Zagazig J. Agric. Res., Vol. 44 No. (6B) 2017 2703-2716

Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

EFFECT OF DIFFERENT CONCENTRATIONS OF TOTAL SOLID ON BIOGAS PRODUCTION FROM POULTRY WASTES SLURRY

Mahmoud M.A. Hussein[1*], M.K.Afify[2], I.I.I. Ghanem[1] and Y.S. Awdallah[2]

1. Agric. Eng. Res. Inst., (AENRI), Giza, Egypt

2. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 16/10/2017 ; Accepted: 29/10/2017

ABSTRACT: Single batch dry anaerobic digestion (AD) experiments of high solid broiler litter (HSBL) at 37 ± 0.5°C (mesophilic condition) and the inoculum concentration of 40% based on wet weight of HSBL were studied until biogas production stopped or/and was negligible to maximize biogas and methane yield form HSBL by overcoming its obstacles of production. Three different phases of HSBL (first: untreated HSBL, second: ground HSBL, and third: sieved HSBL) were used, and they were diluted by tap water according to the dilution ratios (HSBL: Water) of 1:1, 1:2 and 1:4 (wet weight basis). Then, the mixtures were anaerobically digested using batch operated 500ml reactors. Biogas and methane productions were affected by dilution ratio, grinding and sieving pretreatments. The highest biogas productivity from dry AD of untreated, ground, HSBL was 14.27 NL/kg untreated HSBL and 17.80 NL/kg ground HSBL at the dilution ratios of 1 : 4 for 50 days of solid retention time (SRT) respectively. The highest biogas productivity from dry AD of sieved HSBL was 78.74 NL/kg sieved HSBL from feedstock of 10 > PS ≥ 5 at the dilution ratio of 1:4 for 75 days of SRT.

Key words: Broiler litter, dry anaerobic digestion, grinding pretreatment, sieving pretreatment, biogas.

INTRODUCTION

Recent increase in poultry farms on relatively small land area have resulted in high energy requirements for operating these farms and producing large amount of poultry manure. FAO (2017) reported that Egypt produces circa 6.3 million tons of chicken manure from broiler and layer farms annually. Of this amount, the majority was estimated by about 6 M ton/year and composed of broiler chickens. Sakar *et al.* (2009) mentioned that inefficient and unsafe of poultry waste processing can have severe environmental impacts including groundwater contamination, contaminated surface water runoff and the attraction of insects, rodents and other pests and greenhouse gases emission, mostly as methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). This manure is currently treated either by incineration or by composting.

Currently, the global mix of energy comes from fossil, renewable and nuclear energy sources. The dependence on fossil fuels as primary energy source has led to global climate change, environmental degradation, and human health problems. Moreover, the recent rise in fossil fuels prices may drive the current economy towards alternative renewable energy sources with less negative impacts such as biogas.

Güngör-Demirci and Demirer (2004) stated that AD is a waste management technology capable of meeting both of the above mentioned environmental and energy concerns. The dual benefits was achieved by microbiological degradation of organic pollutants, greater inactivation of pathogens and weed seeds, reduction of global warming potential, diminishment of odor and green energy production in the form of biogas. Arogo *et al.*

*** Corresponding author: Tel. :** +201021789659
E-mail address: s.h.mahmoud2011@gmail.com

(2009) found that the source of the organic matter and the management of the AD process affect biogas composition, biogas consists of 55 - 80% methane (CH_4), 20 - 45% carbon dioxide (CO_2) and small amounts of other gases such as ammonia (NH_3), hydrogen sulfide (H_2S), and water vapor may be present. Afilal *et al.* (2014) reported that CH_4 has an energetic interest because it has a high calorific value by about 9.94 kWh/m^3.

Jha *et al.* (2011) stated that dry AD process generally takes place at solid concentrations higher than 10%. Demirer and Chen (2008) suggested that the appropriate inoculum to substrate ratio was 0.02 (*VS/VS*) for manure.

Bujoczek *et al.* (2000), and Magbanua *et al.* (2001) studied the AD of chicken manure (CM) containing TS in the range of 5 to 21.7%, but failed to produce any methane from fresh CM (21.7% TS) without dilution even after 120 days fermentation at 35°C. Moreover, anaerobic batch tests conducted using hog and poultry wastes in various proportions, only to produce a very low amount of methane not exceeding 0.9 ml g^{-1} VS, which was obtained after 99 days experimentation of CM with 17.4% TS and 14.6% VS, respectively.

Abouelenien *et al.* (2009b) has shown that the use of CM as a substrate for methane fermentation in a dry state under mesophilic conditions, generated 4.4 L methane gas per kg of CM, despite ammonia at a high level ranging from 8 to 14 g-N kg^{-1} CM. This clearly demonstrates that spontaneous acclimation of the methanogenic consortia to high levels of ammonia could occur and result in the production of methane even under a high percentage of total solids (25%) and a high level of ammonia.

AD and biogas production are especially suitable for broiler breeding farms because large amount of waste is produced and these farms use too much energy for heating purposes. However, AD of poultry manure has been historically challenging and infrequently implemented due to the major obstacles of heterogeneity of the substrate, high solids content of the substrate, inhibition of methanogenic archaea due to high nitrogen content, and the complex structure of bedding material (lignocellulosic biomass). Thus, the aim of this research is to maximize biogas and methane yield form HSBL by overcoming its production obstacles.

MATERIALS AND METHODS

Experiments were carried out through years of 2015 and 2016 in Agricultural Engineering Research Laboratory at El-Kasassin Horticultural Research Station, Agricultural Research Center to investigate biogas production from poultry wastes slurry against different concentrations of total solid.

Broiler Litter and Inoculum

Seven days old high solid broiler litter (HSBL), which is a mixture of broiler excreta, spilled feed, feathers, and bedding material, were sampled from a commercial poultry farm housing about 6,000 broilers per cycle and an annual manure production 14 ton at Sharkia Governorate (Egypt). Bedding material was chopped wheat straw. HSBL samples were stored in black sealed polyethylene bags to conserve the moisture at 4°C until used.

Anaerobic sludge obtained after wet AD process of cattle manure at dilution ratio (Cattle manure:Water) of 1:2 based on wet weight at mesophilic condition (37±0.5°C) for 50 days of digestion time was used as inoculum. Anaerobic sludge was collected using 20 liter plastic buckets with tight lids and immediately stored in a freezer maintained at -20°C and while further analyses and use. Inoculum was anaerobically digested at 37°C for 50 days for deducting the amount of biogas production by the residual organic matter in the inoculum.

