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Effect of some factors on the production of biogas for domestic purposes

M. K. Elnemr[1] , Sh. El kadi[2] and M. Shata

[1]Agricultural Engineering Department, Faculty of Agriculture, Damietta University, Egypt,
[2]Agricultural Biotechnology Department, Faculty of Agriculture, Damietta University, Egypt

Emails address: moknemr@du.edu.eg[1]; sherifelkadi@du.edu.eg[2]
Corresponding author*: Mohamed.a.shata.1992@gmail.com

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ABSTRACT

The objectives of this study were to comparison between tow different available household wastes and investigate affect the volume of biogas production. Determine the most appropriate mixing ratio between waste and water and also determine the appropriate filling ratio for the fermenter. Microbiological evaluation of fermented wastes mixture were done. The experiment includes three variables. The first variable was the type of waste which included two base crops, which were rotten tomatoes fruits (To) and Jute-mallow green part (Ma). The second variable was the filling ratio (F) with two percentages 50% (F_1) and 75% (F_2) of full tank size. The third variable was the volumetric mixing ratio (M) between water: waste and includes (1:1 as M_1), (1:2 as M_2), (2:1 as M_3) . The experimental results showed that the best treatment produced the most amount of biogas , whether in Jute-mallow (Corchorus olitorus) green part waste or rotten tomato fruit, were (M_2 F_2), which was (the volumetric mixing ratio between water: waste (1:2) + 75% filling ratio), so that it was ٢٥٤٥٤ cm^3 per Jute-mallow green part and ٣٢٩٠٥ cm^3 in rotten tomato fruit. The results also show that the biogas produced from Jute-mallow green part contains a large percentage of methane gas when compared to the biogas produced from rotten tomato fruit, so that the highest percentage of methane gas produced from the samples used for Jute-mallow green part reached 32.5% at the 50% filling ratio and ٤٣,٣٩% in 75% filling ratio, while the highest percentage was in the samples used for rotten tomato fruit ٠,٢٦% in the 50% filling ratio and 0.16% in 75% filling ratio. The highest value of total bacterial count was in treatment (To,M_2,F_1) being 103.05 (x10^7cfu/ml). The highest fungal count was in treatment (To,M_1,F_2) being 26.25 (x10^7cfu/ml). Amylolitic and Protiolytic count were in treatment (Ma,M_3,F_2) being 42 (x10^7cfu/ml) and 41.25 (x10^7cfu/ml), respectively. The highest value of Lipolytic microbes count was in treatment (To,M_3,F_2) being 47(x10^7cfu/ml). The highest value of Cellulolytic microbes count was in treatment (Ma,M_2,F_1) >1100 (x10^7cfu/ml).

1- INTRODUCTION

According to statistics conducted by the International Energy Agency in 2009, there is energy poverty in the world, as there are 1.4 billion people who do not have access to electricity. There are about 2.7 billion people who depend on wood biomass fuel for household purposes, while in Africa the number of people who do not have access to any electrical energy or any type of modern fuel was about 585

million. These statistics also confirmed that 56% of the population of developing countries depend on firewood and charcoal only for cooking **(Sovacool ,2012)**. **(El-Deken et al, 2011)** said that, there is a shortage of energy sources in Egypt, making it a net importer of oil and the size of the Egyptian government's energy support in the 2008/2009 budget has reached 17.8%. Not only that, but they also confirmed that there has been a clear decline in Egyptian oil reserves in the last twenty years, from 4.7 billion barrels at the end of 1987 to 3.7 billion barrels at the end of 2006. There are many energy sources used for domestic purposes, such as solar energy, which has become an important source of energy used for domestic purposes such as electricity production and heating, but its use is still very limited, as we only use 0.015% for electricity production, and 0.3% for heating **(Hayat et al, 2018)**. There is also electricity, which is considered the most important source of energy inside homes, and it is expected that global consumption of electricity will continue to increase, according to the US Energy Information Administration in 2013, where they reported that global energy demand has reached 546.8 8 Quadribillion British thermal units (Btu) ($546.8 * 10^{15}$ Btu) and is expected to reach 820 Quadribillion Btu by 2040. They also confirmed that global electricity consumption will double during the next 15 to 20 years **(Pazheri et al, 2014)**. There is also natural gas, which has become an important source of energy used inside homes for cooking and heating, especially during the past two decades, especially since it surpasses fossil fuels in heat content, and it is expected to continue to achieve growth between 2020 and 2030, as the global shift towards natural gas has reached 23% **(Economides and Wood, 2009)**. There are also liquefied gas cylinders, which are considered an important source of energy, especially in developing countries such as African countries, where the use of liquefied gas in cooking is increasing, especially West African countries such as Nigeria, whose use of liquefied petroleum will reach 80% by 2030 **(Van leeuwen et al, 2017**). One of the energy sources used for domestic purposes as well, which has begun to take its place on the global scene, is biogas, which is considered an important and renewable energy source. It is also distinguished from all previous sources in that it is cheap and inexpensive to produce, and its production is done using techniques that are not complicated and we can use it directly. In cooking and heating processes it also helps to get rid of organic waste **(Al-Saidi et al, 2008)**. The main objective of this study were comparison between two different available home wastes and investigate how they will affect the volume of biogas production. Determine the most appropriate mixing ratio between waste and water and also determine the appropriate filling ratio for the fermenter. Microbiological evaluation of fermented wastes mixture were done.

