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Effect of Solid Content and pH on Biogas Production From Organic Fraction Municipal Solid Waste

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Abstract: The increasing demand on energy and the constraints on environmental aspects motivate the research on municipal solid waste to be an environmentally friendly source of renewable energy. Therefor using the organic fraction of municipal solid household waste in an aerobic digester to produce biogas and a digestate which can be used safely as fertilizer. In this study three reactors of two liter volume are used to investigate the effect of total solid content (10%, 15%, 20%) and pH on the produced amount of biogas. The results revealed that lower percentage of solid content yields the highest amount of biogas and the pH below 6.0 will inhibit the biogas production. The percentage of methane from the 10% reactor was 50.2 % of the gas production.

تأثير نسبة المواد الصلبة والأس الهيدروجيني على إنتاج الغاز الحيوي من المخلفات البلدية الصلبة

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ملخص: الطلب المتزايد على الطاقة والحفاظ على البيئة يدفع لمزيد من البحث في مجال استخدام النفايات البلدية الصلبة كمصدر للطاقة المتجددة، إن استخدام الهضم اللاهوائي للمواد العضوية الموجودة في الفضلات البلدية الصلبة من المنازل يمكن ان يكون مصدراً للغاز الحيوي والبقايا الاخرى يمكن استخدامها كسماد.

في هذه الدراسة تم استخدام ثلاثة مفاعلات بسعة (2 لتر) لكل منها، لدراسة تأثير كمية المواد الصلبة (20% ،15% ،10%) والأس الهيدروجيني على كمية الغاز المنتجة، وأظهرت النتائج أن النسبة الاقل وهي 10% أعطت أحسن إنتاجية وأن انخفاض عامل الأس الهيدروجيني عن 6.0 يؤدي إلى تراجع إنتاج الغاز، وكانت نسبة غاز الميثان المنتج تشكل 50.2% من الغاز المنتج.

Keywords: *Anaerobic digestion (AD), biogas production, organic fraction municipal solid waste (OFMSW).*

1. INTRODUCTION

The continuous increase of municipal solid waste in large cities like Tripoli has become an environmental problem due to the current way of municipal solid waste (MSW) management which is mainly open burying or normal landfills which have become a source of pollution of air, soil and underground water. High fraction of MSW is of organic nature, therefore using the organic fraction of municipal solid waste (OFMSW) as a substrate in anaerobic digestion process to produce biogas is an environment friendly solution where the digestate can be used as fertilizer and source of renewable energy.

K. Stoknes, et al. Studied the treatment of organic waste to produce biogas and the digester residue is being used successfully as a standalone fertilizer and it has been shown that food-to-waste-to food recycling is technically possible [1].

A. H. Zgoni et al studied the effect of total solids concentration on biogas production in lab-scale batch digesters of five liter volume over a range of concentrations between 4 to 10%. Observation results showed that biogas produced increases with increasing total solids concentration up to 10%, and it was concluded that there was no further effect on biogas production after 10% TS, [2].

Wen-biao Han and others studied different ratios of kitchen waste and sludge from waste treatment plant and the results showed that co-digestion efficiency was higher than pure sludge or pure kitchen waste and the best ratio was 1:4 sludge to kitchen waste, [3].

Chengliu Gou, et.al investigated anaerobic co-digestion of sludge and food waste using continuously stirred tank reactors. The results showed the influence of organic loading rate (OLR) on gas production rate as well as the reactor temperature where the gas production rate was enhanced by increased loading rate of the food stock [4].

Lili Yang and others investigated the effect of pH on biogas generation. The results recalled that significant increase of methane yield could be achieved by pH adjustment from food waste and a pH of 8 gives the maximum methane yield of 171.0 ml/g of total solids, which was 7.57 times higher than the pH uncontrolled group [5].

Mukhtar M. Ashur and Iman M. Bengharbia studied the effect of temperature and pH on biogas production from organic fraction of MSW. Experiments were conducted at 35 ^{0}C, 45 ^{0}C, 55 ^{0}C, 65 ^{0}C and the pH was controlled to be close to 7.0. Results revealed that mesophilic condition (35 ^{0}C) yielded the highest biogas production, while the lowest production was at 65 ^{0}C pH below 6.0 inhibited gas production and the methane gas percentage of the produced gas was 45% [6].

In this study, the organic fraction of household waste is used as substrate for anaerobic digestion to investigate the effect of total solid contents and pH as a continuation of previous study on the effect of temperature and pH.

2. MATERIALS AND METHODS

2.1 Materials

The substrate used as feed stock materials for the generation of biogas in the laboratory was mainly kitchen waste made of fruit peel and vegetable waste and cooked food waste. The waste samples were collected from household waste.