The physiochemical characteristics (total solids (TS), volatile solids (VS), organic carbon (OC), total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH4+-N) concentrations, carbon to nitrogen ratio (C/N ratio), and pH) were analyzed for HSBL and inoculum as summarized in Table 1.

Reactor Setup

Experiments were carried out using 500 ml conical flask as a laboratory scale reactor. A reactor was tightly sealed with a natural rubber stopper to exclude oxygen, and it was connected *via* its gas outlet using 5mm plastic flexible

Table 1. Characterization of HSBL and inoculum used in experiments

Parameter	Unit	HSBL	Inoculum
Moisture content	*WW* %	26.89	95.88
TS	*WW* %	73.11	4.12
VS	*WW* %	59.53	3.20
OC	TS %	47.23	45.11
TKN	TS %	2.99	1.70
NH4+-N	mg/l	5084	476
C/N ratio	-	15.80:1	26.54:1
Bulk density	Kg/m^3	254.35	ND
pH	-	8.46	8.75

The analyses were done in soils, water, and environmental research institute.

connectors to a 100 ml burette glass as gas collecting apparatus. The gas collecting device has a valve which was used to run-off the collected gas to analyze. To ensure a constant temperature, reactors were placed in a constant temperature water bath which was insulated and automatically temperature controlled at 37 ± 0.5°C according to Radwan *et al.* (1993) and Verein Deutscher Ingenieure (2004) as shown in Fig. 1.

Experimental Procedure

Experiments A (EA)

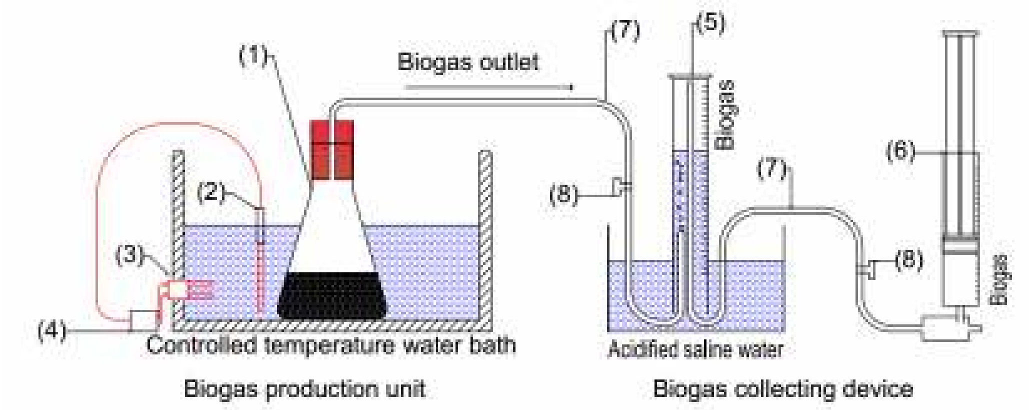
Single batch dry AD experiments of untreated HSBL were conducted for 50 days of SRT to study the effect of TS concentrations in the reactor content (dilution ratio) on biogas and methane production, and the digestibility of HSBL. Experiments were started by mixing untreated HSBL with three different dilution ratios (untreated HSBL: water) 1:1, 1:2, and 1:4 (wet basis). Each one of prepared mixtures was inoculated with the inoculum concentration of 40% (based on wet weight of untreated HSBL) according to Demirer and Chen (2008).

Experiments B (EB)

Grinding pretreatment of seven day old HSBL was carried out by blender grinder to reduce particle size (PS) and make HSBL more homogenized in structure and composition and easy to be digestible. Single batch dry AD experiments of ground HSBL were conducted for 50 days of SRT to study the effect of grinding pretreatment of HSBL on digestibility and biogas and methane production against different dilution ratios (ground HSBL: water) of 1:1, 1:2 and 1:4 at the inoculum concentration of 40% (based on wet weight of ground HSBL).

Experiments C (EC)

Sieving pretreatment was carried out to determine the composite components of HSBL depending on PS and make HSBL more homogeneity in structure and physiochemical characteristics. HSBL was sieved using a group of sieves placed on top of each other. The sieves have circular screen openings with according diameter (10, 5, 3 and 1mm). Sieved HSBL was collected from each sieve and weighed. So that, HSBL composed from four components PS≥10, 10>PS≥5, 5>PS≥3, and PS<1. The composition of sieved HSBL is summarized in Table 2. To individually understand the HSBL particle size behavior on the digestibility, and biogas and methane production, single batch dry AD processes of sieved pretreated HSBL against the dilution ratios (sieved HSBL: water) of 1:1, 1:2 and 1:4 at the inoculum concentration of 40% (based on wet weight of sieved HSBL) were studied for 75 days of SRT.



No.	Part name	No.	Part name
1	Conical flask	5	Burette
2	Pt100 temperature sensor	6	Syringe
3	Heater	7	Plastic flexible connector
4	Autonics temperature controller	8	Valve

Fig. 1. Schematic diagram of laboratory scale reactor

Table 2. Characterization of sieved HSBL

Parameter	Unit	P. S ≥ 10	10 > P. S ≥ 5	5 > P.S ≥ 3	P. S < 1
Water content	*WW* %	16.65	15.59	15.65	11.30
TS	*WW* %	83.35	84.41	84.35	88.70
VS	*WW* %	60.65	62.67	52.04	36.81
OC	TS %	42.21	43.07	35.78	24.07
TKN	TS %	3.17	2.60	2.91	2.1
NH4-N	mg/l	1336	1562	1268	1184
C/N ratio	-	13.32	16.56	12.30	11.46
pH	-	7.74	7.80	7.67	7.71
Bulk density	kg/m^3	203.50	109.70	143.00	438.72

The analyses were done in soils, water, and environmental research institute.

Each one of total sludge (HSBL+ Water + Inoculum) loaded into the reactors, which was labeled through experiments EA, EB, and EC as (R_1, R_2, R_3); (R_4, R_5, R_6); and (R_7, R_8,…, R_{18}), respectively. The details of these 18 batch dry AD Experiments of HSBL are given in Table 3.

The reactors were shaken once a day for 30 sec., manually after daily biogas measurement to achieve a contact between the micro-organisms and their substrate and assist in preventing scum formation (Radwan *et al.,* 1993).

The physiochemical characteristics of each one of total sludge were analyzed before and after AD process.

