IMPROVING BIOGAS PRODUCTION FROM ORGANIC AND AGRICULTURAL WASTES USING WASTEWATER AND STARTER SLURRY

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ABSTRACT

Anaerobic digestion is a well-known technique for waste management which could have constituted health hazard as well as environmental pollution. To enhance the biogas production, Starter Digestate (SD) by 5% of digester volume (T_2) and Agricultural Wastewater (AW) with SD (T3) were performed on raw materials of: Cattle Dung (CD), Poultry Droppings (PD), Sugar beet Leaves (SL) and Water Hyacinth (WH) compared with blank test (T_1) (Tap water) under different fermentation mixtures in order to study their effects on biogas and methane production, total nitrogen and pH.

Results indicated that using agricultural wastewater and starter digestate 5% (T_3) acheived the highest biogas production, methane percentage and total nitrogen comparing with the other treatments. With respect to fermentation mixtures, mixture of 50% SL + 50% WH (B) gave the highest methane percentage (77%), while mixture of 50% PD + 25 % SL + 25% WH (D) produced high concentration of N (5.3%) as a rich fertilizer with an average biogas production (778 mL/day) through fermentation period of 24 days.

Keywords: *Biomass, Starter digestate, Agricultural wastewater, Biogas production, Methane, Total nitrogen.*

INTRODUCTION

Energy concerns have become a high priority topic and focus on the development and optimization of environmentally friendly bio-renewable energy sources. Technologies that are capable of achieving multiple ecologically sound goals such as conserving nutrients and producing renewable energy sources provide producers with an incentive to implement these practices into their operations.

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Nomenclature

CD	Cattle Dung	*PD*	Poultry Droppings
SL	Sugar beet Leaves	*WH*	Water Hyacinth
AW	Agricultural Wastewater	*SD*	Starter Digestate (5%)
M.C.	Moisture content, %	*OC*	Organic carbon, %
TS	Total solids, %	*TVS*	Total volatile solids, %
TN	Total nitrogen, %	*C/N*	Carbon/Nitrogen, ratio

Global attention is shifted to exploit the huge potential of agricultural waste (biomass) using variable biological processes, thereby realizing energy need and simultaneously addressing environmental problems consequent upon these and other players **(Adelakan and Bamgboye, 2009)**.

The use of rural wastes for biogas generation, rather than directly used as fuel or fertilizer, offers several benefits such as, the production of energy resource that can be stored and used more efficiently, the production of stabilized residue (sludge) that retains the fertilizer value of original material and the saving of energy required to produce equivalent amount of nitrogen-containing fertilizer by synthetic process. Anaerobic digestion is a technologically simple process, with a low energy requirement that degraded organic materials by bacteria, in the absence of oxygen, converting it into a methane and carbon dioxide mixture.

Biogas is a mixture of different gases produced as a result of the anaerobic micro-organic action on agricultural waste, with a composition of approximately 50% methane and other gases in relatively low proportions such as CO_2, H_2, N_2 and O_2 **(Gamma'a *et al*., 2006)**.

Methane formation in anaerobic digestion involves four different steps, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

In hydrolysis, complex carbohydrates, fats, and proteins are first hydrolyzed to their monomeric forms by exoenzymes and bacterial cellulosome. In the second phase (acidogenesis), monomers are further degraded into short-chain acids. During acetogenesis, these short-chain acids are converted into acetate, hydrogen, and carbon dioxide. In the last phase, methanogens convert the intermediates produced into methane and carbon dioxide **(Deublein and Steinhauser, 2008)**. The process of anaerobic digestion is running at its optimum temperature range of 25 to 38°C (mesophilic conditions), the latter prefer temperatures in the range of 38°C are greater stability of digestion process **(Köttner, 2003)**. The superiority of co-digestion of 50% CD + 50% PD as influent substrate for biogas and methane production compared to CD or PD alone may be explained on the basis that CD contains a higher amount of carbohydrates and a lower amount of proteins and nutrients required for growth and propagation of microorganisms than those in PD indeed the high level of carbohydrates promotes the growth of acid forming bacteria, but may have positive effect on methane producing bacteria. In addition, the average portions of slowly degradable carbohydrates and lignin is larger in CD than in PD. On the other hand, the higher amounts of proteins and fats in PD make it desirable substrate for biogad and methane production. This may be due to inhabitation of the biological process in the digesters by ammonia and volatile fatty acid resulted from decomposition of proteins and fats, respectively therefore, co-digestion of CD and PD solved most of the above mentioned problems and consequently the daily biogas production increased **(Gelegenis *et al*., 2007)**.

