EFFECT OF MIXING BANANA PEELS WITH FRISH CATTLE MANURE ON BIOGAS PRODUCTION

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ABSTRACT

Egypt is an agricultural country and has a big potential of biogas generation from different types of wastes. Producing of biogas from agricultural wastes gives new and clean energy and good organic fertilizer as a method to protect environment from pollution by wastes. The digestion of banana peels mixed with cow dung for biogas production at laboratory scale was the subject of this investigation. Laboratory experiments were conducted to evaluate the biogas production from mixing banana peels fruits with fresh cattle manure in order to explore their potential application in biogas production. The study was carried out at a control temperature of 35±2°C for a period of 57 days with a total solid concentration of 8% in each reactor. The biogas and methane produced were collected by water displacement method. In the current work, four reactors were used: A, B, C and D contains 0, 20, 40 and 60% banana peels (by weight) mixed with fresh cattle manure respectively. The experiments run out in anaerobic system under control of temperature. The results showed that mixing banana peels ratio of 40% increase biogas production but increasing the ratio to 60 % or more cause decreasing in biogas production.

INTRODUCTION

The main energy reservoirs of the world consist of fossil fuels like petroleum products, natural gas. These fossil fuels are not fulfilling the world energy demand but also creating environmental problems like greenhouse gases **(NCAR, 2008)**. Also the rising of fossil oil potentially diminishing supplies, attendant pollution problems associated with petroleum and allied products. Therefore, the world is going to face a serious problem of energy scarcity after 100 years. On the other hand the problem of agricultural wastes becomes very obvious and aggregated after the harvest of summer crops.

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That is because the farmer is in a rush to cultivate his land therefore getting rid of the wastes usually by burning causing harmful effects on the environment. In addition, storing these wastes in the field after compacting may make it suitable environment for reproduction and growth of pests and pathogens that will attack new crops. Therefore, utilization of agriculture wastes in any other environmentally friendly way is very important. **Shaban and Omaima, (2010)**, addition of the agricultural wastes can be utilized by animal feed production, compost production or utilizing of these wastes in produce biogas. Producing of biogas from agricultural wastes by anaerobic digestion **(AD)** gives a new and clean source of energy and good organic fertilizer as a method to protect environment from pollution by wastes. **Khalid et al., (2010)** indicated that, bananas are grown in more than hundred countries, mostly in the developing world where they represent an important staple food. Banana is an important fruit crops, staple food and cash crop in Egypt, due its great economic importance as well as nutritional value and high availability throughout the year. **Emmanuel et al., (2014)** said that, bananas generate huge waste quantities, currently underutilized and discarded causing detrimental impact to the environment. **Muhammed et al., (2009)** compared the amount of methane produced from different fractions of banana (stem, peel, and fruit) through anaerobic batch digestion assays at 37 °C for a period of 35 days, they found that, the stem, peel and fruit fractions represented 0.84%, 17.71% and 81.46% of the total methane production potential of the whole banana with specific methane yield of 0.256, 0.322, and 0.367 m^3/kg volatile solids respectively. **Latika et al., (2012)**, reported that the banana peel can be converted into glucose which can be used as feedstock to produce ethanol by fermentation and distillation. Furthermore, ethanol by fermentation offers a more favorable trade balance, increased energy security, and a major new crop for a depressed agricultural economy. **Mohapatra et al., (2010**) reported that, banana peels have been found to contain lignin (6-12%), pectin (10-21%), cellulose (7.6-9.6%) and hemicelluloses (6.4-9.4%). Effectively utilize banana wastes for bio-methane production, a promising pre-treatment method must be applied to these materials prior to their anaerobic digestion. Pre-treatment can be mechanical, biological, physicochemical or a combination of these methods. Biological pre-treatment of lignocelluloses substrates includes the use of white-rot fungi, pre-composting, hydrolytic bacteria and commercial enzymes. Drying and milling pre-treatments have been reported to improve the subsequent AD by 5% compared to the untreated. **Muhammad et al., (2009**), reported that, the banana waste is a concentrated source of putrid organic waste, ideal for anaerobic digestion to produce energy while fermentation products can serve as fertilizer with high nutritional value, as well as a valuable energy source in form of biogas. Channeling these peels in to the production of biogas is an efficient way of waste management. So that the object of this work is to make use of banana peels as an agricultural wastes in the production of biogas as a source of clean energy instead of discarded or burned, leading to contamination of the environment.

