

## THE PRODUCTION OF BIOGAS FROM KITCHEN WASTE IN EGYPT

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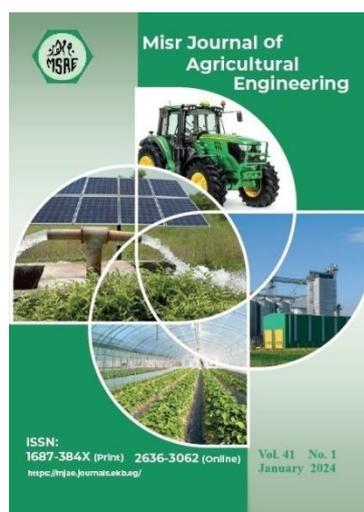
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### Keywords:

Biogas; Anaerobic digestion;  
Kitchen waste; Total solids;  
Volatile solids.

### ABSTRACT

Egypt can become a “zero waste country” in the immediate future by using biogas technology which can solve both energy and waste problems. specially kitchen waste can efficiently be used to produce biogas due to its high calorific value, and biodegradability by microbes. This will reduce dependency on fossil fuels. The current work was carried out to determine kitchen waste composition and characteristics from different standards of living in Egypt and evaluate the effect of living standard on biogas production in Egypt. Kitchen waste collected from three different living standards. There were significant differences among the three living standards H.L., M.L. and L.L. in their total solids (TS%), moisture content % and organic content % and there were not significant differences in their Volatile solids (VS %) and ash content%. By using 9-liter laboratory-scale set-ups, three samples of kitchen waste were digested to indicate the effect of the three standards of living on biogas yield. The results showed that the cumulative gas quantities for the high, medium, and low standards of living were 16.56, 17.59, and 16.44 liters, respectively. The statistical analysis showed a no significant differences between the different standards of living on cumulative gas quantities.

### INTRODUCTION

Egypt is one of the most populous country in the Middle East. It faces rising energy demand with rapid population growth and an expanding economy. This creates significant challenges in maintaining a steady and continuous supply of energy (IRENA, 2018). Furthermore, the use of conventional energy resources has a negative impact on the environment, climatic changes and implicitly on human health (Elashry, 2002; Meggyes and Nagy, 2012). Therefore, all these reasons are serious development concern for Egypt. Renewable energy can aid Egypt not only overcoming its energy needs, but also power sustainable economic growth and provide new jobs opportunities while achieving global climate and sustainable development objectives. Egypt climbs the top of the highest contributing to wastes which found to range between 0.63-0.82 kg/day/capita and the wastes

were mostly composed of food (41-70%) (Abdallah *et al.*, 2020). If this quantity of food waste is digested in anaerobic digestion (AD) process, it can produce about 5.95 billion m<sup>3</sup> CH<sub>4</sub>/year.

Inadequate management of wastes causes several adverse consequences on societies. Most often, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, cholera, typhoid, polluting surface, and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats, and other disease bearing vectors. Also, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming (Sunil *et al.*, 2013).

Biogas is one of a renewable energy sources and as an alternative energy sources which has shown compatibility with combustion engine technology. Biogas technology can overcome the needs of energy as the substitute of petroleum in low income country and also, able to reduce the reliability on petroleum.

Biogas is generally composed of mixture of gases mainly methane and carbon dioxide. The biogas production is cheap and can be utilized for many household and farming applications, heating and vehicle fuel (Elashry, 2001; Muth *et al.*, 2021). Besides, the biogas slurry is a good source of nutrients for plant growth, since manurial of dung is enhanced due to digestion, In the past, researches on biogas have focused majorly on animal dung, kitchen waster and animal excreta as feedstock. One of the methods to produce natural biogas is anaerobic digestion (AD). AD is a process where solid organic matter is recycled to produce biogas, which involves series of reactions mediated by many microorganisms. The reactions involve hydrolysis, acidogenesis and methanogenesis.

