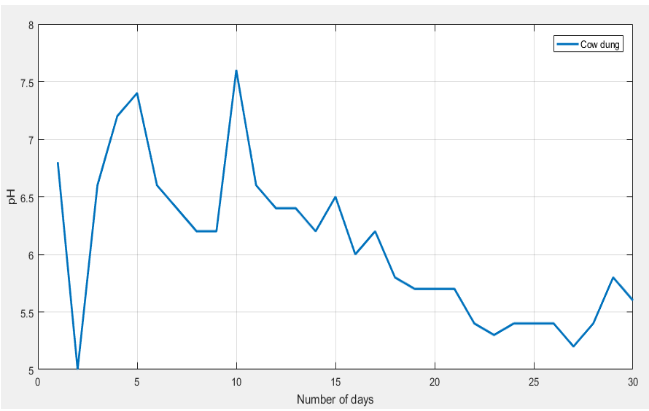

Figure 6. pH of Slurry against number of days

The gradually reduction explains the gradually change of stage of the production of biogas, from hydrolysis to acidogenesis in which the slurry become acidic and form substrate after which it produces biogas.

CONCLUSIONS

The study shown that biogas can be produced from these wastes through anaerobic digestion for biogas generation. These wastes are always available in our environment and can be used as a source of fuel if managed properly. The study revealed further that cow dung as animal waste has great potentials for generation of biogas. The utilization should be encouraged due to high volume of biogas yields.

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Persian Abstract

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چکیده

در این مقاله تولید بیوگاز از فضولات حیوانی بعنوان چایگزین سوخت فسیلی جهت مصرف انرژی مورد بررسی قرار گرفت. از مخزن ۱۸ لیتری پلاستیکی برای دایجستور بی هوازی استفاده گردید. تولید بیوگاز بطول ۳۰ روز مورد مطالعه قرار گرفت. فضولات جمع آورزی شده با نسبت یک به یک با آب رقیق شدو در دامنه حرارتی ارگانیزمهای مزوفیک ۲۰ الی ۳۵ درجه سانتیگراد مورد اجرا قرار گرفت. حجم بیوگاز در روزهای اول ناچیز بود سپس به مقدار ۳۴۰ میلی لیتر در رور رسید. درطی ۳۰ روز کارکرد pH مجیط به تدریج اسیدی شد که نشانه فعالیتهای باکتریهای اسیدوفیل و سپس متانوژنها بود.