2- MATERIAL AND METHODS

2.1.Materials

2.1.1.Plant wastes

Tomato and Jute-mallow waste was obtained from New Damietta city market in June 2022. The focus was on rotten tomatoes and green parts of Jute-mallow.

2.1.2.Inoculum source

One Kg Cow dung was used in each unit as a starting material, and it was obtained from a private cow farm near New Damietta city.

2.1.3.Description of the fermenter

Twelve small cylindrical plastic units were used, with a net volume of 60 L, 56 cm height, also the base diameter was 34 cm and the center diameter was 40 cm (Fig. 1). Then biogas formed during the fermentation period were collected inside a rubber tire, through a plastic tube with a diameter of 6 mm.

Fig. (1): Fermentation units

2.2. Methods

2.2.1 Experimental description

The experimental work of the study was carried out in a private house garden during the period from June 15 to August 20, 2022 in New Damietta city, Damietta Governorate.

Measurements and laboratory work have been done in the Agricultural and biosystems engineering Department and Agricultural bio-technology department, Faculty of Agriculture, Damietta University, Egypt. The experiment continued from the beginning of production until it was confirmed that it stopped for a period of 65 days. The ambient temperature is measured four times a day. Stirring is done by moving the fermenter in a circular manner five turns twice a day.

2.2.2 Experimental variables.

The experiment includes three variables as following:

1. Two types of rotten crops, tomatoes fruits (To) and Jute-mallow green part (Ma). These wastes were prepared by cutting them well by knife so that the decomposition process would be easier.
2. Fermenter filling ratio, 50% (F_1) and 75% (F_2).
3. Mixing ratio between water and waste, (1:1 as M_1), (1:2 as M_2), (2:1 as M_3) .

2.2.3. Measurements:

2.2.3.1 Measuring devices

2.2.3.1.1 Mercury Thermometer

To measure the outside air temperature (°C). Its measurements ranged from (-30 : 50). with an accuracy ± 1°C

2.2.3.1.2 Biogas analyzer

Biogas analyzer Bosean (Fig. 2.) Model (K-600) was used to measure the chemical composition (v/v) produced biogas. Its measurements ranged from (0-100%) for CH4, (0-50%) for CO_2 and (0-3000) ppm for H_2S. It features with an accuracy reach to ±5% of reading with a response time 30 s.

Fig. (2): Biogas analyzer

2.2.3.2 Data collection

Production started in all treatment between the fifth and seventh day from the start of the experiment. The data of the experiment were collected on a weekly basis.

2.2.3.3 Biogas collection.

The produced biogas was collected inside a 20-inch bicycle tire, so that the gas collection tire was emptied twice a week, once when measuring the volume and once when measuring the proportions of the gas components. The volume of the tire was measured directly after separating it from the barrel using the immersion volume measurement method. After the end of the entire experiment period and opening the barrels, samples of the biogas fertilizer inside the fermenter were taken for the microbiological analysis.

2.2.3.4 CH_4 analysis

The percentage of methane (CH_4) and other components of biogas as CO_2 and H_2S were measured once a week using Biogas analyzer.

2.2.3.5 Ambient temperature

The temperature was measured four times a day at (10 am - 12 pm - 4 pm - 10 pm), respectively using a Thermometer.