Biogas technology is a superb wastes management tool which can not only solve energy lack and also waste problems. the worldwide biogas industry has increased by more than 90% between the years 2010 and 2018, while further growth is still expected (Abanades *et al.*, 2021). It can be defined as the gas generated from organic digestion under anaerobic conditions by mixed population of microorganisms which is an alternative energy source primarily consisting of methane, carbon dioxide and hydrogen sulphide. Biogas composition depends on feeding material but some of biogas characteristics can be summarized as an odorless and colorless gas that burns with blue flame like liquid petroleum gas (LPG), 20% lighter than air, has an ignition temperature around the range of 650 to 750 °C and caloric value about 20 MJ/m<sup>3</sup> ( Ahmed *et al.*, 1999; Vij, 2011).

Kitchen waste is organic material which can efficiently be used to produce biogas due to its high calorific value, nutritive value and biodegradability by microbes, which will decrease dependency on fossil fuels (Balat and Balat, 2009; Satyanarayana, S. & Srinvasa, 2017). Food wastage differ through countries for their levels of development and consequently standards of living and also differ in one country from region to another (Gustavsson *et al.*, 2011).

**The aims of this research were:**

- To determine kitchen waste composition and characteristics from different standards of living in Egypt.
- To evaluate the potential of producing biogas in Egypt.

## MATERIAL AND METHODS

### **Kitchen waste composition**

Three different samples with three replicates of kitchen food wastes were collected from different areas and different living standards in El Beheira governorate, Egypt which were selected according to each of their electricity consumption. Samples were firstly sorted into food categories according to different living standards (high, medium, and low). One kilogram of each sample was considered. The components of the samples were classified to identify their contents.

#### **- Kitchen waste characteristics**

The samples were grinded separately, and total solids (TS), volatile solids (VS), moisture content, ash content and organic content were determined according to American Public Health Association (APHA, 1998)

#### **Total solids (TS)**

Total solid (TS) is a measure of the combined of total organic and inorganic matter contained in the feedstock. It was determined as follow: About 20 g of fresh samples with three replicates were weighted to the nearest 0.01 gram ( $W_1$ ) and dried in an oven maintained at 105°C for 12 hour ( $W_2$ ). Percent of TS was calculated by using following equation.

$$TS\% = \frac{W_2}{W_1} \times 100$$

#### **Volatile solids (VS)**

Volatile solid (VS) is a measure of the organic matter contained of the feedstock (excluding the inorganic salts, ash). It was determined as follow: About 3 gram of oven dried sample was weighed ( $W_3$ ) and heated to 550°C for 1 hour in the muffle furnace to constant weight ( $W_4$ ) for each sample. Percent of VS was calculated by using following equation.

$$\% VS = \frac{W_4}{W_3} \times 100$$

#### **Moisture content, Ash content and Organic content**

Moisture content was calculated by using the following equation:

$$\text{Moisture content \%} = 100 - TS$$

Percent of Ash content can be calculated by using the following equation:

$$\text{Ash content \%} = 100 - VS$$

Percent of organic content can be calculated by using the following equation:

$$\text{Organic content} = \frac{TS - \text{Ash content}}{TS}$$

#### **- Evaluating digestion of food waste samples**

To evaluate food waste digestion and the effect of living standards on biogas production, three samples of kitchen food wastes were collected from different areas with three replicates and were digested in laboratory scale units.

As shown in Figure (1) an 18-liter plastic container, plastic cape (to seal container), 4 mm-diameter level pipe (around 2 m long), 4-liters water bottle for collecting gas and a measuring cylinder were used all with three sets for the three living standards kitchen waste samples.

The kitchen waste (KW) was grinded by a home blender into a semi solid state, then diluted with water in a ratio of 1:1, and then fed to the reactor in a batch type feeding method. Total quantity added for each reactor was 9 liters (waste + water). Temperature, pH, and produced gas were daily monitored.