Analytical Methods

The physiochemical characteristics of HSBL, inoculum, and samples taken at the beginning and the end of AD process were used according to the Standard Methods for the Examination of Water and Wastewater (APHA *et al.,* 1995).

Table 3. Details of dry anaerobic fermentation of HSBL

R. No.	Mass of the mix (g)			HSBL type	Experiment
	HSBL	Water	Inoculum		
R_1	50	50	20		
R_2	50	100	20	Untreated HSBL	EA
R_3	50	200	20		
R_4	50	50	20		
R_5	50	100	20	Ground HSBL	EB
R_6	50	200	20		
R_7	50	50	20		
R_8	50	100	20	Sieved HSBL (P.S ≥10)	
R_9	50	200	20		
R_{10}	50	50	20		
R_{11}	50	100	20	Sieved HSBL (10> P.S ≥5)	
R_{12}	50	200	20		EC
R_{13}	50	50	20		
R_{14}	50	100	20	Sieved HSBL (5> P.S ≥3)	
R_{15}	50	200	20		
R_{16}	50	50	20		
R_{17}	50	100	20	Sieved HSBL (P.S <1)	
R_{18}	50	200	20		

- TS, the mass of solid material (dry matter) remaining after evaporating moisture from a sample, was determined by evaporating a mass of 10 - 20 grams of the homogenized representative sample in a drying oven at 103°C ± 2°C, cooling desiccating and weighing procedure until a constant weight is obtained or weight change is less than 4% of previous weight (Standard Method 2540 G).
- VS, usually the organic portion of the manure sample, were determined by ignition of the residue produced in TS analysis to constant weight or weight change is less than 4% of previous weight in a furnace at a temperature of 550 to 600°C (Standard Method 2540 G).
- Total TKN and N-NH4+ were measured as described in Standard Method 4500-Norg and N-NH4, respectively.
- pH measurements were performed by a pH meter (WTW 720 handheld pH meter, Germany) as described in Standard Method 4500H.
- Total phosphorus (P_2O_5) and Potassium (K_2O) was determined after sulfuric digestion according to Tedesco *et al.* (1995).

Measurements and Calculations

Normal volumetric production of biogas

The volume of biogas production (ml) from each reactor was measured daily by gas collecting device (height type) by acidified saline water (200 g of NaCL + 5 g of citric acid + 1L of distilled water) displacement method according to Müller *et al.* (2004).

Gas factor

The values of biogas production (ml), air pressure (mbar), gas temperature (°C) at the measurement time were used to calculate normal volume of biogas (at Standard Temperature and Pressure) by calculating the gas factor using introduced equations by Adebayo *et al.* (2013).

$$F=\frac{(P - PH_2O) \times T_o}{(t + 273.15) \times P_o}$$

Where:

F= Gas factor; To = 273.15°K (Normal temperature); t= Gas temperature in °C; Po= 1013.25 mbar (standard pressure); P = Air Pressure; PH_2O = Water vapor pressure.

Vapor pressure of water (PH_2O)

The respective vapor pressure of water is a function of gas temperature for describing the range between 15 and 30°C, and its given as the following equation introduced by Adebayo *et al.* (2013).

$$PH_2O = Y_o + a.e^{b.t}$$

Where:

Yo = - 4.39605; a = 9.762 and b= 0.0521

Normal biogas volume

The normal volume of daily produced biogas is given by the following equation:

$$Biogas_{daily} = Biogas(ml)_{daily} \times F \;\; Nml$$

Normal biogas productivity

The normal productivity based on weight of fresh HSBL is given by the following equation:

$$\text{Biogas productivity} = \frac{\text{Biogas yield (Nml)}_{HSBL}}{\text{Mass of HSBL (g)}} \text{Nml}/g_{HSBL}$$

Where:

1 N ml/ g FM*=1 NL/kg FM = 1 Nm^3/ton FM

*: Fresh manure

Carbon dioxide concentration (CO_2)

To determine CO_2 percentage in the total produced biogas, a known volume of the collected biogas (V_1) was syringed out by a syringe and dipped in a beaker, filled with concentrated potassium hydroxide solution (2N KOH and pH 13.56 according to Elasri *et al.* (2015)). Then, a volume of concentrated KOH solution was dragged into the syringe to increase the contact area between biogas and concentrated KOH solution. Syringe has yet dipped in concentrated KOH solution to compensate the shrinkage in V_1 due to CO_2 absorption. The syringe was shaken manually for 3–4 min. The volume of the remaining gas (V_2) was used to estimate the volume of absorbed CO_2 (V_1–V_2). The concentration of CO_2 was calculated from this equation:

$$CO_2 = \frac{V_1 - V_2}{V_1} \times 100\%$$

Methane concentration

The concentration of methane CH_4 can be estimated using the introduced equation by Konstandt (1976):

$$CH_4 = 100\% - [CO_2\% + 0.2\% \, H_2S] \, \% \, vol$$

Normal methane volume

The normal volume of daily produced methane is given by the following equation:

$$\text{Daily methane prodcution} = \frac{\text{Daily biogas production (Nml)} \times CH_4\%_{VOL.}}{100} \text{Nml}$$

Normal methane productivity

The normal productivity based on weight of fresh HSBL is given by the following equation:

$$\text{Methae productivity} = \frac{\text{Methane yield (Nml)}_{HSBL}}{\text{Mass of HSBL(g)}} \text{Nml}/g_{HSBL}$$

Energy production

Methane is the flammable gas in biogas composition with the lower heating value of 35.89 kJ L^{-1} (Theuretzbacher *et al.*, 2015). The total methane energy is calculated in kJ/kg of HSBL (wet basis) by multiplying methane productivity with 35.89.

Energy production = Methae productivity (Nl/kg_{HSBL}) × 35.89 kJ/kg

RESULTS AND DISCUSSION

Effect of Dilution Ratios and Grinding and Sieving Process on the Physiochemical Properties of Total Sludge

Table 4 represents the values of TS (%) *WW*, TS reduction (%), VS (%) TS, VS reduction (%), and pH of total sludge loaded in reactors (R_1, R_2,…, R_{18}) before and after dry AD process.

Initial T_S and V_S concentrations and initial pH values were affected by each of dilution ratio, grinding pretreatment, and sieving pretreatment. TS concentration of the reactor content had directly proportional to dilution ratio. After dry AD experiments, values of TS concentration decreased in all reactors when compared to before digestion. Dry matter degradation values were the highest (21.69%, 29.40 and 68.31%) in reactors R_2, R_6 and R_{18} within EA, EB, and EC, respectively.

