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Effect of Temperature and pH on Biogas Production From Organic Fraction-MSW

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تأثير درجة الحرارة والأس الهيدروجيني على إنتاج الغاز الحيوي من المخلفات البلدية الصلبة

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[1] الأكاديمية الليبية. طرابلس ـ ليبيا، [2]مركز بحوث ودراسات الطاقة الشمسية. طرابلس ـ ليبيا

الملخص: الطلب العالمي المتنامي على الطاقة أدى إلى الضغط لزيادة حصة مصادر الطاقة المتجددة، وطاقة الكتلة الحيوية هي أحد البدائل لمصادر الطاقة المتجددة حيث تشكل الفضلات البلدية الصلبة التي تقدر بملايين الأطنان سنويا أحد أهم المصادر، حيث تصل نسبة المواد العضوية فيها إلى 50 %، وهذه الكمية يمكن معالجتها واستخدامها لإنتاج غاز الميتان في الهاضمات اللاهوائية. وتهدف هذه الدراسة إلى التعرف على تأثير درجة الحرارة والأس الهيدروجيني على إنتاج غاز الميتان على نطاق معملي، ثم استخدام هاضم بسعة 2 لتر لإجراء التجارب عند درجات حرارة 35 °م، 45 °م، 55 °م، 65 °م، والتحكم في الأس الهيدروجيني ليكون قريباً من 7.0، وكانت النتائج مشجعة حيث كانت أعلى نسبة إنتاج للغاز الحيوي في درجة حرارة 35 °م واقل نسبة إنتاج عند 65 °م، بينما كان تأثير الأس الهيدروجيني سالبا عندما يقل عن 6.0 حيث يقل إنتاج الغاز الحيوي ويقارب من التوقف، وكانت نسبة غاز الميتان في الغاز الحيوي حوالي 45 % وهي نسبة مشجعة مقارنة بالنتائج المنشورة.

***Abstract*:** The growing global energy demand pushes towards higher share of renewable energy sources. Biomass energy is one of the alternative renewable sources, whereas municipal solid waste (MSW) is one of the important renewable resources estimated in millions of tons per year, about 50% of it is organic. This amount can be treated and used for methane production in anaerobic digesters. The objective of this study is to figure out the effect of temperature and pH on the methane production in laboratory scale batch reactor of 2L size. Experiments were conducted at 35°C, 45°C, 55°C, 65°C, and pH was controlled to be close to 7.0. It was found that mesophilic conditions at 35°C, yielded the highest biogas production, and the lowest production was at 65°C. pH below 6.0 inhibited production. The biogas share was about 45%, which is encouraging compared to other published results.

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

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1. INTRODUCTION

The ever growing energy demand and the more strict environmental regulations bush towards looking for new renewable sources. Application of anaerobic digestion of organic fraction of municipal solid waste to produce methane gas as renewable energy source instead of direct emission to the environment is an excellent way of managing MSW.

Millions of tons of municipal solid waste (MSW) are produced every year, for which disposal is a problem.

Global biogas capacity will reach 22,000 MW by 2025; biogas now represents 1.2% of the annual production of electricity and nearly 10% of renewable energy, with an installed power close to 1500 MW [1].

The technology used in biogas production is simple and can be applied in developing countries. Biogas can also be utilized simply [2].

The anaerobic digestion for the OFMSW can be considered as a pre-treatment process for landfill disposal or composting because it reduces the mass and volume and inactivates the biological and biochemical process, as well as avoiding landfill gas and odour emissions. On this basis AD of OFMSW can be considered as an environmentally friendly resource of renewable energy [3].

Most digestion systems require mechanical pre-treatment of waste to obtain homogeneous feedstock. The pre-processing involves separation of non-digestible materials and shredding to obtain a uniform small particle size feedstock for efficient digestion. The separation ensures removal of materials which may decrease the quality of the feed stock or recyclable materials such as glass, metals, stones etc. [3, 4].

Many parameters affect the digestion process, temperature is the most important parameter in anaerobic digest. Like all biological processes, anaerobic digestion is very sensitive to temperature. Three temperature zones can be distinguished for which bacterial populations are effective.

- The psychrophilic zone for temperatures lower than 20 °C.
- The mesophilic zone for temperatures between 25 and 35 °C.
- The thermophilic zone for temperatures above 45 °C.