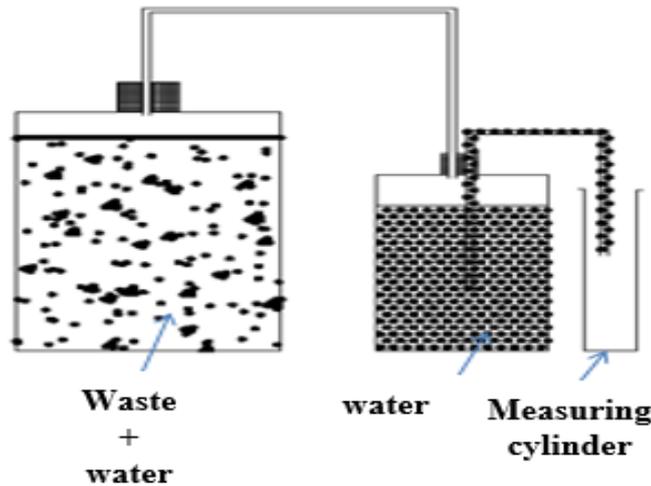


Figure (1): Laboratory- scale reactors set-up

**RESULTS AND DISCUSSIONS**

**Kitchen waste composition**

Table (1) and figure (2) illustrate the components of kitchen waste for each standard of living (high (HL)– medium (ML) – low (LL)). The results showed that the highest percentage of carbohydrate residues represented in bread, pasta and rice and was with the medium living class. While the highest percentage of vegetable and fruit waste was with the high living class, followed by the low and then the medium class.

**Table (1): Food waste samples composition**

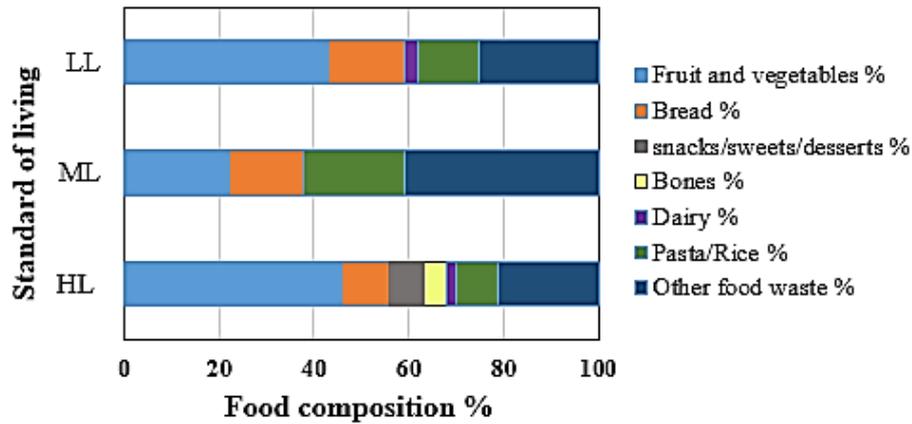
	HL	ML	LL
Fruit and vegetables %	45.88±2.5	21.80±4.94	42.97±10.7
Bread %	10.24±3.07	16.37±0.67	15.77±2.73
snacks/sweets/desserts%	7.15±7.90	0.00	0.00
Bones %	4.85±5.03	0.00	0.00
Dairy %	1.42±2.71	0.00	3.33±3.89
Pasta/Rice %	9.39±4.47	20.93±3.36	13.17±11.4
Other food waste %	21.06±2.27	40.90±5.41	24.77±5.31