MATERIALS AND METHODS

1. Collection and preparation of banana peels:

The chemical analysis of banana peels indicated that, they contain lignin (6-12%), pectin (10-21%), cellulose (7.6-9.6%) and hemicelluloses (6.4-9.4%) (**Mohapatra et al., 2010**). Banana peels were collected from the local markets in Alexandria city. They cut into small pieces (0.5-1cm), and washed with tap water several times to remove any external dirt. They were air dried to remove the free water (**Figure 1**). After that they dried into oven for 24 hours at 105°C. The dried peels grinded into powder (0.5-1 mm) and kept in an air tied bottle prior to the experiments as shown in **Figure 2**. The physical and chemical composition of the materials (peel mix) were evaluated before and after digestion using standard procedures **(AOAC, 1990)** as shown in **Table 1**. The dried banana peels after those were mixed with cattle manure with a ratio of 20, 40 and 60% by weight.

Fig. (1): Banana peels before and after cutting and air drying

Fig. (2): Banana peels after grinded into powder

Table 1: physical-chemical analysis of different mixtures before and after digestion

Parameter	Reactor A Control		Reactor B 20%		Reactor C 40%		Reactor D 60%	
	before	after	before	after	before	after	before	after
pH	7.26	7.02	7.15	6.95	7.32	7.01	7.44	6.53
Reactor temp.	34.5	34.7	35	34.9	35.1	35	34.9	35.2
Moisture cont.	96	92	94	89	91	87	88	86
Total solids	8.5	11.5	9	11	8.7	10.2	9.5	10.5
Volatile solids	88.2	84.8	85.2	82.4	89.7	86.1	87.8	86.3
Carbon cont.	49	47.1	47.33	45.8	49.8	47.8	48.78	47.94
Nitrogen cont.	1. 87	1.82	1.86	1.75	2.11	1.98	2.25	2.21
C/N Ratio	26.2	25.88	25.45	26.17	23.6	24.14	21.68	21.69

2. Laboratory analysis:

Laboratory analysis before starting every experiment consisted of: cattle manure condition including **pH**, moisture content **(*MC*)**, total solids **(*TS*)**, volatile solids **(*VS*)** and carbone to nitrogen ratio **(C/N ratio)**. The measured values of the previous parameters are shown in **Table (2)**.

2.1. Moisture contents:

Moisture contents (***MC***) were determined in peels by using the laboratory oven. The samples were kept for about 2-3 hours in the oven at 110°C. The procedure was adapted from the book “standard methods 21st edition”.

2.2. Total solids:

To determine the total solids (***TS***) an approximately 10 g was placed on a foil plate and dried to a constant weight at 105°C.

$$\textit{Total Solids},\ \% = \textit{Final weight}\ (g) \times 100\ /\ \textit{Initial weight}\ (g) \qquad (1)$$

Volatile solids:

Volatile solids (***VS***) were determined using Muffle furnace model 186A. The procedure was adapted from the book "standard methods 21st edition". The samples were kept in the furnace for about 45 minutes at 550°C. The dried residue from total solids analysis was weighed and heated in a crucible for two hours at 500°C in a preheated furnace. After cooling the crucible and ash were weighed.

$$\textit{Volatile Solids},\ \% = 100 - \left(\left(V_3 - V_1\right) \times 100 / \left(V_2 - V_1\right)\right) \qquad (2)$$

Where

V_1 = Weight of the crucible, V_2 = Weight of dry residue and crucible,

V_3 = Weight of ash and crucible (after cooling)

2.3. Carbon to nitrogen ratio (C/N ratio)

FAO (1992), reported that, nitrogen present in the feedstock to provides an essential element for synthesis of amino acids, proteins and nucleic acids; and it is converted to ammonia which, as a strong base, neutralizes the volatile acids produced by fermentative bacteria. An overabundance of nitrogen in the substrate can lead to excessive ammonia formation, resulting in toxic effects. Thus, it is important that the proper amount of nitrogen be in the feedstock, to avoid either nutrient limitation (too little nitrogen) or ammonia toxicity (too much nitrogen).