2.2.3.6 Microbiological analysis

2.2.3.6.1 Collection and preparation of Samples

Twelve samples of waste used in conducting the experiments were collected after complete decomposition to conduct the microbiological analysis at to the laboratory of the Agricultural Microbiology Department, Faculty of Agriculture, Damietta University, Egypt, for determining general and specific microbial groups. Decimal serial dilutions were prepared and only one ml of the last three dilutions were used for the following examinations. Specific methods and media were used for enumeration of the microbial counts of different groups of microbial flora such as nutrient agar medium **(Datta et al., 2011)** for both total bacterial count **(Sneed et al., 2004)** . The detection of aerobic spore forming bacteria was done by pasteurization the dilutions at 80°C for twenty minutes in a water bath, then the dilutions were transferred on nutrient agar medium and under aseptic conditions and the plates were incubated at 30°C for three days **(Kilinc and Cakli, 2004)**. Potato dextrose agar medium

(Datta et al, 2011) for fungal count, MacconKey broth medium **(Li and Qi , 2012)** for Coliform count **(Walter, 1961)**, Staph medium (No. 110) **(Åhman et al, 2019)** plates for detection of Staphylococcus aureus **(Walter, 1961)**. Proteolytic, amylolytic and lipolytic microorganisms were determined on nutrient agar medium supplemented with skim milk, starch or oil, respectively **(Abd-Elmageed et al., 2020)** . Basal salt media containing filter paper for cellulolytic microorganisms **(El-Fadaly et al., 2015)**.

2.2.3.6.2 Cultivation methods

Poured plate method **(Gupta et al., 2012)** was used for total bacterial count, fungal count, Proteolytic count, amylolytic count and lipolytic count. From all the samples after preparing suitable serial dilutions, one ml was plated in triplicates into sterilized glass Petri dish. About fifteen ml of melted suitable medium at about 45°C was aseptically poured in each sterilized glass Petri plate, then mixed well and left the plates for solidification. All plates and tubes were incubated at a suitable temperature for a suitable time according the microbes in a digital incubator (Switc, MPM Instruments s.r.l.,Bernareggio/Made in Italy). The developed colonies were counted per each plate, after the incubation period. The mean values of colonies were calculated as follows: The bacterial or fungal count (colony forming unite, cfu) (cfu/ml or cfu/g) = the mean number of three replicates of the same dilution x reciprocal of the dilution which used **[(Li and Qi , 2012), (Peterson et al., 2001), (Elminshawy et al., 2020)]**. The mostprobable number (MPN) technique **(Li and Qi, 2012)** was used for counting cellulolytic microorganisms. Three decimal dilutions of each sample in the last three replicates were used. 1 ml of each suitable dilution of samples were added to test tube containing suitable cultivation media, then incubated at suitable temperature for a suitable time according the microbes. The number of positive tubes were recorded. The most probable number of microbes per gram or ml of sample was calculated from standard tables **[(Mabrouk et al., 2017), (Suessner et al., 2014), (Elminshawy et al, 2019)]**.

3- RESULTS AND DISCUSSION

3.1. Biogas production

3.1.1. Biogas production from Jute-mallow wastes

Fig (3) shows the total amount of biogas produced from Jute-mallow wastes. It shows that the greatest amount of gas produced was 25454 cm^3 through the treatment (M_2 , F_2), which was (volumetric mixing ratio between water: waste (1:2) + 75% filling ratio. while the least amount of biogas produced was 13156 cm^3 through the treatment (M_3 , F_1), which was (volumetric mixing ratio between water: waste (2:1) + 50% filling ratio). From table (1) which show the average weekly temperature during the experiment. it is noted that there was a direct relationship between temperature and the amount of biogas produced, in the first and second weeks, the lowest temperatures were recorded, which were 28.8 and 29.6, respectively. Because of this, the lowest amount of biogas was produced in these two weeks. An increase in production was also observed in most treatments in the sixth week, when the highest temperature was recorded, which was 30.1 °C. Also, stability in biogas production was observed in most of the treatments in the seventh week because they recorded the same temperature as the sixth week.