**- Kitchen waste characteristics**

**Total solids and moisture content**

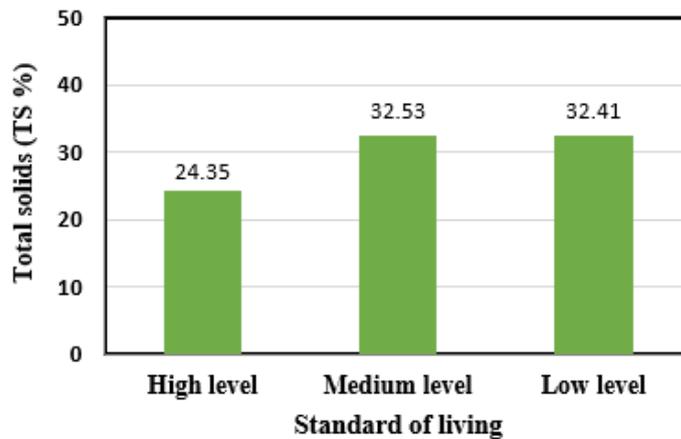
Total solids (TS) and moisture content values for high, medium, and low-level standards are shown in Figures (3 and 4), respectively. The statistical analysis (ANOVA) using LSD at 0.05

significant level, showed that there are significant differences between the three levels in their total solids (TS) and moisture content.

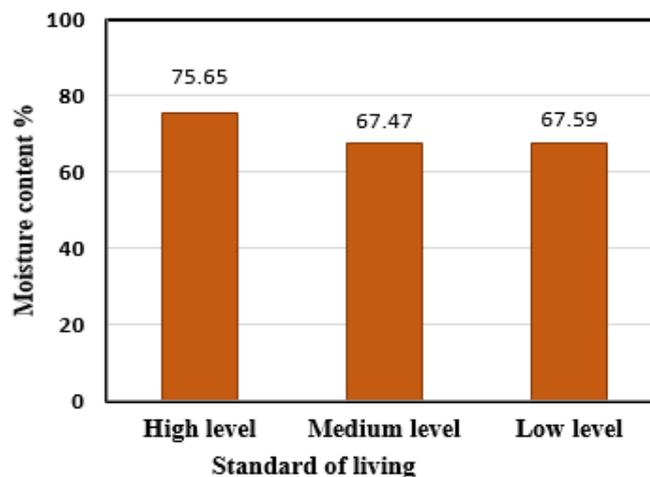


**Figure (2): Food waste samples composition for different standard of living**

The comparison showed that there is no significant difference between medium and low-level standards, and there is significant difference between high and medium level and also high and low level in total solids and moisture content, and this could be attributed to unlike medium and low levels, the high level has the highest quantity of fruits and vegetables in high level standard's waste which have high moisture content compared with other food wastes.



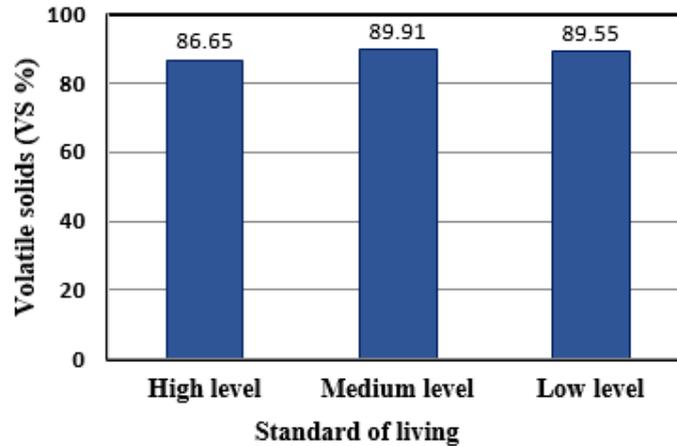
**Figure (3): Percentage of total solids for three standards of living**



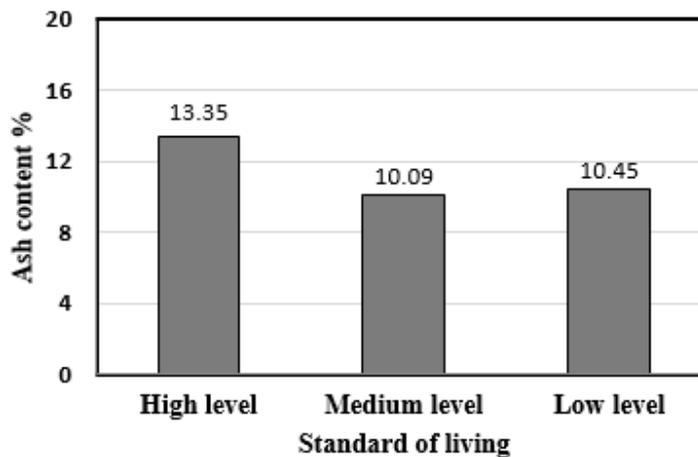
**Figure (4): Moisture content percent for three standards of living**