With respect to utilize agricultural wates in digestion process, the most common use of waterhyacinth is raw material for composting and substrate for biogas **(Abdelhamid and Gabr, 1991)**. **Parawira *et al.* (2004)** studied and characterized the anaerobic batch biodegradation of potato waste alone and when co-digested with sugar beet leaves. The effects of increasing concentration of potato waste expressed as percentage of total solids (TS) on methane yield and productivity were investigated. They found that co-digestion of potato waste and sugar beet leaves improved the accumulated methane production and improved the methane yield by 31–62% compared with digestion of potato waste alone. **Lehtomaki *et al.* (2007)** evaluated anaerobic co-digestion of grass silage, sugar beet tops and oat straw with cow manure by in semi-continuously fed laboratory continuously stirred tank reactors (CSTRs). The highest specific methane yields of 268, 229 and 213 LCH_4/kg TVS added in co-digestion of cow manure with grass, sugar beet tops and straw, respectively, were obtained when feed with 30% of crop in the feedstock.

Compared with that in reactors fed with manure alone at a similar loading rate, volumetric methane production increased by 65, 58 and 16% in reactors fed with 30% TVS of sugar beet tops, grass and straw, respectively, along with manure. **Eltawil and Belal (2009**) studied anaerobic batch biodegradation of five co-digested mixtures in terms of methane yield and energy production as follows: Mixture 1 (potato waste + sugar beet leaves), mixture 2 (cattle dung), mixture 3 (water hyacinth + cattle dung), mixture 4 (rice straw + cattle dung + poultry droppings) and mixture 5 (bagasse + cattle dung). The peak values of gas generation reached up to 0.344 and 0.476 L/day for control and handle stirring in case of mixture 5. The results showed significant differences in biogas production between control and stirring for different mixtures. The biogas generation increased by stirring with 60.33% compared to control. The highest values of CH_4 were 75, 69.7 and 68.6% for mixtures 1, 5 and 3, respectively. **Mark and Ken (2006) and Jagadish *et al.* (2012)** stated that water hyacinth is one of the fastest growing aquatic weed. However this deleterious weed is a potential source of biomass to produce biogas, which is an eco-friendly biofuel. In their study, poultry litter was used as inoculum at mesophilic conditions. The results showed that Poultry Litter Inoculum (PLI) improved biogas yield significantly and increased biogas yield nearly two times when compared to water hyacinth substrate without PLI. **Nges *et al.* (2012)** stated that there is increasing competition for waste as feedstock for the growing number of biogas plants. The feasibility of supplementing a protein/lipid-rich industrial waste (pig manure, slaughterhouse waste, food processing and poultry waste) mesophilic anaerobic digester with carbohydrate-rich energy crops (hemp, maize and triticale) was therefore studied in laboratory scale batch and continuous stirred tank reactors (CSTR) with a view to scale-up to a commercial biogas process. Co-digesting industrial waste and crops led to significant improvement in methane yield per ton of feedstock and carbon-to-nitrogen ratio as compared to digestion of the industrial waste alone. Biogas production from crops in combination with industrial waste also avoids the need for micronutrients normally required in crop digestion. **Gissén *et al.* (2014)** stated that the presence of sugar beet in the substrate mix brings many advantages. This substrate is very digestible and has a methane yield of 419 m^3/TVS, which is higher than 360 m^3/TVS in the case of maize.

With regard to the effect of using agricultural wastewater and starter slurry as an active substrates for enhancement of the biogas production, the digested substrate (usually named digestate) is rich in macro and micro nutrients and therefore, suitable to be used as plant fertilizer comparing with raw animal manure. **Mahnert *et al.* (2005)** stated that there are different reasons depending on the setup and the performance of the batch experiment. One reason might be the bioactive population of the bacteria provided for the anaerobic process in the batch reactor. To start the anaerobic process in a batch, an inoculum (starter substrate) containing a biodiversity of bacteria similar to those in the biogas plant, where the substrate shall be used, is necessary. This is usually done in the way that the outlet biomass sludge of the biogas plant is used as starter material in the batch process (inoculum). **Rojas *et al.* (2010)** analyzed how the starter used for the batch experiment influences the digestion process. The results showed a significant stirring effect on the anaerobic digestion only when seed sludge from a biogas plant was used as a starter. In this case, the experiments without stirring yielded only about 50% of the expected biogas for the investigated substrates. The addition of manure slurry to the batch reactor as part of the starter improved the biogas production. The more diluted media in the reactor allowed a better contact between the bacteria and the substrates making stirring not necessary.

The present research work explores a suitable way to use organic wastes in the environment (cattle dung and poultry droppings), which constitute a serious problem, served as useful raw materials, because animal wastes contain the necessary micro-organism for biogas production. The digestion of sugar beet as another raw material was suggested due to its high output energy yields in contrast to their low energy input requirements. Finally, water hyacinth, which is rich in nitrogen and other essential nutrients usually responsible for clogging water ways, affecting navigation, fishing and recreational activities were also another raw material for the research work.

According to the above previous works done that taken in author's consideration and the conditions available, the objectives of the present work are then to:

- Utilize a starter digestate and agricultural wastewater as a bioactive for enhancing the biogas production.
- Study the effect of combined different wastes mixtures on the fermentation period and methane percentage.
- Determine the nutrient values and the characteristics of the digested substrates as a rich fertilizer supplement for agricultural producers.