After dry AD experiments, values of VS concentration decreased in all reactors when compared to before digestion. VS reduction values were the highest (30.72%, 58.06 and

Table 4. Physiochemical properties of total sludge before and after AD process

R. No.	TS (%) WW		TS Reduction (%)	VS% TS		VS Reduction (%)	pH	
	Initial	Final		Initial	Final		Initial	Final
R_1	31.12	24.84	20.18	81.23	76.50	24.77	8.74	6.84
R_2	22.81	17.87	21.69	81.94	75.86	30.72	8.68	7.99
R_3	15.20	12.46	18.04	83.56	78.44	28.43	8.77	6.97
R_4	32.72	31.23	4.54	65.06	45.03	56.00	7.60	6.76
R_5	26.22	23.95	8.66	63.70	51.68	39.06	7.78	6.67
R_6	17.92	12.65	29.40	69.63	49.01	58.06	7.82	6.40
R_7	34.75	30.89	11.11	72.23	67.17	21.33	7.87	7.21
R_8	24.96	21.92	12.18	69.89	67.81	9.25	8.14	6.65
R_9	17.50	15.30	12.57	69.39	58.45	37.94	8.09	6.78
R_{10}	35.49	33.72	4.97	70.50	59.57	38.35	7.96	7.12
R_{11}	23.89	22.04	7.74	71.26	68.47	12.42	7.92	6.90
R_{12}	15.35	12.22	20.40	69.54	61.08	31.24	7.87	8.22
R_{13}	35.03	31.55	9.94	63.84	58.50	20.15	7.90	7.13
R_{14}	24.75	22.18	10.36	65.76	48.46	51.04	7.97	8.27
R_{15}	18.97	8.18	56.88	63.86	57.14	24.53	8.06	8.20
R_{16}	37.27	36.19	2.91	41.21	32.71	30.66	7.84	7.39
R_{17}	25.91	22.37	13.66	48.52	39.92	29.50	7.88	7.34
R_{18}	18.47	5.85	68.31	44.02	33.25	36.65	7.76	8.24

The analyses were done in soils, water, and environmental research institute.

51.04%) in reactors R_2, R_6, and R_{14} within EA, EB, and EC, respectively. This may be attributed to amount of water used. Where, water content in the substrates is essential for the activities of the AD process. Ground HSBL has obtained higher VS reduction values compared to the untreated HSBL after dry AD at dilution ratios 1:1, 1:2 and 1:4 since small particle size gave a large surface area for substrate adsorption and thus allowed the increased microbial activity.

pH value is important parameter for assessing the efficiency of dry AD experiments. After dry AD of untreated HSBL and ground HSBL, the pH values decreased in all reactors when compared to before digestion. This may be attributed to accumulation of VFAs resulting from degradation of organic matter. Ground HSBL has obtained lower final pH values compare to the untreated HSBL after dry AD at dilution ratios 1:1, 1:2 and 1:4 due more microbial activities were occurred, resulting accumulation of VFAs.

After dry AD experiments of sieved HSBL (EC), the pH values increased in the reactors of R_{12}, R_{14}, R_{15}, and R_{18} when compared to before digestion, and they were 8.22, 8.27, 8.20, and 8.24. This may be attributed to the methane-producing bacteria consume the acids, alkalinity is produced and the pH within these reactors will increase or/and may be due to the production of alkali compounds (*e.g.,* ammonium ions) during the degradation of organic compounds. The pH values decreased in the other reactors when compared to before digestion. This may be attributed to accumulation of VFAS resulting from degradation of organic matter.

Effect of Dilution Ratios, Grinding and Sieving Processes on Biogas Productivity

Biogas productivity provides a common basis for comparison between different trails. Biogas productivity of 20 grams of inoculum, used in inoculating of later dry AD experiments was about 81.5 Nml.

Fig. 2 represents comparison between biogas productivity from ground and untreated HSBL with respect to mass of HSBL in the content of reactor (NL/kg HSBL) against dilution ratios of 1:1, 1:2 and 1:4 at the inoculum concentration of 40% for 50 days of SRT.

Biogas productivity was affected by dilution ratio and grinding pretreatment. Increasing the dilution ratio from 1:1 to 1:2 and 1:4 led to increase biogas productivity of dry AD of untreated HSBL (EA) from 9.07 NL/kg HSBL to 12.20 and 14.27NL/kg HSBL since water content in the substrates is essential for the microbial activities of the AD process. These productivities are higher than that of 3.19 L/kg poultry dropping which was produced from AD of poultry dropping at 8% TS concentration for 30 days at temperature between 27-35°C when the mass mixing ratio was 1.08kg poultry dropping and 0.32 kg of fresh rumen content of freshly killed cattle as inoculant (Aremu and Agarry, 2013).

Biogas productivity from dry AD of ground HSBL (EB) was 15.45, 13.51, and 17.80NL/kg HSBL from reactors R_4, R_5 and R_6 at the dilution ratios of 1:1, 1:2 and 1:4 respectively. These productivities are higher than that of was produced by Aremu and Agarry (2013).

Biogas productivity from dry AD of ground HSBL was higher than that produced from untreated HSBL against dilution ratios of 1:1, 1:2, and 1:4 by about 70.89%, 10.65%, and 24.73%, respectively. This may be attributed to more organic matter degradation and higher biogas yield from dry AD of ground HSBL due to increased active surface area and easy access for degradative enzymes.

At dry AD experiments of A and B, The dilution ratio of 1:4 at the inoculum concentration of 40% is the most important quantity condition since it produced the highest biogas productivity of 14.27 and 17.80 NL/kg HSBL, respectively.

Biogas productivity with respect to mass of sieved HSBL in the content of reactor (NL/kg sieved HSBL) from dry AD of feedstocks of PS≥10, 10> PS ≥5, 5> PS ≥3, and PS<1 against dilution ratios of 1:1, 1:2, and 1:4 and the inoculum concentration of 40% for retention time of 75 days (EC) is represented in Fig. 3.

Biogas productivity was affected by dilution ratio and sieving pretreatment. The highest biogas productivity against dilution ratios of 1:1, 1:2, and 1:4 was 16.16, 21.82, and 78.74NL/kg sieved HSBL from dry AD of feedstocks of PS≥10, 5 < PS ≥3, and 10 < PS ≥ 5, respectively.