**Analysis of volatile solids (VS) and ash content**

The VS and ash content values for high, medium, and low-level standards are shown in Figures (5 and 6) respectively. The statistical analysis showed that there are no significant differences among the three levels (high, medium, and low living standards) in their volatile solids of kitchen waste and ash content.



**Figure (5): Percentage of volatile solids for three standards of living**



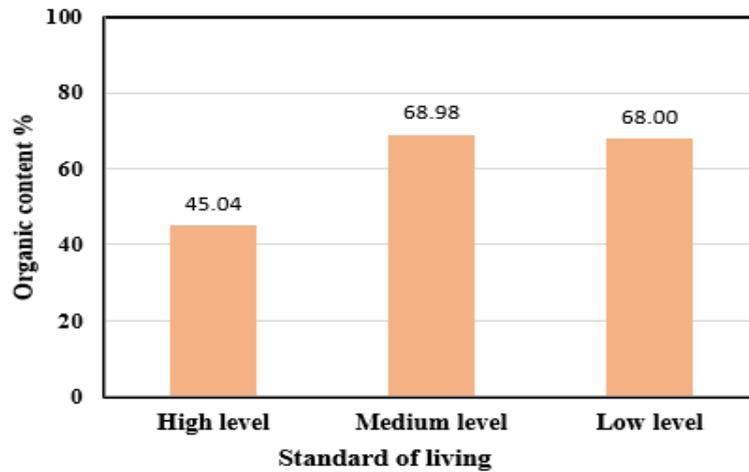
**Figure (6): Ash content percentage for three standards of living**

**Organic content**

Figure (7) illustrate the organic content values for high, medium, and low-level standards. The figure shows that the highest value was 68.98% with medium-level. The statistical analysis showed that there are significant differences among the three levels in their organic content of kitchen waste. The comparison showed that there is no significant difference between medium and low-level standards and there is significant difference between high and medium level and high and low level in organic content of their food waste.

**C/N ratio for kitchen waste**

Table (2) shows C/N ratios of kitchen waste with an average of 19.8, 22.3 and 21.0 for high, medium, and low levels, respectively. The results agree with (Ramzan *et al.*, 2010; Xu *et al.*, 2018) who explained that the values of C/N ratio for different types of kitchen wastes are ranged from 11.4 to 36.4. Also, all values of C/N ratios for the kitchen waste of the three living standards are all within the preferable range (16:1 to 25:1) for AD process as (Deublein and Steinhauser, 2011) mentioned.



**Figure (7): Organic content percentage for three standards of living**

**Table (2): C/N ratios for kitchen waste samples for three standards of living**

		Standard of living		
		H.L.	M.L.	L.L.
C/N ratio	R1	19.3	22.4	20.8
	R2	21.7	25.2	22.0
	R3	18.6	19.5	20.4
	Average	19.8	22.3	21.0