The feed stock was shredded, after which non-degradable waste components were removed to reduce the size and to have a homogeneous mixture of the feed stock for three laboratory scale anaerobic batch digesters.

2.2 Inoculum preparation

The inoculum used in all experiments was prepared in the laboratory from cow dung and organic fraction of household waste with the proportion of 2:1 (which was 270 g cow dung, 135 g of household waste) and water added to make 1600 ml solution. It was under thermophilic condition 55 ^{0}C. 20% of inoculum was added to each experiment to start up the reactor.

2.3 Test method

In this study, three different percentages of the total solids of the pre-treated substrate 10%, 15%, and 20% were introduced to three reactors. Sodium hydroxide solution was added to increase the pH when it decreased below 6, pH was monitored to be kept above 6 and not to exceed 7.

3. EXPERIMENT SETUP

Batch digester type was used in this study alongwith three laboratory scale anaerobic glass reactors of two liter volume having three outlets from the top. The first outlet was used to introduce the thermocouple, the second outlet for pH meter, and the third outlet for gas collection. The reactors were placed in a water bath with a controlled electrical heater to keep the reactor temperature at 35 °C. The volume of produced gas was measured by the displaced volume of water, which is equivalent to the biogas produced in the reactor. The experimental setup is shown in Figure 1.

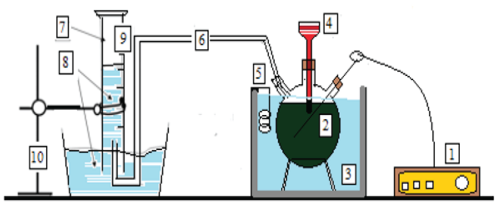

Figure (1). Schematic of experimental set up [6].
Key: 1- Thermocouple, 2- Digester, 3- Heating water bath, 4- pH digital meter, 5- Heat control, 6-Tube, 7- Biogas, 8- Water, 9- Measuring cylinder, 10- Clamp.

Samples of produced gas were collected in special bags to be analysed in (gas chromatography). The inoculum used in each digester was obtained from laboratory prepared, using fresh cow dung.

4. RESULTS AND DISCUSSION

4.1 Effect of OFMSW

The collected data from the three anaerobic batch reactors were presented as follows. The first digester (R1) contains 10% of OFMSW, biogas production starts after 24-hours from loading, gas production reaches a maximum after 48-hours where the amount of biogas produced was 2000 ml as shown in Figure 2. The total cumulative gas production reaches 7200 ml after 10-days.

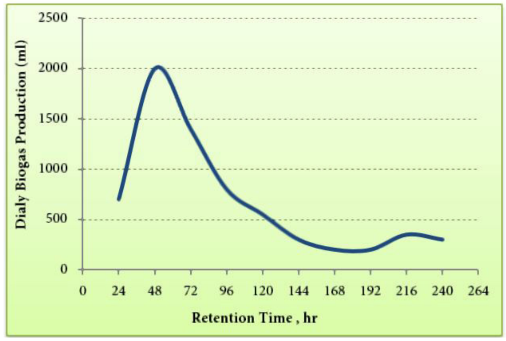

Figure (2). Daily Biogas Production in R1 (10% OFMSW).

Regarding the second reactor (R2) with 15% of OFMSW the cumulative biogas production was 7090 ml and the daily produced gas was as shown in Figure 3. It is noted that the amount of biogas product is nearly the same as 10% of OFMSW, also, the highest volume of biogas production was 3450 ml at the end of first day.

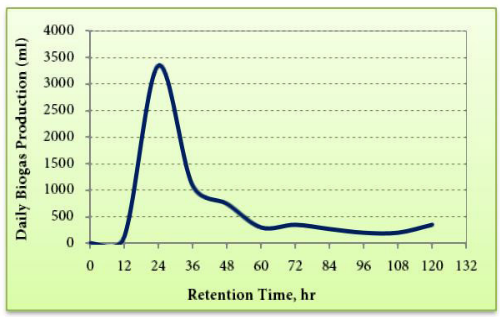

Figure (3). Daily Biogas Production in R2 (15% OFMSW).