The highest biogas productivity of dry AD experiments C was 78.74 and followed by 78.06 and 56.74 NL/kg sieved HSBL from dry AD of feedstocks of 10 < PS ≥ 5, 5 < PS ≥3, and PS<1 against the dilution ratio of 1:4. This may due to the balance between acidogenesis and methanogenesis processes through dry AD of these feedstocks due to the characteristics of these feedstocks and amount of water used, and this directly appeared in final pH values. These productivities are higher than that of produced by Aremu and Agarry (2013) and from dry AD experiments A and B.

Effect of Dilution Ratios, Grinding and Sieving Processes on Methane Productivity

Methane productivity provides a common basis for comparison between different trails. Methane productivity of 20 grams of inoculum, used in inoculating of later dry AD experiments was about 72.99 Nml. Methane productivity was affected by dilution ratio, grinding pretreatment, and sieving pretreatment.

Fig. 4 displays comparison between methane productivity from ground and untreated HSBL with respect to mass of HSBL in the content of reactor (NL/kg HSBL) against dilution ratios of 1:1, 1:2, and 1:4 at the inoculum concentration of 40%.

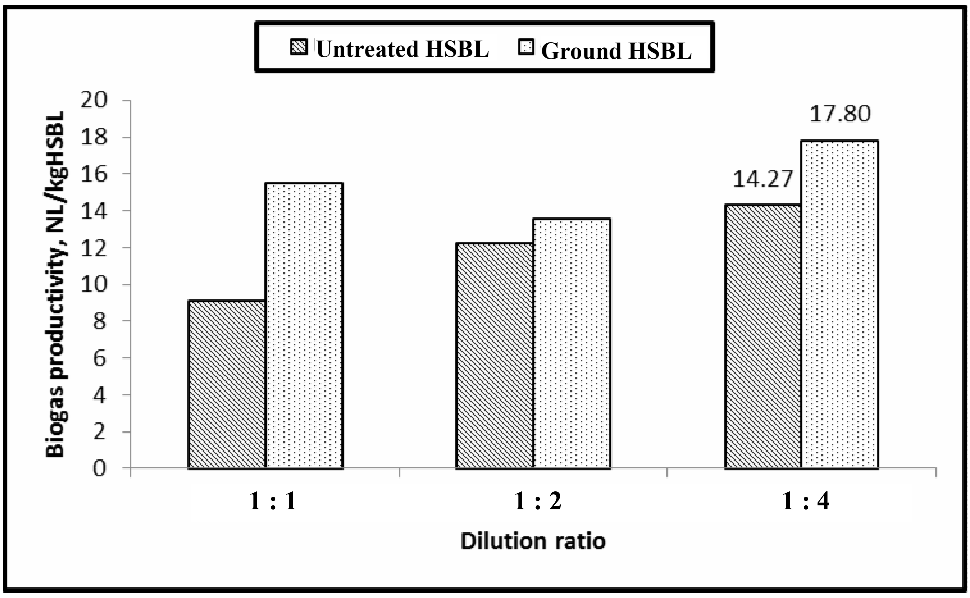


Fig. 2. Biogas productivity from dry AD of untreated and ground HSBL with respect to mass of HSBL in the content of reactor

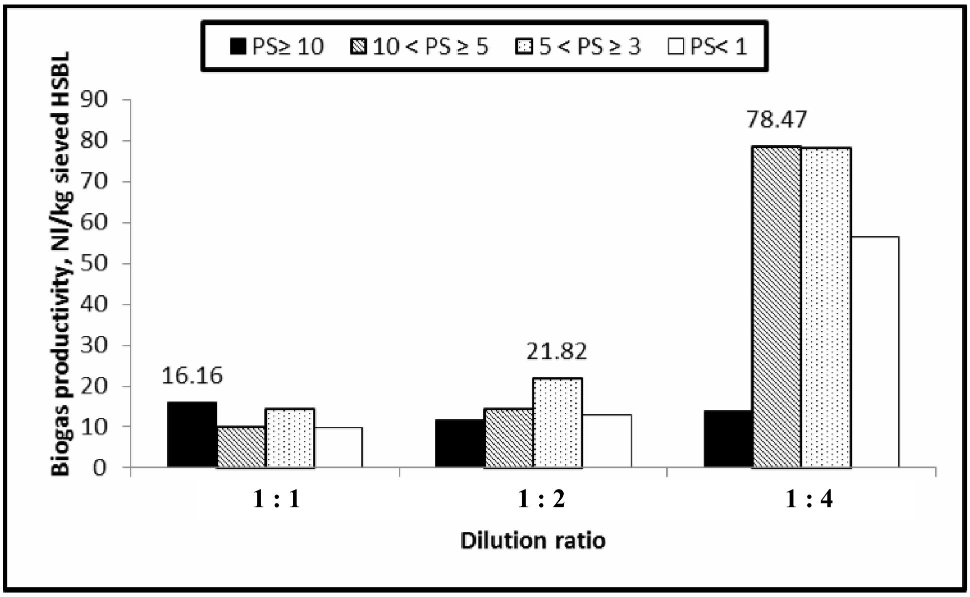


Fig. 3. Biogas productivity from dry AD of sieved HSBL with respect to mass of sieved HSBL in the content of reactor

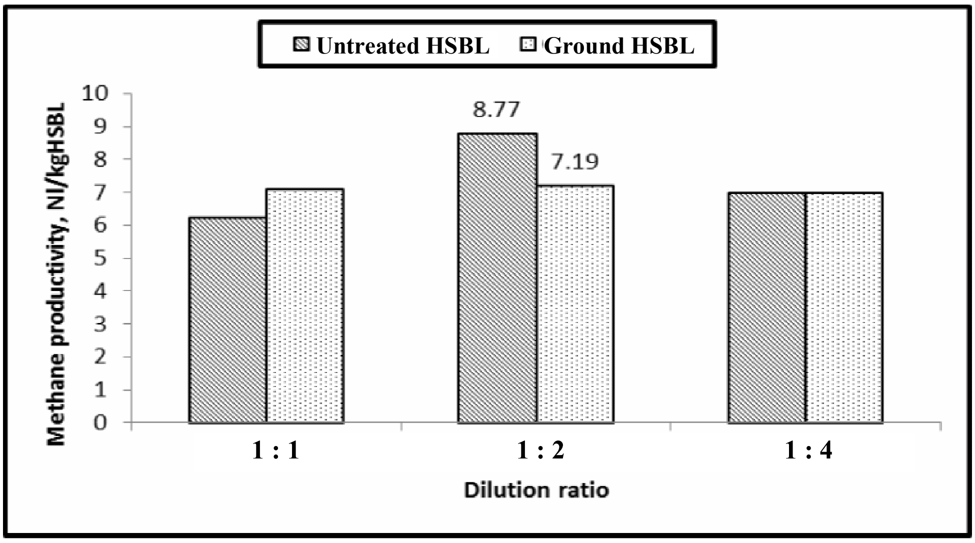


Fig. 4. Methane productivity from dry AD of untreated and ground HSBL with respect to mass of HSBL in the content of reactor