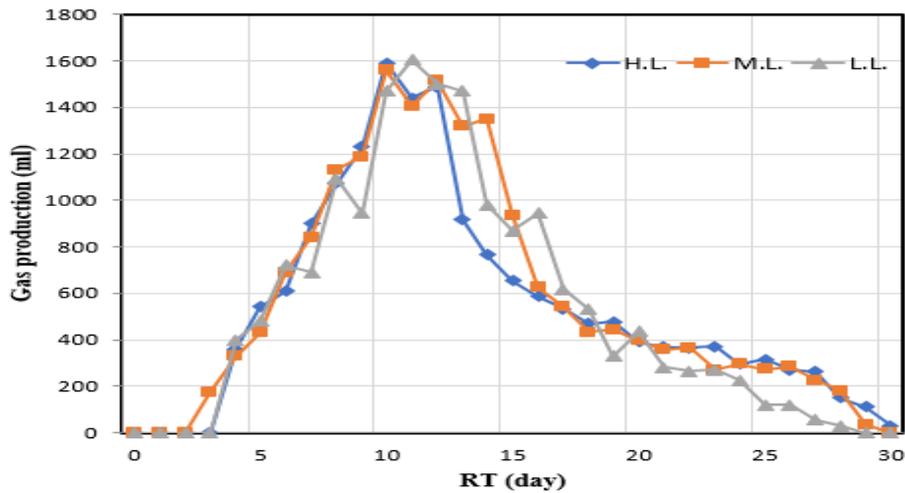
**- Biogas yield**

Three samples with three replicates were collected from 3 different living standards to evaluate digestion for kitchen waste by using 3 laboratory-scale set-ups. Nine liters of feedstock (food waste + water) fed to each reactor in a batch type method with not controlling AD parameters. The average of temperature, pH and produced gas quantity were recorded daily for 30 days retention time.

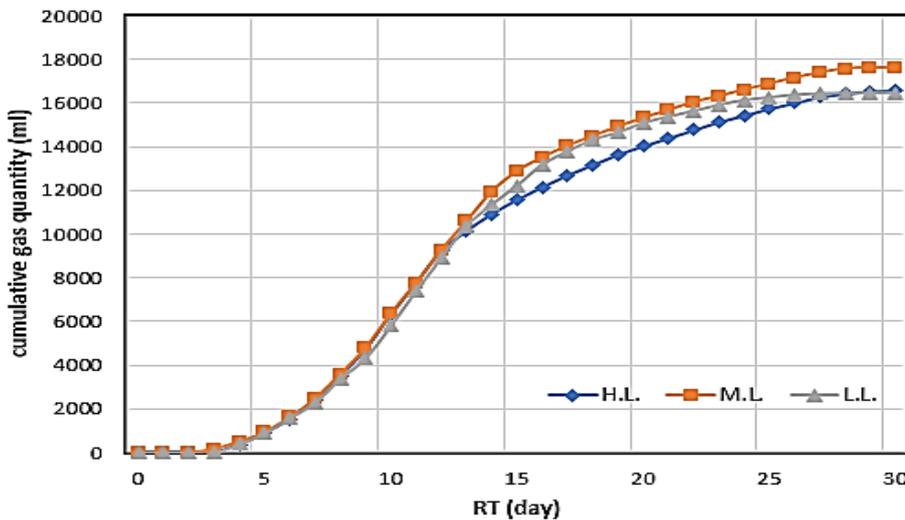
As the fermentation process proceeds, fatty acids are produced from organic waste by the acidogenesis of bacteria; accordingly, the pH value of the mixture drops. This causes a drop in the activity of the bacteria, especially the methanogenic bacteria (Sreekrishnan, Kohli and Rana, 2004; Deublein and Steinhauser, 2011).

Through the experiment pH decrease from 7.2 as a maximum value to 2.6 as a minimum value that made the mixture too acidic which is not preferable in AD process. pH is preferred to be within the range from 6.0 to 8.5 so controlling pH will be required by titrating with NaOH solution to improve the production of biogas.

Daily gas production and cumulative gas quantity are shown in figures (8) and (9) respectively. The three set have shown cumulative gas production of 16.56 L, 17.59 L and 16.45 L with production gas rate of 13.95, 14.82 and 13.85 L/kg Volatile solids (VS) added respectively. The gas production rate of the three sets is almost the same which indicates that the living standard has no effect on waste composition and then biogas production through anaerobic digestion (AD) process.