Above 70 °C, the usual bacterial populations are inactive [1].

This work was carried out to investigate methane production from OFMSW from household at different temperature conditions

2. ANAEROBIC DIGESTION

Anaerobic Digestion (AD) of organic material is a well known natural process of biodegradation performed by specific microorganisms that transform a biodegradable substrate into biogas and solid residue defined as digestate [5].

The digestion of organic materials by the micro-organisms produces biogas. Biogas typically consists of 50 to 65 % (volume) CH_4, 35 to 50 % (volume) CO_2, 4 to 6 g/m^3 of H_2S and 30-160 g/m^3 of water [6].

The process is best understood if split into the three main stages: hydrolysis, acidogenesis and methanogenesis, as shown in Figure 1.

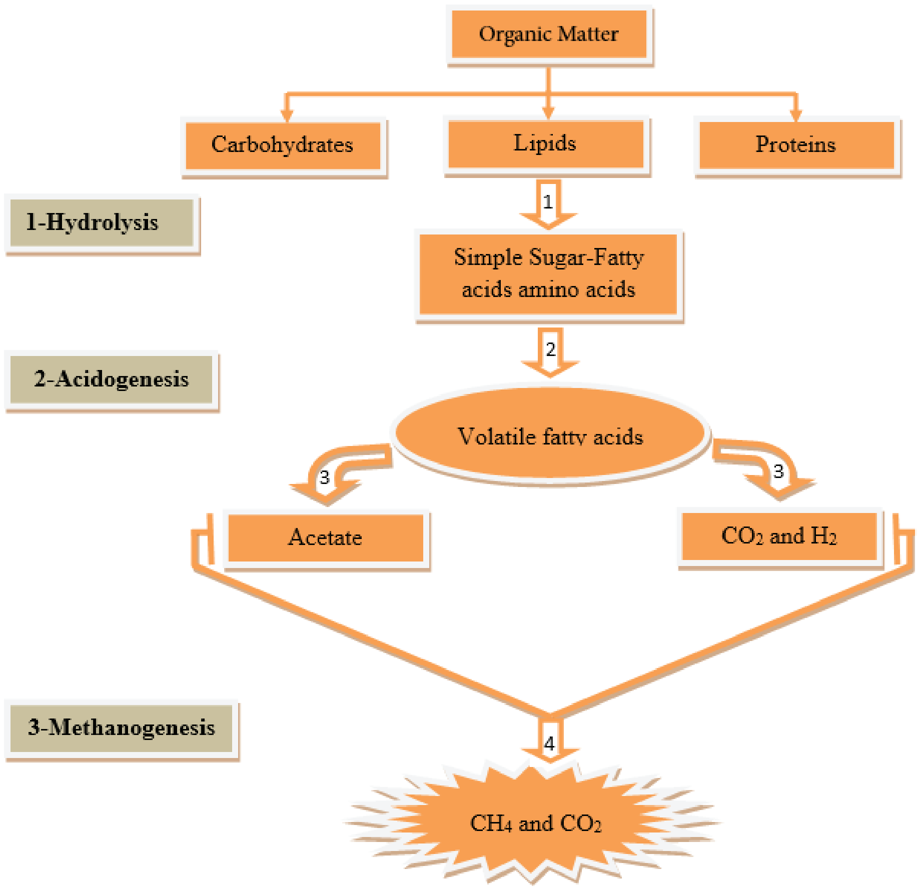

Figure (1). The stages of anaerobic digestion (AD) process

- **Stage I hydrolysis.** In this stage complex organic compounds (carbohydrates, proteins, and lipids) are converted to simple organics (sugar, amino acids, and peptides) for use as an energy source and cell carbon, chemicals such as (NaOH) can be added during this step in order to decrease the digestion time by regulating pH to provide a higher methane yield.
- **Stage II acidogenesis.** In this stage acid producing bacteria, convert the intermediates of fermenting bacteria into acetic acid, hydrogen and carbon dioxide. These bacteria are anaerobic and can grow under acidic conditions to produce acetic acid. They need oxygen and carbon, and they use dissolved O_2 or bounded-oxygen. The acid-producing bacteria create anaerobic condition which is essential for the methane producing microorganisms. The simple molecules from acidogenesis are further digested by bacteria called acetogens to produce CO_2, hydrogen and mainly acetic acid.
- **Stage III methanogenesis.** In this stage methane is produced by bacteria called

methane formers in two ways, either by means of cleavage of two acetic acid molecules to generate carbon dioxide and methane, or by reduction of carbon dioxide with hydrogen. The acetate reaction is the primary producer of methane because of the limited amount of hydrogen available [3, 7, 8].