Table 1. Average weekly temperature

Weeks	Average temperature, °C
Week 1	28.8
Week 2	30
Week 3	29.9
Week 4	29.6
Week 5	30
Week 6	30.1
Week 7	30.1
Week 8	29.8
Week 9	30

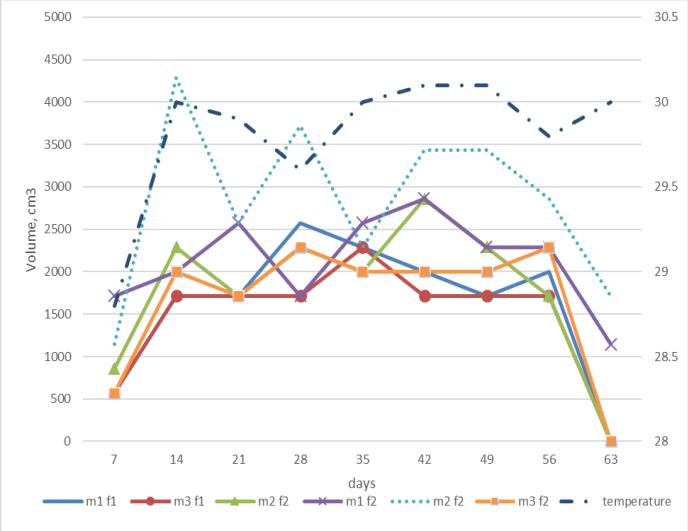

Fig. (3): The amount of biogas produced from Jute-mallow waste at different temperatures and treatments.

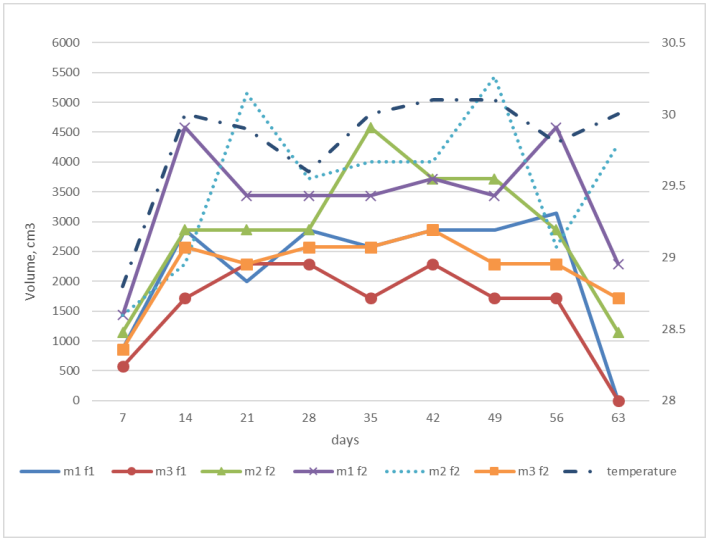

Fig. (4): The amount of gas produced from tomato waste at different temperatures and treatments.

3.1.2. Biogas production from tomato wastes

Fig (4) shows the total amount of biogas produced from tomato wastes. It shows that the greatest amount of gas produced was 32905 cm^3 through the treatment (m_2, f_2), which was (volumetric mixing ratio between water: waste (1:2) + 75% filling ratio. while the least amount of biogas produced. was 14300 cm^3 through the treatment (m3, f1), which was (volumetric mixing ratio between water: waste (2:1) + 50% filling ratio). From table (1) which show the average weekly temperature during the experiment, it is noted that there was a direct relationship between temperature and the amount of biogas production,

Where in the fourth week the lowest temperature were recorded, which was 29.6 . Because of this, the lowest amount of biogas was produced in this week. An increase in production was also observed in most treatments in the sixth week, when the highest temperature was recorded, which was 30.1 degrees. Also, stability in biogas production was observed in most of the treatments in the seventh week because they recorded the same temperature as the sixth week.

3.1.3 Cumulative biogas production

Fig. (5) shows the cumulative biogas production for each treatment during the experiment.