MATERIALS AND METHODS

The present study was carried out at the Faculty of Agriculture lab condition, Zagazig University, Zagazig city (30° 2' N latitude and 31°12' E longitude), in Eastern Delta, Sharkia Governorate, Egypt during season of 2016 using lab scale anaerobic digester.

1. Experimental setup

1.1. Substrates

To prepare the slurry of the fermentation mixtures, some of the raw materials were collected as follow:

- **Organic wastes**

Fresh cattle dung and poultry droppings were collected from animal farm, Sharkia Government, Egypt and brought to the lab. Chemical composition of the used animal wastes was determined as in Table 1.

Table 1. Chemical composition of the used animal wastes

Animal Wastes	Characteristics								
	M.C., %	TS, %	TVS, %	Ash, %	OC, %	TN, %	C/N ratio	Protein, %	pH
CD	88.4	11.6	86.4	13.6	50.12	2.1	28	12.9	6.93
PD	74.7	25.3	74.3	25.7	43.10	3.24	19	20.65	6.8

- **Agricultural wastes**

Water hyacinth and sugar beet leaves were used as agricultural wastes. Sugar beet leaves was collected from the farm, while water hyacinth (*Eichornia crassipes*) was collected from irrigation channel (to avoid heavy metals). Chemical properties of the used agricultural wastes were measured as illustrated in Table 2.

Table 2. Chemical properties of the used agricultural wastes

Agricultural Wastes	Characteristics								
	M.C., %	TS, %	TVS, %	Ash, %	OC, %	TN, %	C/N ratio	Protein, %	pH
SL	91.8	8.2	76.4	23.6	44.32	1.7	18	9.5	6.7
WH	93.7	6.3	79.4	20.6	46.06	1.86	16	12.9	7.1

These wastes were sun dried and chopped into small pieces **(Yavini *et al*., 2014)**. Dried of water hyacinth leaves were used according to **Hussein (1992)** who found that using the dried and grinded water hyacinth as leaves gave the highest biogas production than fresh or roots.

- **Starter digestate**

Digestate residual was taken from former anaerobic digester that fed by PD and CD (50/50%, w/w), as an active material that quickly starts fermentation for the mixtures under study on anaerobic conditions. The chemical properties of the starter digestate were 92.4 % M.C., 7.6% TS, 66.5% TVS, 33.5% Ash, 38.57% OC, 2.6% TN, 21.6 C/N ratio, 16.3% protein and 6.25 pH. It was added by 5% of the effective digester volume.

- **Agricultural wastewater**

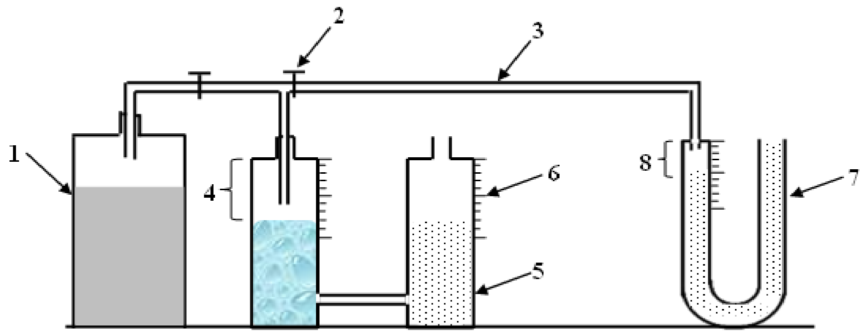
Wastewater obtained from open drainage was used. It contains macro- and micro-nutrients with no heavy metals, so, it is easy to be used in anaerobic digestion for improving the biogas production. TN and pH of an agricultural wastewater were 3.1% and 7.77, respectively.

1.2. Anaerobic digester

Five vertical digesters were installed under this study from local material (unused material) as a lab scale to accomplish anaerobic digestion of 2 L volume with actual digestion volume of 1.5 L for studying the effects of some fermentation mixtures and conditions on biogas production and therefore, being applicable for what will be reached from the obtained results to be used for large digesters scale. The digester was filled with the fermentation mixtures and then sealed with butyl rubber stoppers to be under pressure in the absence of oxygen. The plastic top cover can be easily opened and closed after each run to clean the digester as shown in Fig.1. The produced gas pressure through digestion, displace the equivalent volume of water to the calibrated cylinder according to **(Adelekan and Bamgboye, 2009)**. Valves were fixed between the units to be under control.

In order to measure the methane content, the collected gas in the headspace was passing in an agent of carbon dioxide (KOH) with concentration of 40 % in a U tube **(Okeke and Ezekoye, 2006)** that can be used as a gas scrubber.

To prepare the slurry media for mixtures, water was added to the different prepared raw materials (v/w) in a 2:1 ratio to form slurry of desired total solids concentration (7-10 %) before loading into separate digesters of uniform capacity of 1.5 L.



1. Anaerobic digester, **2.** Hand valve, **3.** Connecting pipe, **4.** Gas gathering place, **5.** Calibrated biogas Cylinder, **6.** Graduated scale, **7.** Acid gas scrubber tube (KOH) and **8.** Remaining gases from scrubbing.