**Figure (8): Gas production for laboratory-scale reactors**



**Figure (9): Cumulative gas quantity for laboratory-scale reactors**

### CONCLUSION

The amount of food waste is gradually increasing with the development progress of economic and population for countries, increasing carbon footprint estimated. These reasons calling for using advanced methods to recycle food waste into energy and reduces carbon emissions. Biogas technology is a distinctive waste management tool that can solve both energy and waste problems with a low capital and operating costs. Kitchen waste coming from households can efficiently be used as a raw material to produce biogas due to its high calorific value, and biodegradability by microbes, which will reduce dependency on fossil fuels and maintains a clean environment. This study investigated the effectiveness of kitchen waste and the effect of different living standards on biogas production in Egypt. The results indicate that kitchen waste which coming from households is a suitable raw material for wet mesophilic anaerobic fermentation. This material is easily biodegradable even without the application of pretreatments. Anaerobic digestion of kitchen waste using simple and compact digester is a more feasible proven technology and economical for households in urban areas and rural regions. The change in living standard almost has a negligible effect on the gas production rate. Government should be taken more steps to promote community level biogas plants.

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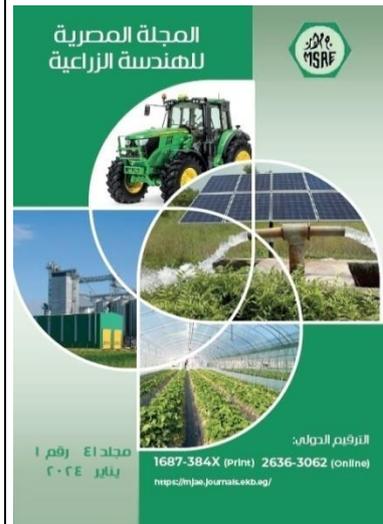
## إنتاج الغاز الحيوي (البيوجاز) من مخلفات المطابخ في مصر

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### الملخص العربي

يمكن أن تصبح مصر "دولة خالية من النفايات" في المستقبل القريب. وذلك باستخدام تكنولوجيا إنتاج الغاز الحيوي (البيوجاز) التي يمكن بها ان تحل المشاكل المتعلقة بالطاقة والمخلفات. يمكن استخدام نفايات المطابخ بشكل خاص بكفاءة لإنتاج الغاز الحيوي نظرًا لقيمتها الحرارية العالية وقابليتها للتحلل الحيوي بواسطة الميكروبات، مما يقلل الاعتماد على الوقود الأحفوري. تم تنفيذ هذا العمل لتحديد مكونات نفايات المطبخ وخصائصها من مستويات المعيشة المختلفة في مصر وتقييم تأثير مستوى المعيشة على إنتاج الغاز الحيوي في مصر. تم جمع نفايات المطبخ من ثلاثة مستويات معيشية مختلفة. كانت هناك اختلافات كبيرة بين مستويات المعيشة الثلاثة المرتفعة والمتوسطة والمنخفضة في المواد الصلبة الكلية (%TS) والمحتوى الرطوبي % والمحتوى العضوي % ولم تكن هناك فروق معنوية في المواد الصلبة المتطايرة (%VS) ومحتوى الرماد %. وباستخدام وحدة معملية سعة ٩ لتر، تم هضم ثلاث عينات من مخلفات المطبخ للإشارة إلى تأثير مستويات المعيشة على إنتاج الغاز الحيوي. أظهرت النتائج ان كمية الغاز التراكمية المنتجة للمستويات المعيشة المرتفعة والمتوسطة والمنخفضة كانت ١٦,٥٦ و ١٧,٥٩ و ١٦,٤٤ لترًا على التوالي. وأظهر التحليل الإحصائي عدم وجود فروق معنوية بين المستويات المعيشية الثلاث على كمية الغاز المنتجة.



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### الكلمات المفتاحية:

الغاز الحيوي؛ الهضم اللاهوائي؛ مخلفات المطبخ؛ المواد الصلبة الكلية؛ المواد الصلبة المتطايرة