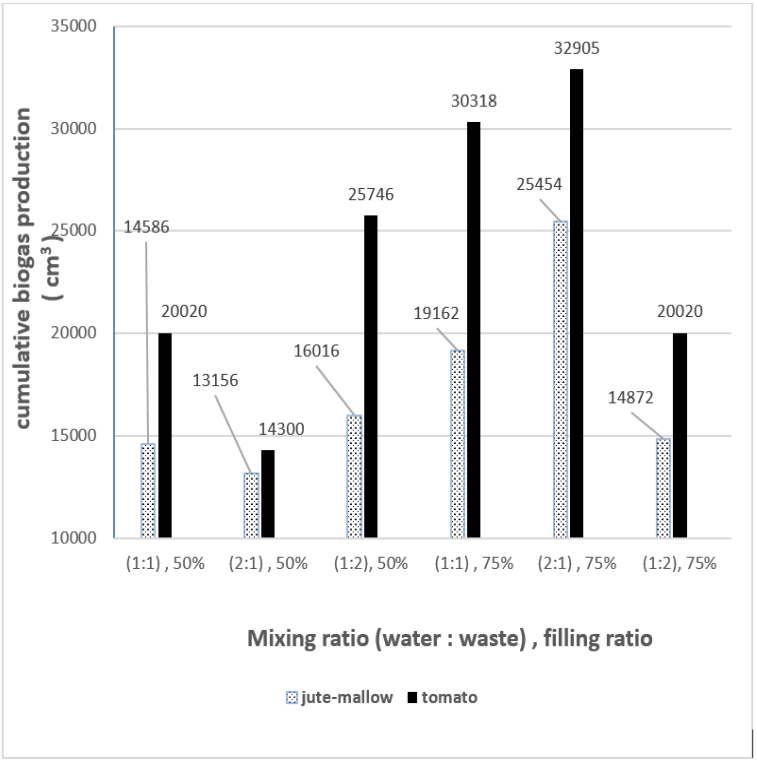

Fig. (5): Cumulative biogas production

3.2. Biogas analysis

The components of the resulting gas were analysed more than once during the experiment in order to determine the evolution of the proportions of its components during the various stages of gas production. Table (2) show that the maximum percentage of methane reached 43.39%, in the mixing ratio of (2 : 1) between water and Jute-mallow waste with 75% filling ratio. Also the average highest percentage of methane was 17.8% in the mixing ratio of (2 : 1) between water and Jute-mallow waste with 50% filling ratio. while table (3) show the minimum percentage of methane was 0.09%, in the mixing ratio of (1 : 2) between water and tomato waste with 75% filling ratio. Also the average lowest percentage of methane was 0.018% in the same treatment. Table (3) also show that amount of H_2S was zero in most treatments. Also show that the highest percentage of CO_2 reached 29%, in the mixing ratio of (2 : 1) between water and tomato waste with 50% filling ratio. Also table show the lowest average percentage of CO_2 was 4.48%, in the mixing ratio of (1:2) between water and tomato waste with 75% filling ratio.

Table 3. Components of biogas production

	Mixing ratio (water : waste)	filling ratio	CO_2 (%)	H_2S (PPM)	Maximum CH_4 (%)	Average CH_4 (%)
Jute-Mallow	1:1	50	6.03	1	29.29	14.34
	2:1	50	8.3	0	32.5	17.81
	1:2	50	6.62	0	10.95	4.04
	1:1	75	7.77	0	26.35	9.49
	1:2	75	4.48	0	18.47	4.65
	2:1	75	7.39	0	43.39	12.31
Tomato	1:1	50	10.68	0	0.26	0.35
	1:2	50	7.36	0	0.23	0.092
	2:1	50	29	0	0.2	0.072
	1:1	75	6.3	0	0.13	0.044
	1:2	75	9.6	0	0.09	0.018
	2:1	75	15.29	0	0.16	0.032

3.3. Microbiological analysis of the samples

3.3.1.Total bacterial count

The highest value of total bacterial count was in treatment (to,m_2,f_1) being 103.05 ($x10^7$cfu/ml), which was (tomato + volumetric mixing ratio between water: waste (1:2) + 50% filling ratio). While the lowest value was in treatment (to,m_3,f_1) being 8.65 (x107cfu/ml) which was (tomato + volumetric mixing ratio between water: waste (2:1) + 50% filling ratio). These results were similar that obtained by **Elhenawy et al. (2021)** who count the total bacteria and they found that, the highest number of total bacterial count in water samples being $970x10^7$ cfu/ml and lowest number being 420x107 cfu/ml. On the other hand, **Nimame et al. (2022)** found that, total heterotrophic bacteria count was 1.5×10^6 cfu/g.