Fig. 1. Schematic of biogas experimental digester

Recommended water content was determined for each sample as reported by **(Lo *et al.*, 1981)**:

$$D_w = R_m\,[(TS_{rm} - TS_{dig}) / TS_{dig}] \qquad \textbf{(1)}$$

Where: D_w: Amount of required water, L; R_m : Amount of raw materials added, kg; TS_{rm}: Total solids of raw materials, %; TS_{dig}: Total solids of fermentation materials, %

2. Experimental procedures

Experimental procedures were aimed to select the proper mixture of the used substrates that gives the highest biogas production.

2.1. Experimental layout

The biogas production as well as methane content was experimentally measured under the following treatments as shown in Fig. 2:

Five different fermentation mixtures: **(A):** 50% CD + 50% PD; **(B):** 50% SL + 50% WH; **(C):** 50% CD + 25 % SL + 25% WH; **(D):** 50% PD + 25 % SL + 25% WH and **(E):** 25% CD + 25% PD + 25 % SL + 25% WH.

Three different fermentation conditions: **(T_1):** Mixture + Tap water [Control]; **(T_2):** Mixture + SD (5% of effective digester volume) + Tap water and **(T_3):** Mixture + SD (5% of effective digester volume) + AW.
Biogas potential tests were performed under condition of about 25^{o}C room temperature (mesophilic conditions) and pH 7. The PH of the slurry was measured every 5 days using a digital PH meter with model of 915, Cat. 13-636-916.2 and an accuracy of ± 0.01 pH unit.
Digesters were stirred manually twice a day for keeping the digester contents homogenous.

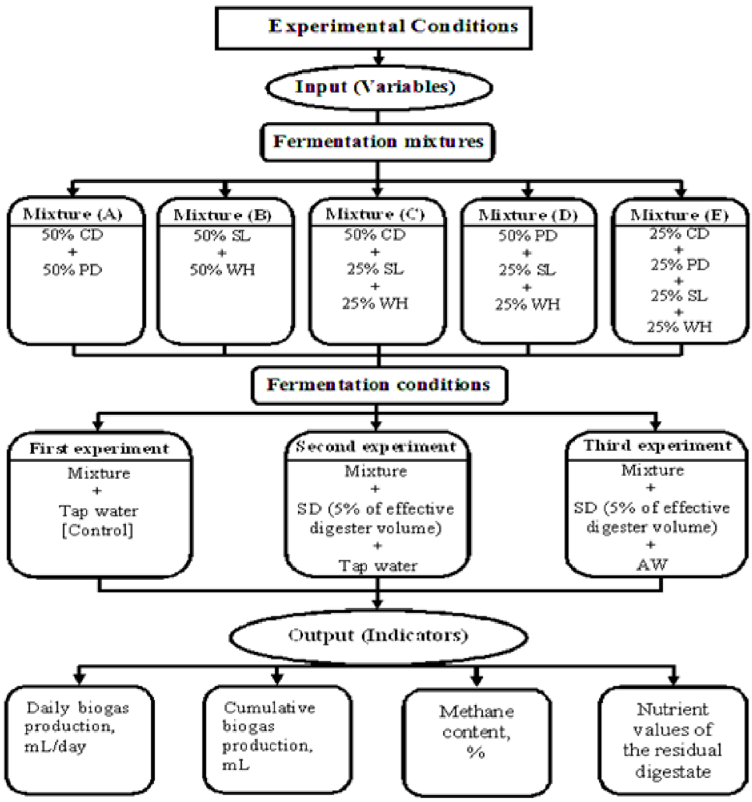


Fig. 2. The experimental layout diagram

2.2. Measurements and determinations

- **Daily biogas production**

The daily biogas production (mL/day) was volumetrically measured using the wetted displacement method.

- **Methane and Carbon dioxide percentage**

The volume of CH_4 and CO_2 were determined using potassium hydroxide

(KOH) 40% as previously mentioned. The percentage of CO_2 was calculated as follow:

Percentage of CO_2 = $[(V_1 - V_2) / V_1] \times 100$ **(2)**

Where: V_1 : volume of biogas before removal of CO_2, ml and

V_2 : volume of methane and the other gases after removal of CO_2, ml.

Konstandt (1976) mentioned that the percentage of methane CH_4 can be estimated through recognition of CO_2 percentage from this equation:

Percentage of CH_4 = 100% - [CO_2% + (3% H_2S and other gases)] **(3)**

Where: 3% is the average of H_2S and the other gases which constitute about 1-5% in the produced gas **(GTZ, 1999)**.

- **Chemical analysis**

Chemical analysis was done to the raw substrates and final residual digestate in order to determine values of nutrients which considered a good rich fertilizer as macro and micro nutrients (TS, TVS, Ash, Protein, Nitrogen content, C/N ratio and organic carbon).

- **Total solids (TS)**

Different samples were taken and dried in an electrical oven at 105^{o}C for 24 hours and then weighted using digital balance till reaching the equilibrium to determine total solid mass.