Methane productivity from dry AD of untreated HSBL (EA) was 6.21, 8.77 and 6.98 NL/kg HSBL against the dilution ratios of 1:1, 1:2 and 1:4 from reactors R_1, R_2 and R_3, when methane concentrations were 71.63%, 73.96% and 53.09%, respectively. Whereas, methane productivity of dry AD from ground HSBL (EB) was 7.09, 7.19 and 6.96NL/kg HSBL against the dilution ratios of 1:1, 1:2, and 1:4 from reactors R4, R5 and R6, when methane concentrations were 50.04%, 57.13% and 43.32%, respectively.

Methane productivity of dry AD experiments B was lowering than that of produced from dry AD experiments A at dilution ratios of 1:2 and 1:4. This may be attributed to the imbalance between acidogenesis and methanogenesis through dry AD experiments B because grinding process increased active surface area and easy access for degradative enzymes and the growth rate of acidogenesis bacteria is about ten times higher than acetogenesis and methanogenesis bacteria according to (Kalyuzhnyi 1997; Vavilin *et al.,* 2001). On the other hand, Methane productivity of dry AD experiments B was higher than produced from dry AD experiments A at dilution ratio of 1:1.

The highest methane productivity of dry AD experiments A and B was 8.77 and 7.19NL/kg HSBL at dilution ratio of 1:2, respectively. These productivities were higher than that of 6.9 L/kg CM produced from second batch fermentation of methane for 55 days at 35°C and the CM: Inoculum ratio of 1:2 on volume per volume basis for the residue of the methane fermentation of ammonia-stripped CM at 35°C for 75 days after second stripping of ammonia (Abouelenien *et al.,* 2009a).

The dilution ratio of 1:2 with the inoculum concentration of 40% is the most important qualitative condition through dry AD experiments A and B due to it produced a biogas with the highest calorific value of about 87.432 kWh/Mg HSBL and 71.680 kWh/ Mg HSBL for 50 days of SRT, respectively. These energy productions are lower than that of (100 kWh/Mg) produced from dry AD of organic fraction of municipal solid waste (OFMSW) at the waste: inoculum ratio of 1:1 (Di Maria *et al.,* 2012).

Methane productivity with respect to mass of sieved HSBL in the reactor content (NL/kg sieved HSBL) from dry AD of sieved HSBL ($PS \geq 10$, $10 > PS \geq 5$, $5 > PS \geq 3$ and $PS<1$) against dilution ratios of 1:1, 1:2, and 1:4 and the inoculum concentration of 40% for retention time of 75 days (EC) is represented in Fig. 5.

The highest methane productivity against each of the dilution ratios of 1:1, 1:2 and 1:4 was 9.77, 15.78 and 55.92 NL/kg sieved HSBL from dry AD experiments of feedstocks of $PS \geq 10$, $5 < PS \geq 3$, and $10 < PS \geq 5$, when methane concentrations were 63.12%, 73.51% and 71.64%, respectively.

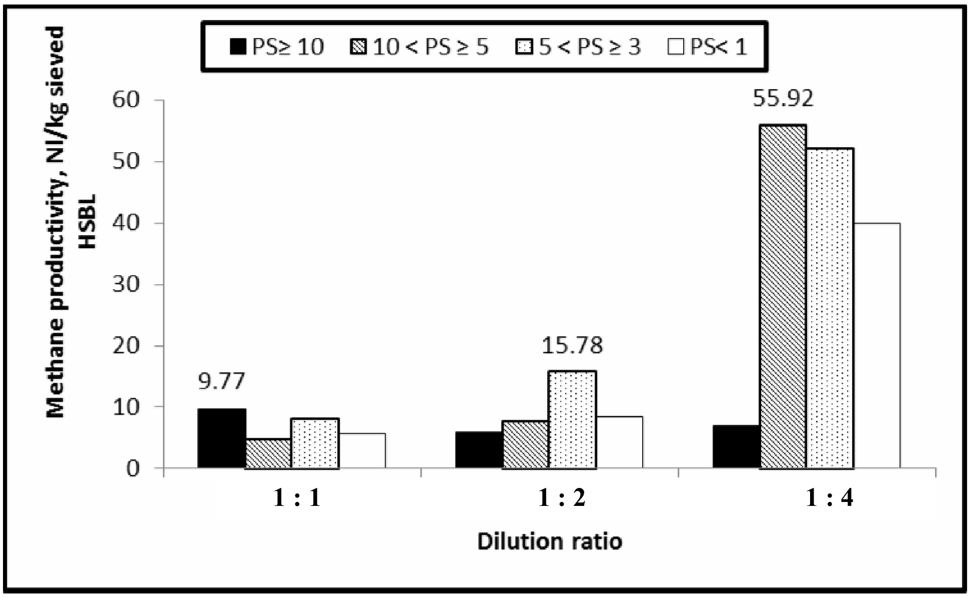


Fig. 5. Methane productivity from dry AD of sieved HSBL with respect to mass of sieved HSBL in the content of reactor

The highest methane productivity of dry AD experiments C was 55.92NL/kg sieved HSBL and followed by 52.02 and 39.87 NL/kg sieved HSBL from dry AD of feedstocks of 10 < PS ≥ 5, 5 < PS ≥3, and PS<1 against the dilution ratio of 1:4 in reactors R_{12}, R_{15} and R_{18}, and when methane concentrations were 71.64%, 67.11% and 71.13%, respectively. This may due to the balance between acidogenesis and methanogenesis processes through dry AD of these feedstocks and this directly appeared in final pH values. This productivity is not so low when compared with results obtained by Lehtomäki *et al.* (2007), where the methane productivity was 62 m^3/Mg fresh feed when the feed ratio (chicken manure: kitchen waste) by fresh matter was about 1:32. On the other hand, this productivity was higher than that produced by Abouelenien *et al.* (2009a) and produced from dry AD experiments A and B.