3.3.2.Total Fungal count

The highest value of total fungal count was in treatment (to,m_1,f_2) being 26.25 ($x10^7$cfu/ml), which was (tomato + volumetric mixing ratio between water: waste (1:1) + 75% filling ratio). while the lowest value was in treatment (to,m_1,f_1) being 0.05 ($x10^7$cfu/ml). which was (tomato + volumetric mixing ratio between water: waste (1:1) + 50% filling ratio). Non similar results were obtained by **Nimame et al. (2022)** who count the total fungal and they found that, total heterotrophic fungi count was 3×10^3 cfu/g.

3.3.3.Amylolitic microbes count

The highest value of Amylolitic microbes count was in treatment (ma,m_3,f_2) being 42 ($x10^7$cfu/ml), which was (Jute-mallow + volumetric mixing ratio between water: waste (2:1) + 75% filling ratio). while the lowest value was in treatment (ma,m_1,f_1) being 12.75 ($x10^7$cfu/ml). which was (Jute-mallow + volumetric mixing ratio between water: waste (1:1) + 50% filling ratio). non similar results were obtained by **Elhenawy et al. (2021)** who count the Amylolitic microbes and they found that, The maximum value of Amylolytic microorganisms count being $22x10^4$ cfu/ml and lowest value being $13x10^4$ cfu/ml.

3.3.4.Protiolytic microbes count

The highest value of Protiolytic microbes count was in treatment (ma,m_3,f_2) being 41.25 ($x10^7$cfu/ml), which was (Jute-mallow +

volumetric mixing ratio between water: waste (2:1) + 75% filling ratio)while the lowest value was in treatment (ma,m_2,f_1) being 3.2 ($x10^7$cfu/ml). which was (Jute-mallow + volumetric mixing ratio between water: waste (1:2) + 50% filling ratio). non Similar results were obtained by **Elhenawy et al. (2021)** who count the Protiolytic microbes and they found that, the highest value of Proteolytic microorganisms count being $50x10^4$ cfu/ml and lowest value being $46x10^4$ cfu/ml.

3.3.5.Lipolytic microbes count

The highest value of Lipolytic microbes count was in treatment (to,m_3,f_2) being 47 ($x10^7$cfu/ml),) which was (tomato + volumetric mixing ratio between water: waste (2:1) + 75% filling ratio). while the lowest value was in treatment (ma,m_3,f_1) being 23.4 ($x10^7$cfu/ml) which was (Jute-mallow + volumetric mixing ratio between water: waste (2:1) + 50% filling ratio). Similar results were obtained by **Elhenawy et al. (2021)** who count the Lipolytic microbes and they found that, The maximum value of Lipolytic microorganisms count being $24x10^4$ cfu/ml and lowest value being $16x10^4$ cfu/ml.

3.3.6.Cellulolytic microbes count

The highest value of Cellulolytic microbes count was in treatment (ma,m_2,f_1) and 10 being >1100 ($x10^7$cfu/ml),) which was (Jute-mallow + volumetric mixing ratio between water: waste (1:2) + 50% filling ratio). while the lowest value was in treatment (ma,m_1,f_1) being 15 ($x10^7$cfu/ml) which was (Jute- mallow + volumetric mixing ratio between water: waste (1:1) + 50% filling ratio). non similar results were obtained by **EL-Shinnawi et al. (1989)** who count the Cellulolytic microbes and they found that, the Cellulolytic microbes count was 4.65×10^3.

4- CONCLUSION

The experimental results showed that the best treatment produced the most amount of biogas, whether in Jute-mallow green part waste or rotten tomato fruit, was (m_2, f_2), which was (the volumetric mixing ratio between water: waste (1:2) + 75% filling ratio). Also, the amount of methane in the biogas produced from Jute-mallow green part waste is greater than in the biogas produced from rotten tomatoes.

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CONFLICT OF INTEREST:

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION:

El-nemr, M. K., El-Kadi, SH., Shata, M. A: developed the concept of the manuscript. Shata wrote the manuscript. All authors checked and confirmed the final revised manuscript

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الملخص العربي

دراسة على العوامل المؤثرة على إنتاج الغاز الحيوي للأغراض المنزلية

م. النمر[١]. ش. القاضي[٢]. م. شطا[١]

[١]قسم هندسة النظم الزراعية والحيوية، كلية الزراعة، جامعة دمياط، مصر.