$TS = (M_{Ts} / M_f) \times 100$ **(4)**

Where: M_{TS}: mass of total solids and

M_f: fresh mass.

- **Total volatile solids (TVS)**

Total volatile solids were obtained from *TS* in amufflefurance at 550^{o}C for 2hours. It was calculated as the difference between the weights of *TS* and the ash content as follow:

$TVS = TS - Ash$ **(5)**

- **Organic carbon (OC)**

The percentage of OC was estimated from the percentage of TVS using the following equations according to **(Faure and Deschamps, 1990)**.

$OC = TVS / 1.724$ **(6)**

- **Total nitrogen (TN)**

Nitrogen is one of the five major elements found in organic materials such as protein. The Kjeldahl method of nitrogen analysis is the worldwide standard for calculating the protein content in raw substrates and the anaerobically digested. This method depends on 5 g of solid samples (5 mL liquid samples) was digested by adding 10 mL of concentrated H_2SO_4 with 1% copper and then, 50 mL of 40% NaOH. The final volume was adjusted to be 100 mL by diluted water. Distillation was done in Kjeldahl unit; the released ammonia was received in 5 mL saturated boric acid solution. Ammonia was estimated by titration.

RESULTS AND DISCUSSION

The obtained results will be discussed under the following heads:

1. Effect of different mixtures on daily biogas production

The daily biogas production with respect to different mixtures versus fermentation period is illustrated in Fig. 3. It can be noticed that the biogas production rate was very low through the first days and thereafter started to increase with increasing the retention period and reached to the peak values and then, decreased. The peak fermentation period was differed with different mixtures; it was 23 days for mixtures A and C under T_1; 23 days for mixtures A, C, D and E under T_2, while 24 days for mixtures A, C and E under T_3.

The maximum rate of daily biogas production was 789 mL/day for mixture C under T_1, while it was 1567 mL/day for mixture D under T_2 and 1660 mL/day for mixture A under T_3. Treatment T_3 gave 764.48, 349.05, 543.61, 778 and 587.51 mL/day as the highest values of the average daily biogas production under A, B, C, D and E, respectively comparing with other treatments. This may be due to high nitrogen content of the used starter digestate and agricultural wastewater.

It is revealed from obtained results that mixture B gave the lowest values of daily biogas production as compared to the other mixtures under all treatments. This may be due to that the agricultural wastes anaerobic degradation yardstick involves the presence of high lignocelluloses with low nitrogen content **(Igoni *et al.*, 2008)**. Thus, a high volatile solid contents of substrates may not necessary translate to high biogas yield due to the presence of non-available volatile solids in form of lignin. It is important to note that the volatile matter content of any substrate accounts for the proportion of solids that is transformed into biogas **(Ituen *et al.*, 2007)**. Hence, for a successful digestion to provide enough microorganisms to serve as inoculum, the process of co-digestion of agricultural wastes with cattle manure, poultry dropping, starter digestate and agricultural wastewater will provide a balance between the lignin content and the carbon to nitrogen ratio **(Nuhu *et al*., 2013)**.

2. Cumulative biogas production under different mixtures

Based on daily biogas production, the cumulative biogas is determined as shown in Fig. 4 through digestion test.

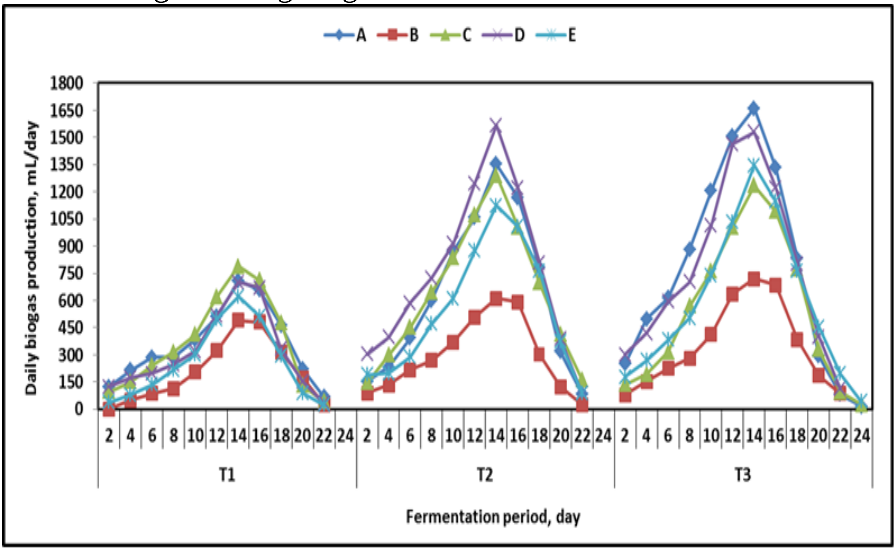


Fig. 3. Effect of different mixtures on daily biogas production through fermentation period