The Nitrogen content was obtained in laboratory using Kjeldahl method while, carbon content of the feedstock was measured by considering the volatile solids content that was expressed as a percentage and the total carbon content were obtained from volatile solids data using an empirical equation as reported by **Badger et al., (1979)**:

$$\textit{Carbon},\ \% = VS\,(\%) / 1.8 \qquad (3)$$

Hence, the carbon to nitrogen ratio for each treatment is calculated by dividing the carbon percentage by nitrogen percentage.

Table 2: Characters of raw materials

Raw materials	MC%	TS%	VS%	pH	C/N ratio
Fresh banana peels	68.15	31.85	89.4	6.5	25.5
Fresh cattle manure	82.13	17.87	88.2	7.48	26.2

3. Experimental design and setup:

Anaerobic digestion was carried out in four glass reactors (2 liter each), as shown in **Figure (3)**. The four reactors A, B, C, and D were put inside a glass box (water bath 35×35×25cm), which has heater, fan and thermostat. Each reactor connects with two glasses with soft pipes, the first glass full of water and the second one is empty to receive the water from the first glass which represents the gas quantity according to water displacement method. While the methane content was monitored by using water displacement method after passing the gas through 5% NaOH solution to absorb the carbon dioxide (**Veeken and Hamelers, 1999**)

Fig. (3): A photo of the four reactors used in the experiment

The thermostat is fixed on the cover of the water bath and its pulp was put inside the water. The thermostat electrically connects to a heater and rotary fan. When water temperature decreases less than 35°C the heater and fan work until the temperature raise to 35°C. The room temperature in this experiment was ranged between 18 and 28°C during the 57 days of the experiment. The materials used for this experiment were mixtures of grinded banana peels with cattle manure.

4. Reactors filling:

A 300g of cattle manure were diluted with tap water to get 8-10 % total solids content to get large amount of gas which agreed with most researchers (**Budiyono, et al., 2010, Rashwan et al., 2012, Tsunatu D. et al., 2014**). The initial moisture content of the manure was determined in three replicates by drying the samples in the oven at temperature of 105 ˚C for 24 hours. The moisture content was determined according to **Eq. 4** in terms of wet basis (**Anonymous 1998**).

$$MC\,(w.b.)\% = \frac{m_w}{m_w + m_d} \times 100 \qquad (4)$$

Where:

***MC* (*w.b.*) %** = Moisture content of fresh manure (%), m_w = mass of water in the manure (g), m_d = mass of dry matter in the manure (g).

To achieve the desired moisture content for preparing the required total solid, an amount of water was added to the manure based on the following equation (**Anonymous 1998**):

$$m_{wa} = \frac{(TS_f - TS_S)}{TS_S} \times m_m \qquad (5)$$

Where:

TS_f = initial total solid content of fresh manure (%, w.b.), TS_s = desired total solid content of substrate manure (%, w.b.), m_m = initial mass of manure (kg), m_{wa} = the mass of water added to manure (kg).

Different weights of banana peels 0, 60, 120, 180 g represent 0%, 20%, 40%, and 60% of cattle manure weight. They were mixed with cattle manure were used. The ratio of banana peels were 0%, 20%, 40%, and 60% by weight for the reactors A, B, C, and D respectively. Reactor A was chosen to be the control reactor. It was filled with only 300g cattle manure diluted with water to get 8-10% TS.