[٢]قسم البيوتكنولوجيا الزراعية ، كلية الزراعة، جامعة دمياط، مصر

كانت أهداف هذه الدراسة هي المقارنة بين نوعين من المخلفات المنزلية المختلفة المتاحة ومعرفة مدى تأثيرها على حجم إنتاج الغاز الحيوي. تحديد نسبة الخلط الأنسب بين النفايات والمياه وكذلك تحديد نسبة التعبئة المناسبة للمخمر. تم إجراء التقييم الميكروبيولوجي لخليط النفايات المتخمرة. تم استخدام اثني عشر وحدة بلاستيكية اسطوانية صغيرة، بحجم صافٍ ٦٠ لتر، وارتفاع ٥٦ سم، كما كان قطر القاعدة ٣٤ سم وقطر المركز ٤٠ سم. ثم تم جمع الغاز الحيوي المتكون أثناء فترة التخمير داخل إطار مطاطي، من خلال أنبوب بلاستيكي بقطر ٦ مم. تتضمن التجربة ثلاثة متغيرات وهي: محصولين أساسيين وهما ثمار الطماطم الفاسدة (To), والاجزاء الخضراء من نبات الملوخية(Ma)، والمتغير الثاني هو نسبة ملئ المخمر وذلك بنسبتين مئويتين ٥٠% (F_1) و٧٥% (F_2)، والمتغير الثالث هو نسبة الخلط الحجمي بين الماء والنفايات وتشمل (M_1 as 1:1), (M_2 as 1:2), (M_3 as 2:1). أظهرت النتائج التجريبية أن أفضل معاملة أنتجت أكبر كمية من الغاز الحيوي سواء في مخلفات الأجزاء الخضراء من الملوخية أو ثمار الطماطم الفاسدة كانت (م٢ ف٢)، والتي كانت (نسبة الخلط الحجمي بين الماء: النفايات (١:٢) + نسبة الملئ ٧٥%) بحيث كانت 25454 cm^3 من الأجزاء الخضراء للملوخية و ٣٢٩٠٥ cm^3 من ثمار الطماطم الفاسدة. كما أظهرت النتائج أن الغاز الحيوي الناتج من الأجزاء الخضراء للملوخية يحتوي على نسبة كبيرة من غاز الميثان مقارنة بالغاز الحيوي الناتج من ثمار الطماطم الفاسدة، بحيث أن أعلى نسبة من غاز الميثان المنتجة من العينات المستخدمة للأجزاء الخضراء للملوخية وبلغت النسبة ٣٢,٥% في نسبة الملىء ٥٠% و43.39% في نسبة الملىء ٧٥%، بينما كانت أعلى نسبة في العينات المستخدمة لثمار الطماطم الفاسدة 0.26 % في نسبة الملىء ٥٠% و٠,١٦% في نسبة الملىء ٧٥%. كما كانت أعلى قيمة للعدد البكتيري الكلي كانت في المعاملة (to,m_2,f_1) حيث بلغت ١٠٣,٠٥ .(x107cfu/ml) ، أعلى تعداد فطري كان في المعاملة (to,m_1,f_2) حيث بلغ ٢٦,٢٥ .(x107cfu/ml)كان عدد الأميلوليك والبروتيوليتيك في المعاملة (ma,m_3,f_2) ٤٢ (x107cfu/ml) و٤١,٢٥ (x107cfu/ml) على التوالي. أعلى قيمة لعدد الميكروبات الدهنية كانت في المعاملة (to,m_3,f_2) حيث بلغت ٤٧ .(x107cfu/ml) ، أعلى قيمة لعدد الميكروبات المحللة للسيلول كانت في المعاملة (ma,m_2,f_1) < ١١٠٠.(x107cfu/ml) .ونتيجة لذلك يتم التوصية بنسبة خلط (١:٢) بحيث يكون كمية المخلفات ضعف كمية الماء كما يتم التوصية بنسبة ملئ ٧٥% من حجم المخمر، وبناء على كمية غاز الميثان الناتجة يفضل استخدام الأجزاء الخضراء من مخلفات نبات الملوخية عن استخدام الطماطم الفاسدة.

الكلمات المفتاحية: الغاز الحيوي، علم الأحياء الدقيقة، التخمر اللاهوائي