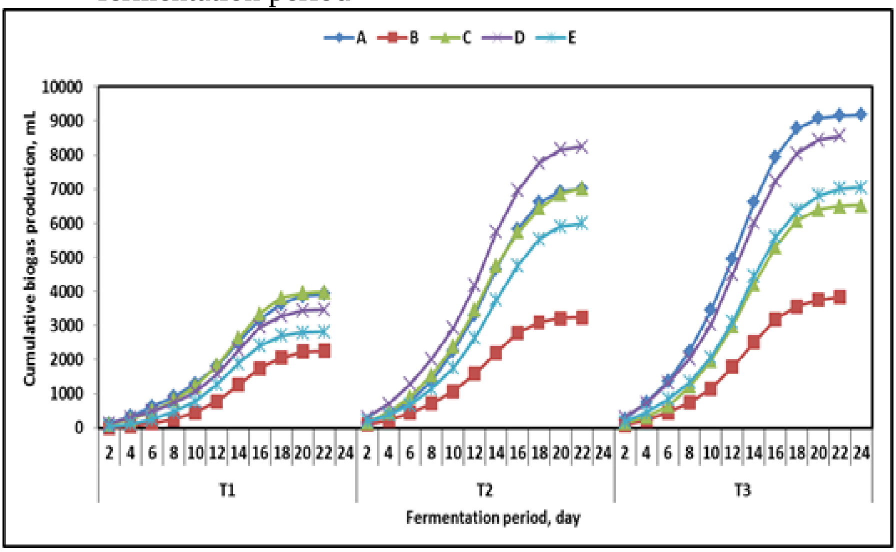


Fig. 4. Cumulative biogas production under different mixtures through fermentation period

It is cleared that accumulated biogas was gradually increased with digestion time. It was started from the 1st day and increased continuously at slow rate to reach the maximum values at the last day. This increase is compatible with the volatile removal fraction; because of the VS was the basic food of anaerobic bacteria and its amount continuously decreased during digestion process.

The peak values of cumulative biogas production were reached to be 3926.9, 2255.3, 3990.1, 3465.8 and 2813.1 mL for T_1, while 7013.8, 3236.6, 7020, 8250.7 and 5987.9 mL for T_2, however the values were 9173.7, 3839.5, 6523.3, 8558 and 7050.1 mL for T_3 under A, B, C, D and E, in that order. The use of T_3 improves the organic solubilization (acceleration of hydrolysis step through digestion). The rate of biogas production using T_3 and mixture A was increased by about 6:1 comparing with the effective volume.

3. Variation of methane production under different mixtures

Methane production is an important economic factor in anaerobic digestion. The differences in methane yield percentage with respect to fermentation period under different mixtures are illustrated in Fig. 5.

Results indicated that the highest values of CH_4 were produced in the first two weeks, thereafter the CH_4 production slowed down for all treatments. This could be explained by the fact that the more easily degradable compounds were finished during the first 2 weeks and slow degradation of complex material taking place after that period **(Parawira *et al*., 2004)**. The highest values of CH_4 percentage were 73, 75, 71, 71 and 75% for T_1; 75, 77, 73, 75 and 76% for T_2; while they were 75, 77, 73, 74 and 76% for T_3 under mixtures of A, B, C, D and E, respectively, which can be used to obtain an alternative energy source biogas which has the lower heating values of 24820, 25500, 24140, 24140 and 25500 kJ/m^3 for T_1; 25500, 26180, 24820, 25500 and 25840 kJ/m^3 for T_2; while, 25500, 26180, 24820, 25160 and 25840 kJ/m^3 for T_3, in that order and so usage of this energy source instead of the natural gas which has the lower heating value of 34,000 kJ/m^3 as **(Recebli *et al.*, 2015)**. Added to that 4.7 kW.h of electricity could be produced by 1 m^3 biogas **(Widyastuti *et al*., 2013)**. According to this information biogas usage to produce electricity means the recovery of the waste energy to the economy.

Mixture B gave the highest recorded percentages of CH4 added to that high sugar content, low protein percentage in fermentation mixture, thereby accelerated the hydrolysis step and reflected on methane percentage. This is consistent with **Kadam and Boone (1996)** who stated that ammonia primarily produced from the protein degradation may inhibit methanogens, because unionized ammonia can diffuse across the cell membrane to directly inhibit the activity of cytosolic enzymes or affect intracellular pH and other cations.