The dilution ratio of 1:4 and the feedstock of 10< PS≥5 at the inoculum concentration of 40%, are the most important quantity and qualitative conditions for dry AD experiments C since it produced the highest biogas productivity of 78.47NL/kg HSBL and biogas with the highest calorific value of about 557.49 kWh/ Mg sieved HSBL for 75 days of SRT, respectively. This energy is higher than that obtained by Di Maria *et al.* (2012) and lower than that obtained by Lehtomäki *et al.* (2007). Lehtomäki *et al.* (2007) produced 620KWh/Mg from AD of the mixture of chicken manure and kitchen wastes at mixing ratio of 1:32 based on weight of fresh matter.

Fertilizing Production

The physiochemical characteristics for effluent of dry AD of HSBL (digestate) at the most quantity and qualitative dilution ratio and HSBL type is shown in Table 5.

The physiochemical properties of digestate (TS, VS, OC, NH^+_4-N, TKN, P_2O_5, K_2O and pH) decreased compared to that of HSBL. Digestate sample taken after AD experiments contained on average 87.89% *WW* and 12.11% *WW* of moisture content and dry matter (TS), respectively. Digestate contained average 60.80%TS and 35.27% TS of organic matter and organic carbon, respectively. Digestate contained average 1583 ppm, 38 ppm, 1.34% TS, 2.8% TS, and 4.32%TS of ammonium nitrogen (NH^+_4-N), nitrates (NO_3), total nitrogen, total phosphorus (P_2O_5), and total potassium (K_2O), respectively. Digestate contained on average 2.76 mEq/l of total VFAs. The pH value of digestate was average 8.23.

Table 5. Physiochemical properties of digestate and HSBL

Parameter	HSBL	Digestate
Moisture content (%$_{WW}$)	26.89	87.89
TS (%$_{WW}$)	73.11	12.11
VS (%$_{TS}$)	81.43	60.8
OC (%$_{TS}$)	47.23	35.27
NH^+_4-N	5084	1583
Nitrates	46	38
TKN (%$_{TS}$)	2.99	1.34
Total phosphorus (P_2O_5) (%$_{TS}$)	3.28	2.8
Total potassium (K_2O) (%$_{TS}$)	4.6	4.32
VFAs, mEq/l	ND	2.76
pH value	8.46	8.23

The analyses were done in soils, water, and environmental research institute.

Conclusion

Results have demonstrated that treatment of HSBL by dry AD is feasible and positively at mesophilic conditions, inoculum concentration of 40% based in wet weight of HSBL, and shaking regime of once a day for 30 sec.

Biogas and methane production was affected by dilution ratio, grinding and sieving pretreatments. At dry AD of untreated HSBL, the dilution ratio of 1:4 was the most important quantity ratio since it produced the highest biogas yield (795.21Nml), but the dilution ratio of 1:2 was the most important qualitative ratio due to it produced the highest methane yield (511.40 Nml).

Grinding pretreatment made HSBL more homogeneity in composition by reducing particles size less than 3 mm. Grinding pretreatment of HSBL led to increase biogas yield compare to that of produced from untreated HSBL. The highest biogas yield from dry AD of ground HSBL was 971.72 Nml at the dilution ratios of 1:4, which is higher than that of produced from dry AD of untreated HSBL by about 22%. The highest methane yield of dry AD of ground HSBL was 432.40Nml at the dilution ratios of 1:2, which was lower than that produced from dry AD of untreated HSBL by about 15.45%.

Sieving pretreatment made HSBL more homogeneity in structure and physiochemical characteristics. HSBL composed from four components PS ≥ 10, 10 > PS ≥ 5, 5 > PS ≥ 3, and PS < 1 depending on particle size (screen opening diameter). The highest biogas yield from dry AD of sieved HSBL was 4004.85Nml, and followed by 3984.40 and 2904.90Nml, which produced from AD of feedstocks of 10 > PS ≥ 5, 5 > PS ≥ 3, and PS<1 at the dilution ratio of 1:4. The highest cumulative methane yield produced from dry AD of sieved HSBL was 2869.14Nml, and followed by 2674.08 and 2066.27Nml which produced from AD of feedstocks of 10 > PS ≥ 5, 5 > PS ≥ 3, and PS<1 at the dilution ratio of 1:4. Thus, the dilution ratio of 1:4 and feedstocks of (10 > PS ≥ 5, 5 > PS ≥ 3, and PS<1) are the most important quantity and qualitative conditions for dry AD of sieved HSBL.

The calorific value of the highest methane productivity from dry AD of untreated, ground, and sieved HSBL was 87.43, 71.68, and 557.49 kWh/Mg HSBL.

REFERENCES

Abouelenien, F., Y. Kitamura, N. Nishio and Y. Nakashimada (2009a). Dry anaerobic ammonia–methane production from chicken manure. Appl. Microbiol. and Biotechnol., 82 (4): 757-764.

Abouelenien, F., Y. Nakashimada and N. Nishio (2009b). Dry mesophilic fermentation of chicken manure for production of methane by repeated batch culture. J. Biosci. and Bioeng., 107(3): 293-295.

Adebayo, A.O., S.O. Jekayinfa and B. Linke (2013). Effect of co-digestion on anaerobic digestion of cattle slurry with maize cob at mesophilic temperature. J. Energy Technol. and Policy, 3(7): 47-54.

Afilal, M., O. Elasri and Z. Merzak (2014). Caractérisations des déchets organiques et évaluation du potentiel biogaz (organic waste characterization and evaluation of its potential biogas). J. Mater. Environ. Sci., 5 (4): 2014.

APHA, A.W.W.A. and WEF (1995). Standard Methods for the Examination of Water and Wastewater. Washington, Ame. Public Health Assoc.

Aremu, M. and S. Agarry (2013): Enhanced biogas production from poultry droppings using corn-cob and waste paper as co-substrate. Int. J. Eng. Sci. and Technol., 5 (2): 247-253.

Arogo, J.O., Z. Wen, J. Ignosh, E. Bendfeldt and E.R. Collins (2009). Biomethane technology. Coll. Agric. and Life Sci., Virginia Polytechnic Inst. and State Univ., 442-881.

Bujoczek, G., J. Oleszkiewicz, R. Sparling and S. Cenkowski (2000). High solid anaerobic digestion of chicken manure. J. Agric. Eng. Res., 76 (1): 51-60.