In the third reactor (R3) with 20% OFMSW the production of biogas was the lowest one as it was only 5720 ml and the daily produced gas as show in Figure 4. In the second day the pH dropped to 4.9 which effects the production of biogas that dropped to 50 ml, and this is attributed to production of acids derived from protein, fat and carbohydrate components, coming from food waste in the feed stock. A higher solid content will demand more of the bacteria, which may cause the anaerobic consortium system to crash if it is not prepared. One danger of high solid content would be that the acidogenic bacteria, which act early in the digestion process and reproduce quickly given enough substrate, would multiply and produce acids rapidly. The methanogenic bacteria, which take longer to increase their populations, would not be able to consume the acids at the same rate. The pH of the system would then fall, killing more of the methanogenic bacteria and leading to digester failure.

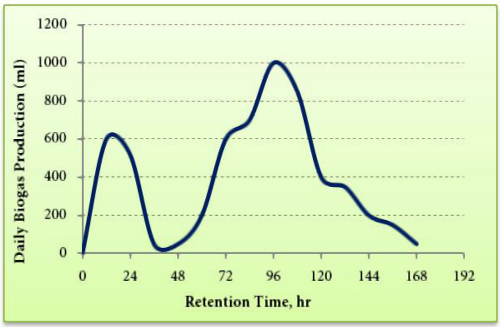

Figure (4). Daily Biogas Production in R3 (20% OFMSW).

4.2 Effect of pH

Figure 5 shows pH variation in the three reactors where at total solid content of 10% and 15% OFMSW the rang of pH was within (6-7). This range is suitable for better productivity of biogas, while at total solid content of 20% OFMSW it was noted that the pH drop to 4.9 which is very low for methanogenic bacteria the production of biogas dropped to 50 ml, stability of pH is an important factor during the test, where it should be kept around 7.0 for the best condition for methane production.

4.3 Comparisons between the three reactors

Cumulative biogas yield of each reactor is shown in Figure 6, where it is clear that lower solid content (10%) gives the highest yield followed by 15% and the lowest was 20% of OFMSW and this is attributed to the composition of OFMSW where food waste consists high fraction of proteins and fats.

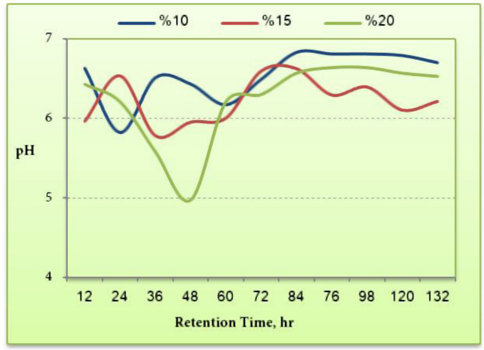

Figure (5). pH measurements R1, R2 and R3 (10, 15 and 20%).

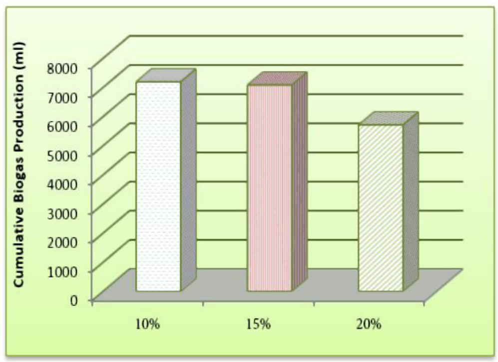

Figure (6). Cumulative Biogas Production from OFMSW (10, 15 and 20%).

5. BIOGAS ANALYSIS

Due to limited possibility of gas analysis, only two samples were collected for analysis 10% fraction of OFMSW and 20% fraction of OFMSW as shown in Table 1. Results reveal that 10% OFMSW gives the highest methane percentage of 50.2% of the total gas and at 20% OFMSW lower methane rate of 45.10% is attributed to the increase of ammonia.

6. CONCLUSIONS

In the current research, a laboratory scale batch reactor was used to investigate the effect of solid content and pH, passed on the obtained results the following conclusions were drawn.

- From the results obtained the quality and the quantity of biogas produced mostly depend on the optimum mix of substrate.
- Higher total solid content leads to a decrease in biogas yield. It is concluded that for wet anaerobic digestion the total solids should be less than 15%.
- Biogas containing 50% methane can be produced from OFMSW from household in 2 liter laboratory batch digesters, a maximum yield of biogas was about 7200 ml achieved at mesophilic 37 ^{0}C condition and total solid content of 10%.

Table (1). Biogas analysis from different OFMSW (mol %)

Component	10% OFMSW (Mol %)	20% OFMSW (Mol%)
CH_4	50.2	45.10
CO_2	41.2	44.8
N_2	7.3	10.09
H_2S	1.4	0.017

7. RECOMMENDATIONS

- Due to difficulty in analysing the biogas samples only two samples were analysed for better results. A gas analyser should be available in the lab.
- Further investigations should be carried out under different conditions.

8. REFERENCES

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