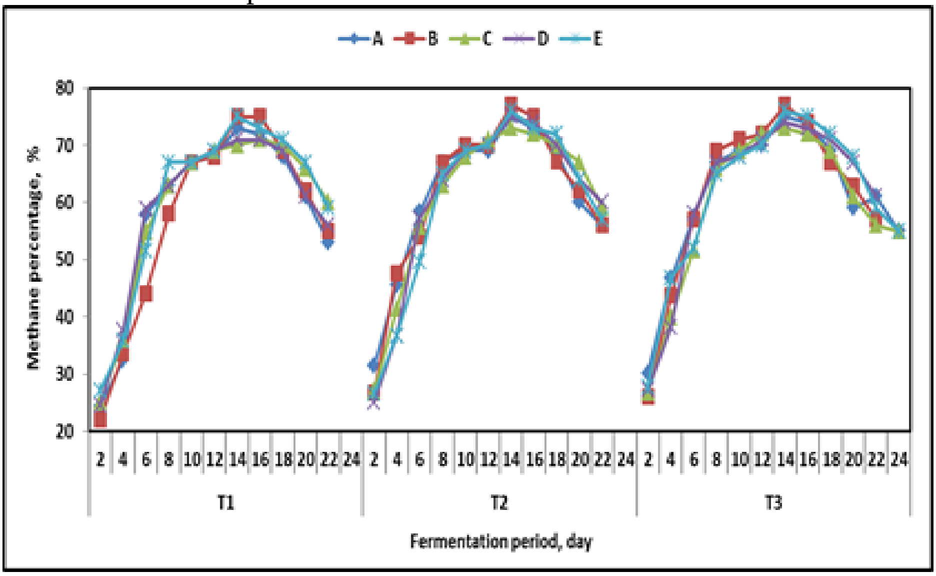


Fig. 5. Variation of methane percentage (CH_4) under different mixtures through fermentation period

4. Total nitrogen and pH of the final residual digestate under different mixtures

Total nitrogen and pH of the fermented mixtures are shown in Fig. 6. Obtained data revealed that T_3 (5.3%) > T_2 (4.1%) > T_1 (3.8%) in total nitrogen percentage under using mixture D. The high concentration of nutrients gives the slurry a high potential as fertilizer that can be used for soil improvement. While, mixture D gave the nitrogen percentage (5.3%) > E (4.2%) > A (4.1%) > C (3.7%) > B (3.3%) under using T_3. Nutrient concentration will increase slightly during digestion because of the loss of volatile solids, associated with methane generation. Due to the anaerobic conditions, most of the nitrogen in the sludge will be found in organic form, followed by ammonium and a very small part as nitrate **(Hons *et al.*, 1993)**.

Using agricultural waste water in T_3 of anaerobic digestion saved the quantity of usage water added to that high concentration of nitrogen which affected digestion process.

Regarding the hydrogen ion concentration (pH) in the final digested slurries for all mixtures, the recorded results showed that it ranged between 6.6 and 6.83 after fermentation period. The low pH levels were recorded supported by inhibition of methanogenesis, which was below the range for methanogenic activity. Therefore, the starter and agricultural wastewater are added since they are a high concentration of methane bacteria which capable to increase the gas production.

High content of sugars in mixture B, the mixture was acidified and thereby, pH was increased comparing with other mixtures.

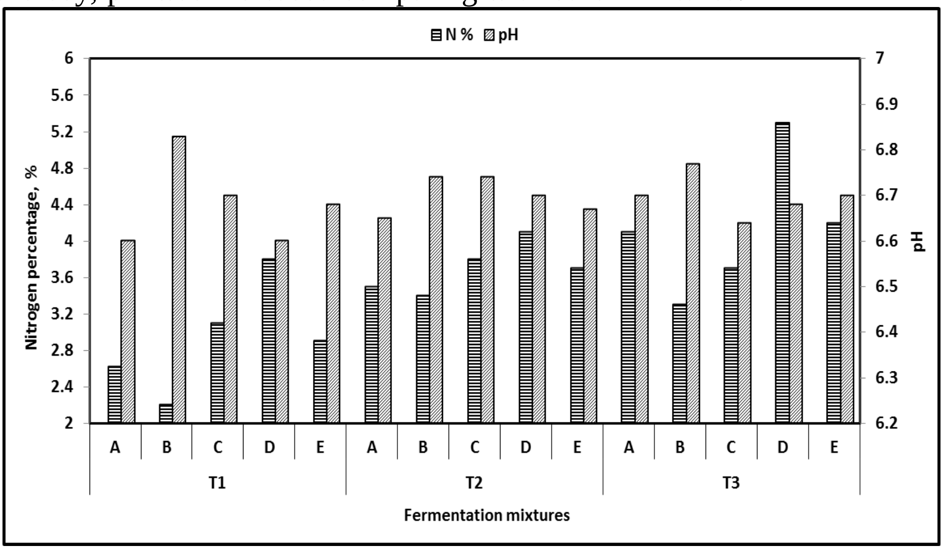


Fig. 6. Variation of total nitrogen percentage and pH of residual digestate under different fermentation mixtures

CONCLUSION

Analyses of the obtained experimental results from this study revealed that using starter with agricultural wastewater (T_3) for a digestion process increased the biogas production and methane content under the following conditions:

- For increasing the biogas production; mixture D > A > E > C > B.

- To get high methane percentage; mixture B > D > E > A > C.
- For obtaining a high concentration of N as a rich fertilizer; mixture D > E > A > C > B.

The total nitrogen of the poultry droppings can be increased by the addition of water hyacinth and sugar beet leaves (D) which provides atmosphere for the anaerobic microorganisms.

Based on the above discussion; recycling of wastes and biogas production requires strong governmental support to be successful, investments and technological skills that would solve great problems in developing countries.