Demirer, G. and S. Chen (2008): Anaerobic biogasification of undiluted dairy manure in leaching bed reactors. Waste Manag., 28 (1): 112-119.

Di Maria, F., A. Sordi and C. Micale (2012). Optimization of solid state anaerobic digestion by inoculum recirculation: The case of an existing mechanical biological treatment plant. Appl. Energ., 97: 462-469.

Elasri, O., M. Afilal, I. Hafidi, O. Boujibar and T. Chafik (2015). Proposition of biogas filtration system. J. Mater. Environ. Sci., 6 (10): 2804-2810.

FAO (2017): Befs assessment for Egypt: (sustainable bioenergy options from crop and livestock residues).

Güngör-Demirci, G. and G.N. Demirer (2004). Effect of initial cod concentration, nutrient addition, temperature and microbial acclimation on anaerobic treatability of broiler and cattle manure. Biores. Technol., 93 (2): 109-117.

Jha, A.K., J. Li, L. Nies and L. Zhang (2011). Research advances in dry anaerobic digestion process of solid organic wastes. Afr. J. Biotechnol., 10 (64): 14242-14253.

Kalyuzhnyi, S. (1997). Batch anaerobic digestion of glucose and its mathematical modeling. Ii. Description, verification and application of model. Bioresource Technol., 59 (2): 249-258.

Konstandt, H.G. (1976). Engineering's operation and economics of methane gas production. Seminar on microbial energy conversion Gottingen,Germany, Erich Goetze Verlag.

Lehtomäki, A., T. Paavola, S. Luostarinen and J. Rintala (2007). Biokaasusta energiaa maatalouteen: Raaka-aineet, teknologiat ja lopputuotteet. Jyväskylän yliopiston bio-ja ympäristötieteiden laitoksen tiedonantoja 85.

Magbanua, B.S., T.T. Adams and P. Johnston (2001). Anaerobic codigestion of hog and poultry waste. Bioresource Technol., 76 (2): 165-168.

Müller, W.-R., I. Frommert and R. Jörg (2004). Standardized methods for anaerobic biodegradability testing. Re/Views in Environ. Sci. and Bio-Technol., 3 (2): 141-158.

Radwan, A., H. Sebak, N. Mitry, E. El-Zanati and M. Hamad (1993). Dry anaerobic fermentation of agricultural residues. Biomass and Bioenergy, 5 (6): 495-499.

Sakar, S., K. Yetilmezsoy and E. Kocak (2009): Anaerobic digestion technology in poultry and livestock waste treatment-a literature review. Waste Manag. and Res., 27 (1): 3-18.

Tedesco, M.J., C. Gianello, C.A. Bissani, H. Bohnen and S.J. Volkweiss (1995). Análises de solo, plantas e outros materiais, Ufrgs Porto Alegre.

Theuretzbacher, F., J. Blomqvist, J. Lizasoain, L. Klietz, A. Potthast, S.J. Horn, G. P.J. Nilsen, A. Passoth and V.A. Bauer (2015). The effect of a combined biological and thermo-mechanical pretreatment of wheat straw on energy yields in coupled ethanol and methane generation Bioresour. Technol., 194: 7–13.

Vavilin, V.A., S.V. Rytov, L.Y. Lokshina, J.A. Rintala and G. Lyberatos (2001): Simplified hydrolysis models for the optimal design of two-stage anaerobic digestion. Water Res., 35 (17): 4247-4251.

Verein Deutscher Ingenieure, V.E. (2004). Green paper: Fermentation of organic materials). Beuth Verlag GmbH, D-10772 Berlin.

تأثيـر تركيــزات مختلفـــة للمـادة الصلبــة علـى إنتاج الغـاز الحيـوي من مخلفات الدواجن المســـــيله

محمود محمد أحمد حسين[1] – محمود خطاب عفيفي[2] – إبراهيم إبراهيم إبراهيم غانم[1] – ياسر صبح عوض الله[2]

١- معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

تم دراسة تجارب التخمر اللاهوائي الجاف لمخلفات دواجن التسمين (زرق+ مادة الفرشة المكونة من تبن القمح) بنظام الدفعة الواحدة عند درجة حرارة تخمر ٣٧ ± ٠,٥°م ونسبة لقاح ٤٠% على أساس الوزن الرطب للمخلف حتى توقف إنتاج الغاز الحيوي بهدف تعظيم إنتاج الغاز الحيوي والميثان منها وذلك عن طريق التغلب على عقبات الإنتاج، لقد استخدمت مخلفات الدواجن في ثلاث صور(الصوره الأولي: المخلف بدون معاملة ، الصورة الثانية: المخلف بعد معاملته بالطحن و الصورة الثالثة: المخلف بعد معاملته بالغربلة) عند ثلاث مستويات من الخلط بالمياه (مخلف : مياه) ١:١، ١:٢و ١:٤ علي أساس الوزن الرطب للمخلف، لقد هضمت الخلائط (المخلف + اللقاح + المياه) لاهوائيا باستخدام مخمرات معملية سعة ٥٠٠مللتر، وكانت أهم النتائج المتحصل عليها: أقصى إنتاجية للغاز الحيوي من عملية التخمر اللاهوائي للمخلف بدون معاملة ١٤,٢٧ لتر عياري/ كيلوجرام مخلف عند نسبة خلط بالمياه ١:٤ خلال فترة تخمر ٥٠ يوم، أقصي إنتاجية للغاز الحيوي من عملية التخمر اللاهوائي للمخلف المطحون ١٧,٨٠ لتر عياري/كيلو جرام مخلف مطحون عند نسبة خلط بالمياه ١:٤ خلال فترة تخمر ٥٠ يوم، أقصى إنتاجية للغاز الحيوي من عملية التخمر اللاهوائي للمخلف المعامل مسبقا بالغربلة ٧٨,٧٤ لتر عياري /كيلوا جرام من المخلف المعامل بالغربلة ($5 \leq PS < 10$) عند نسبة خلط بالمياه ١:٤ خلال فترة تخمر ٧٥ يوم.

المحكمون :

١- أ.د. محمد علي أحمد عبدالهادي أستاذ ورئيس قسم الهندسة الزراعية- كلية الزراعة بالإسماعيلية- جامعة قناة السويس.

٢- أ.د. محمـــد سعد الدين الشـــال أستاذ الهندسة الزراعة المتفرغ- كلية الزراعة- جامعة الزقازيق.