3.EXPERIMENTAL PROCEDURE

Laboratory scale 2-liter batch reactor was used. The feed stock was collected from the organic fraction household solid waste.

J-type thermocouple was used to measure temperature of the reactor and temperature of the hot water bath used to keep the reactor temperature at the required temperature.

Digital pH meters were used to monitor the pH during the retention time.

The produced biogas was collected in graduated cylinder under water as shown in Figures 2 and 3.

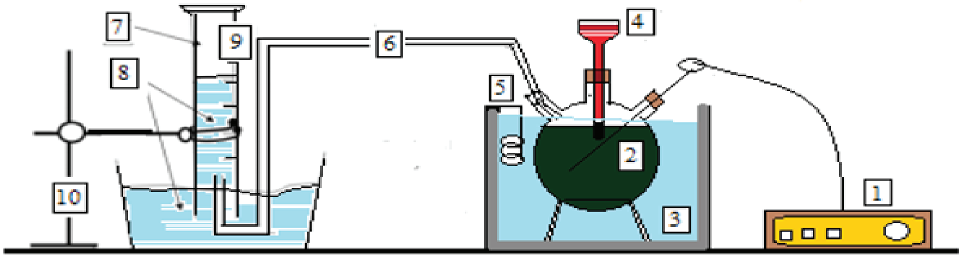

Figure (2). Schematic of experimental set up

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.

Figure (3). Batch anaerobic digester reactor

The first step was to prepare the inoculum from cow dung and organic fraction municipal solid waste (OFMSW) with the proportion of 2:1.

Experiments were carried out in four anaerobic digester flasks (size 2 L) used to investigate temperature effect at (35, 45, 55 and 65 °C), to keep the temperature of digester constant, water bath with thermostat control were used.

4. RESULTS AND DISCUSSION

The biogas production in the first reactor (R1) which was kept at 35 °C started slowly after 24 hr. The daily biogas production reached a maxim of (3000 ml) after 96 hr, as shown in Figure 4. This is attributed to pH level. At the beginning of the experiment the pH was around 8 for the first reactor (R1), then started to decrease to reach a minim of 5.3 after 72 hr. The anaerobic bacteria especially the methanogens are sensitive to the acid concentration within the digester and their growth can be inhibited at pH levels below 6. To avoid acidic media solution of NaOH was added to increase the pH to 7.8 as shown in Figure 5.

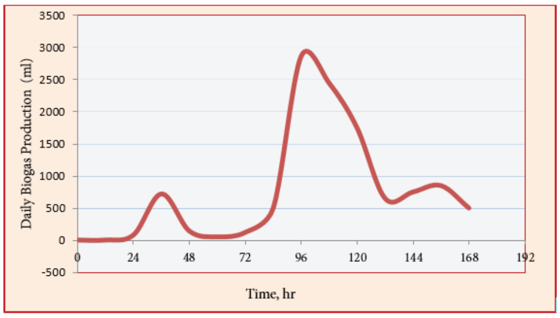

Figure (4). Daily biogas production in R1 (T=35°C)

Figure 6 shows the daily biogas production in the second reactor (R2) which operates at 45°C. The biogas production started after 12 hours and dropped to a minimum after 72 hours due to low pH. After that pH was adjusted to about 6.5. The biogas production increased to a maximum of 3500 ml, then dropped until it stopped after seven days. The best production was at the pH range of (6.31-6.43) on the third day, as shown in Figure 7.