5. Measuring quantity and quality of biogas

The gas production is daily measured by water displacement method whereas the quality, which is the percentage of methane from the biogas, is estimated by the displacement of sodium hydroxide, with a process held one next to the other. A mount of gas volume produced in the digester was captured in a bottle filled with water, which was kept under pressure. The gas coming out of the digester is stored in the displaced bottle. Adding back the displaced water to the displacement bottle would push out the biogas stored before; and passing it through 5 % NaOH solution. The CO_2 from the biogas would be retained in the solution whereas the methane would displace its equivalent volume of NaOH. Collecting the displaced solution and measuring its volume using a measuring cylinder would give the volume of methane from the produced biogas (**Veeken and Hamelers, 1999**). Hence, it would be possible to estimate the percentage of methane in the biogas, using the following simple equation.

$$CH_4, \% = \frac{Displaced\ NaOH}{Displaced\ Water\ (volume\ of\ biogas)} \times 100 \qquad (4)$$

RESULTS AND DISCUSSION

According to **Table (1)**, it can be seen that, the results showed little variation between different reactors in pH. The initial pH values of all reactors were ranged between 6.53 and 7.89 which agreed with various reports, and showed that the methanogenic bacteria are highly sensitive to pH and perform optimally in the pH range of 6.5 to 7.5 (**Garba et al., 1996** and **Uzodinma et al., 2008**). The C/N ratios of these agricultural wastes were within the optimum range of C/N ratio for biogas production under mesophilic condition, which is 20-30:1 (**Deublein and Steinhauser 2008**). The results of the experiment which carried out for the 57 days retention time indicates that different volume of banana peels mix with fresh cattle manure affected the total biogas production. The biogas production is graphically shown in **Figure (4),** which indicates that, reactor A started the production on the 4^{th} day and reached to maximum value on the 29^{th} day (**800 ml**). Reactor B started the production on the 3^{rd} day and reached to maximum value on the 6^{th} day (**870 ml**). Reactor C started the production on the 3^{rd} day and reached to maximum value on the 7^{th} day (**1250 ml**). Reactor D started the production on the 4^{th} and reached to maximum value on the 17^{th} day (**850 ml**).

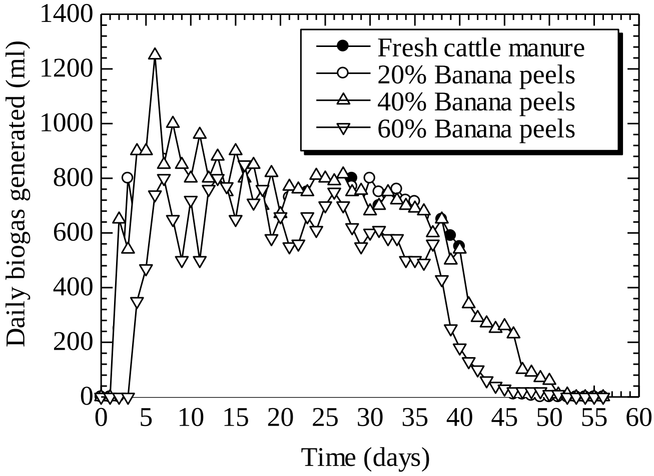

Fig. (4): Daily biogas production of different mixing banana peels with fresh cattle manure

Table 3. showed, the results of total biogas generated from all reactors. According to this table, production of reactor C (40% banana peels) gave the highest value of biogas (**32061** ml) with average of **562.47** ml/day. This high production value from reactor C was may attributed to the fact that a pH value between **7.32** and **7.01** is optimum for increased biogas and also may attributed to the balanced C/N ratio. The yield of biogas from any substrate is highly dependent on the C/N ratio of the material, concentration, pH, temperature (**Ponsá et al, 2008 & NNFCC, 2011**). In the case of C/N ratio, 25~30:1 is optimum for biogas production (**Maishanu et al, 1991**). Reactor A produced the smallest value of biogas (**22525** ml) with average of **395.17** ml/day. The low total biogas production from reactor D may be attributed to the general dominance of carbohydrates material in manure especially expense of protein and lipids which have been reported by **(Hobson, 1983)** to be the essential precursors for methane production, major constituent of biogas. Also dairy-cattle manure contains a refractory or non-biodegradable organic portion ranging from 38% to 63% of the total **(Loehr, 1984**).