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الملخص العربى

تحسين إنتاج الغاز الحيوي من المخلفات الزراعية والعضوية باستخدام مياه الصرف الزراعى والبادئ

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تعد تكنولوجيا البيوجاز والتي تعتمد علي التخمر اللاهوائى للمخلفات الصلبة والسائلة من التكنولوجيات المنتشرة في العديد من دول العالم لمعالجة مخلفات الصرف ومخلفات المزرعة النباتية والحيوانية والقمامة بطريقة اقتصادية وآمنة صحياً لحماية البيئة من التلوث مع إنتاج غاز الميثان كمصدر جديد ومتجدد للطاقة يساهم إلى حد كبير في ترشيد استهلاك الطاقة التقليدية كالبترول وحماية البيوماس من الحرق المباشر.

البيوجاز خليط من غازي الميثان (٥٠-٧٠٪) وثاني أكسيد الكربون (٢٠-٢٥٪) مع مجموعة غازات أخرى مثل كبريتيد الأيدروجين والنيتروجين والأيدروجين تتراوح نسبتها بين ٥-١٠٪ ، والبيوجاز غاز غير سام عديم اللون ويتخلف بعد إنتاجه سماد عضوي جيد غني في محتواه من

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المادة العضوية والعناصر السمادية الكبري والصغري فضلاً عن احتوائه علي الهرمونات النباتية والفيتامينات ومنظمات النمو ويكون خالياً من الميكروبات المرضية وبذور الحشائش حيث تهلك تماماً أثناء تخمر المخلفات العضوية مما يجعله سماداً نظيفاً لايلوث البيئة ولا خطورة من استخدامه في تسميد جميع المحاصيل .

لذا فقد اتجه البحث الى استخدام البادئ (٥%) ومياه الصرف الزراعى كمحفز لزيادة انتاج الغاز الحيوى ، بالإضافة الى دراسة تأثير خليط من المخلفات على نسبة الميثان وكذلك تقدير محتوى ناتج عملية التخمر من العناصر المغذية كسماد خصب للتربة

تم تنفيذ التجارب على خمسة مخمرات رأسية حجمها الفعلى ١.٥ لتر لدراسة تأثير استخدام خمسة مخاليط مختلفة من المخلفات وهى: (A) ٥٠% روث الماشية + ٥٠% زرق الدواجن ، (B) ٥٠% ورد الماء + ٥٠% أوراق بنجر السكر ، (C) ٥٠% روث الماشية + ٢٥% ورد الماء + ٢٥% أوراق بنجر السكر ، (D)٥٠% زرق الدواجن + ٢٥% ورد الماء + ٢٥% أوراق بنجر السكر ، (E) ٢٥% روث الماشية + ٢٥% زرق الدواجن + ٢٥% ورد الماء + ٢٥% أوراق بنجر السكر ، تحت تأثير ثلاث ظروف للتخمر وهى: (T_1) المخلوط + المياه (الكنترول) ، (T_2) المخلوط + المياه + البادئ (٥% من حجم المخمر الفعلى) و (T_3) المخلوط + البادئ (٥% من حجم المخمر الفعلى) + مياه الصرف الزراعى تحت ظروف تشغيل درجة حرارة الغرفة (٢٥°م) في مدى بكتريا الميزوفيليك مع اجراء عملية التقليب مرتين يدويا بمعمل كلية الزراعة – جامعة الزقازيق خلال عام ٢٠١٦.

تم تقييم أداء هذه المخمرات الرأسية المستخدمه تحت تأثير العوامل السابقة على كلا من الانتاج اليومى للغاز ، الانتاج الكلى خلال مدة التخمر ، نسبة الميثان ، نسبة النيتروجين ودرجة الحموضة ، لامكانية تطبيق ماسيتم التوصل اليه من نتائج على نطاق واسع من المخمرات.

وقد أظهرت النتائج أن استخدام المعاملة بمياه الصرف الزراعى والبادئ (T_3) كان لها تأثير واضح على زيادة انتاج الغاز ونسبة الميثان تحت تأثير المخاليط الآتية:

- لانتاج عالى من الغاز يوصى باستخدام: D > A > E > C > B.
- لزيادة نسبة الميثان فى الغاز الناتج فكان: B > D > E > A > C.
- للحصول على نسبة نيتروجين عاليه فى السماد الناتج من عملية التخمر يستخدم: D > E > A > C > B .

استنادا إلى المناقشة الواردة أعلاه ، فإن إعادة تدوير المخلفات و انتاج الغاز الحيوي يتطلب الدعم الحكومي القوي والاستثمارات والمهارات التكنولوجية التي من شأنها أن تحل مشاكل كبيرة في البلدان النامية.

لذا يوصى الباحث بإعادة تدوير المخلفات الزراعية بتحويلها الى منتج ذو قيمة وتعظيم الاستفاده منها كمصدر متجدد للطاقه وتجنب تأثيرها السئ على البيئة بإمكانية انتاج أكبر كمية من الغاز والسماد من هذه المخلفات.