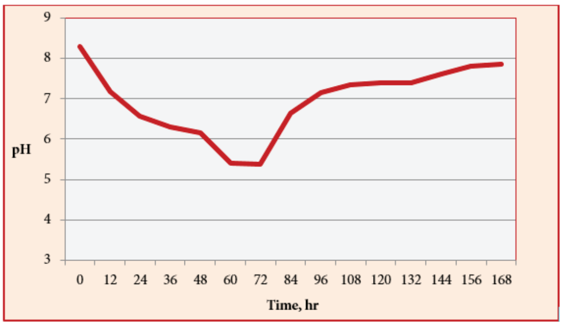

Figure (5). pH measurements in R1 (T= 35°C)

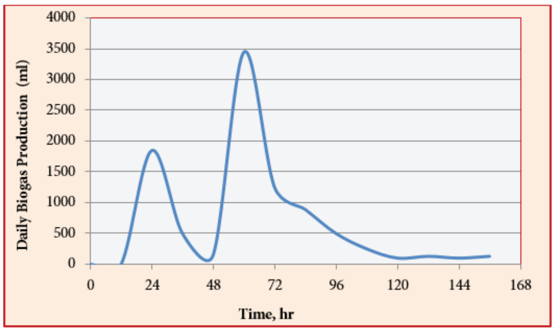

Figure (6). Daily biogas production in R2 (T=45°C)

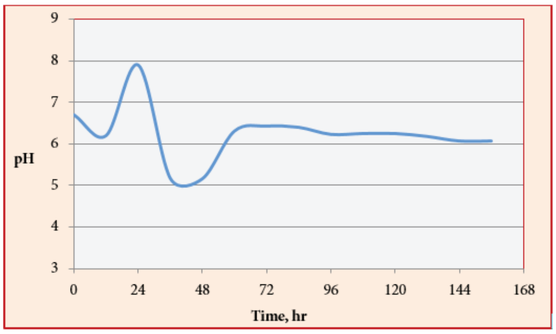

Figure (7). PH measurements in R2 (T= 45°C)

In the third reactor operated at 55°C, biogas production rate started fast in the first and second days, and then the reaction was considered to be failed, which is attributed to poisoning by ammonia due to high protein content, as shown in Figure 8.

The pH measurements in the third reactor as in Figure 9 show low pH environment with continuoing acid production. The methanogens were inhibited and ultimately, process failure was the result.

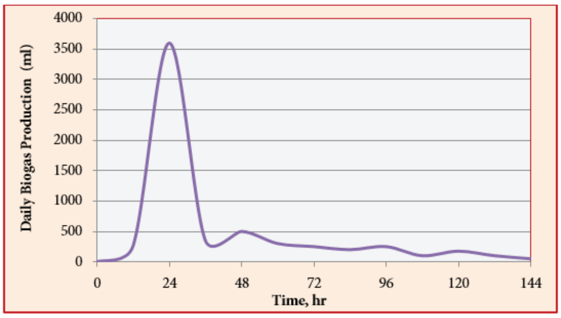

Figure (8). Daily biogas production in R3(T=55°C)

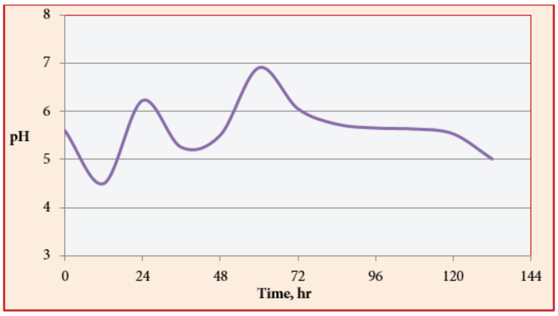

Figure (9). pH measurements in R3(T=55°C)

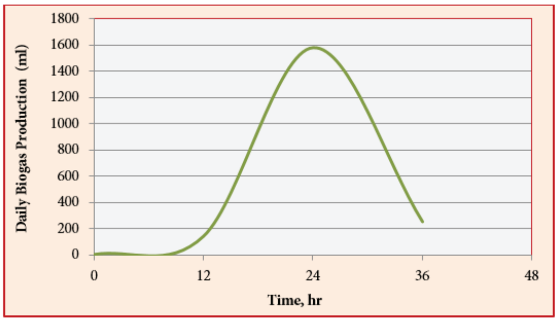

Figure (10).Daily biogas production in R4(T=65°C)

In the fourth reactor operating at 65 °C, the daily biogas production continued for less than two days, then stopped, as shown in Figure 10. The pH in the second day, was 6.83, which is not very low, as shown in Figure 11.