Table 3. The total and mean volume of biogas generated

Parameter	Reactor A 0% b. peel	Reactor B 20 % b. peel	Reactor C 40% b. peel	Reactor D 60% b. peel
Total biogas generated (ml)	22525	24795	32061	23151
Mean volume of gas produced (ml/day)	395.17	435	562.47	406.16

Figure (5) shows the accumulation over 57 days, where the results indicated that there are big differences between the four reactors. Throughout the 57 days of retention time, reactor A achieved smallest quantity of gas (**22525** ml) while reactor C achieved largest quantity of gas (**32061** ml). Reactors B and C gave approximately equal quantity of gas.

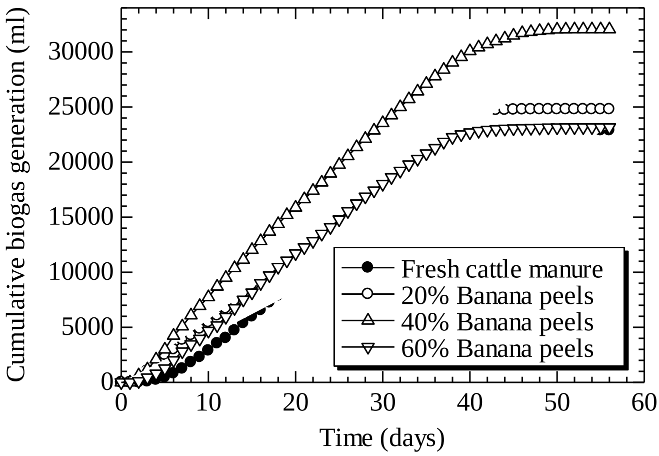

Fig. (5): Cumulative biogas generation

Figure 6. shows methane percentage versus retention time. Methane production from reactor A started on the 3rd day and got to its peak on the 19th day. Reactor B commenced methane production on the 3rd day and got to its peak on the 16th day. While reactor C commenced methane production on the 3rd day and got to its peak on the 19th day**.**

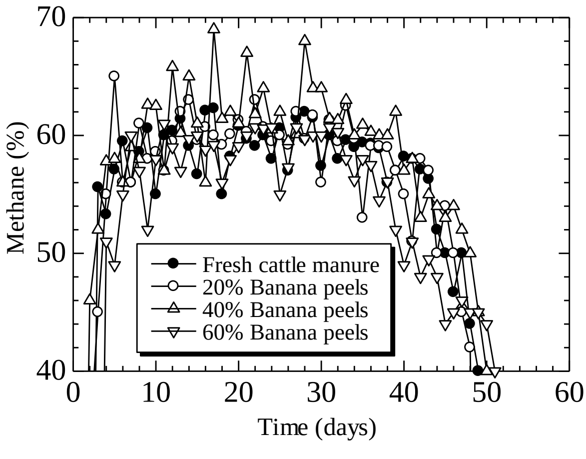

Fig. (6): Daily methane production

While reactor D commenced methane production on the 5th and got to its peak on the 13th day**.** The difference in the lag time may be attributed to different commencement time of the activities of the methanogens.

Hence, reactor A with pure cattle manure gave average methane percent of 55.5%. Reactor B with banana peels of 20 % gave average methane percent of 57.1%. The reactor C with banana peels of 40 % gave average methane percent of 62.3%. Reactor D with banana peels of 60 % gave average methane percent of 56 %.

CONCLUSIONS

The main aim of this study is to make use of agricultural wastes such as banana peels in the production of biogas as a source of clean energy instead of discarded or burned, leading to contamination of the environment. This study has shown good results of gas production when using a mixing of 40 % banana peels with cattle manure. The reactor C which has 40 % banana peels gave the largest amount of gas compared with other reactors. In all reactors the gas started generation after 3-4 days due to the activity of the bacteria. Reactor A started the production on the 4th day and retched to maximum value on the 29th day (800 ml/day) with average methane percent of 55.5%. Reactor B started the production on the 3rd day and retched to maximum value on the 6th day (870 ml/day) with average methane percent of 57.1%. Reactor C started the production on the 3rd day and retched to maximum value on the 7th day (1250 ml/day) with average methane percent of 62.3%. Reactor D started the production on the 4th and retched to maximum value on the 17th day (850 ml/day) with average methane percent of 56 %.