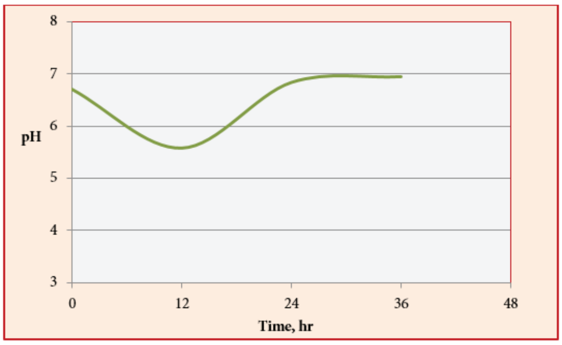

Figure (11). pH measurements in R4 (T= 65°C)

Figure 12 shows the cumulative biogas yield volume generated from the OFMSW substrate at different temperatures (35, 45, 55 and 65°C).

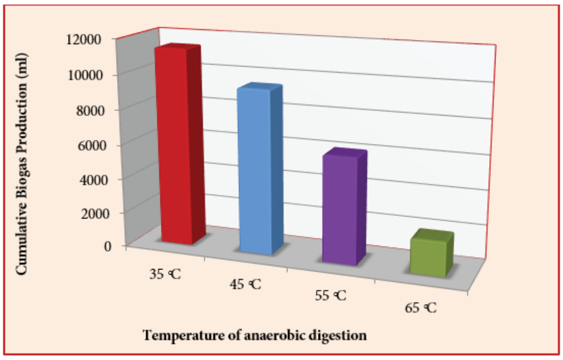

Figure (12). Cumulative biogas production from different temperatures

It is clear that maximum production of biogas from OFMSW was at mesophilic condition (35°C) temperature and 45°C, while the lowest production was at 65°C, and is decreasing with increasing temperate, it is also depending on the type of feed stock.

Samples from the produced biogas were analyzed using natural gas analyzer type C (Cep 3800 for varian). The results were in good agreement with published data, as shown in Table 1.

Table (1). Biogas analysis

Component	(Mol %)
CH_4	45.10
CO_2	44.8
N_2	10.09
H_2S	0.017

5. CONCLUSION

In this study, a laboratory scale batch digester was used to investigate biogas production at different temperatures. Based on the results obtained in the present work, the following conclusions can be drawn.

- Biochemical methane potential can be carried out at laboratory batch digester.
- OFMSW from households consists mainly of food waste and it should be mentioned that food waste has a high fat content which has negative effect on biogas production.
- The study reveals that anaerobic digestion can occur in the mesophilic range which has longer retention time.
- pH is an important factor for the digestion of municipal solid waste, low pH will inhibit the methanogenesis bacteria and as a consequence the process will fail. There is a possibility to maintain a stable pH within accurate range by addition of chemicals like NaOH & $NaHCO_3$.

6. REFERENCES

[1]. M. Maghanaki, B, Ghobadian, G. Najafi, R. Janzadeh Galogah . Potential of Biogas Production in Iran. Renewable and Sustainable Energy Reviews 2013; 28:702-714.

[2]. Fabien, M. An Introduction to Anaerobic Digestion of Organic Wastes. Find Report. Remade Scotland; 2003.

[3]. Von der, F. F. Anaerobic Digestion of Organic Solid Waste for Energy Production. Ph.D. Karlsruhe; 2009.

[4]. Gizachew Assefa Kerga. Optimum Production of Biogas from Bio-Municipal Solid Wastes Using Two Stage Anaerobic Digester. Addis Ababa University, School of Grabuate Studies. Addis Ababa Insitute of Technology, Department of Chemical Engineering; 2011.

[5]. C. Roati, S. Fiore, B. Ruffino, F. Marchese, D. Novarino and M.C. Zanetti (2012). Preliminary Evaluation of the Potential Biogas Production of Food-Processing Industrial Wastes. American Journal of Environmental Sciences 2012; 8:291-296.

[6]. B. T. Nijaguna. Biogas Technology. New Age International 2002; 46-48

[7]. Suyog, V. Biogas Production from Kitchen Waste. A Seminar Report submitted in partial fulfillment of the requirements for Bachelor of Technology (Biotechnology), Department of Biotechnology and Medical Engineering, National Institute of Technology, Rourkela; 2011.

[8]. Mansour-Al Sadi. Design and Building of Biogas Digester for Organic Materials Gained For Solid Waste. Msc thesis. Faculty of Graduate Studies, An-Najah National University, Nablus-Palestine; 2010.