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الملخص العربى

تأثير خلط قشر الموز مع مخلفات الماشية على إنتاج الغاز الحيوى

محمد أبو الحمد عبد الحى رشوان*

يحتل الموز مركزاً كبيراً فى التجارة العالمية حيث يؤدى دوراً هاماً فى اقتصاد كثير من الدول بالإضافة إلى قيمته الغذائية العالية وإقبال المستهلك عليه أكثر من باقى الفواكه الأخرى لما يتميز به من حلاوة الطعم والنكهة المميزة علاوة على توافره بالأسواق طوال العام وقابلية ثماره للنقل والتداول والتخزين. وتعتبر مصر من أهم الدول العربية المنتجة للموز فى قارة أفريقيا (٧٦١٠٠٠ طن مترى حسب إحصائيات سنة ٢٠٠٦) حيث يحتل المكانة الرابعة من حيث الأهمية الاقتصادية فى تجارة الفاكهة بعد الموالح والعنب والمانجو كما يعتبر الموز من أكبر وأسرع محاصيل الفاكهة عائداً. وعادة ينتج عن جمع وأكل و تصنيع الموز كمية كبيرة من المخلفات والتى تسبب الروائح الكريهة نتيجة لتحللها مما يسبب تلوث البيئة ، غير أنها تعتبر غنية بالعناصر الكربوهيدراتية والبروتينية التى يمكن الاستفادة بها فى انتاج الغاز الحيوى. وبناء على ما سبق فإن هذا البحث يهدف الى الاستفادة من مخلفات الموز فى إنتاج الغاز الحيوى وذلك بدراسة تأثير خلطها مع مخلفات الماشية بنسب مختلفة لمعرفة مدى تاثيرها على زيادة كمية الغاز ونوعيته. ولتحقيق ذلك استخدام أربعة مخمرات زجاجية (أ، ب، ج، د) سعة كل منها ٢ لتر وتم وضع وخلط المكونات بالنسب الآتيه:-

المخمر (أ) يحتوى على ٣٠٠ جم مخلفات ماشية فقط تم تخفيفها بالماء للحصول على ٨-١٠% مادة صلبة واستخدم هذا المخمر ككنترول. المخمر ب يحتوى على ٦٠ جم من قشر الموز(٢٠%) من وزن المخلفات والباقى مخلفات ماشية وتم التخفيف بالماء للحصول على ٨-١٠% مادة صلبة. المخمر (ج) يحتوى على ١٢٠ جم من قشر الموز (٤٠ %) والباقى مخلفات ماشية وتم التخفيف بالماء للحصول على ٨-١٠% مادة صلبة. المخمر (د) يحتوى على ١٨٠ جم من قشر الموز(٦٠ %) و الباقى مخلفات ماشية وتم التخفيف بالماء للحصول على ٨-١٠% مادة صلبة. وقد تم وضع المخمرات الاربعة داخل حمام مائى درجة حرارته ٣٥ درجة مئوية يتم التحكم فيها من خلال سخان كهربى متصل بثيرموستات حرارى وتم وضع قلاب لتقليب الماء يعمل أثناء تشغيل السخان لضمان توزيع الحرارة على المخمرات الأربعة داخل الحمام المائى، وتراوحت درجة حرارة الغرفة بين ١٨ و ٢٨ درجة مئوية. وقد تم استقبال الغاز المتجمع بطريقة ازاحة الماء. وقد أظهرت النتائج ما يلى :-

إضافة قشور الموز الى المخلفات الحيوانية أدى الى زيادة واضحة فى كمية الغاز الناتج مقارنة مع مخمر الكونترول. إضافة قشور الموز بنسبة ٤٠ % الى مخلفات الماشية أعطى معدل انتاجية للغاز أعلى من المخمرات الأخرى, حيث وصل انتاج الغاز الى٣٢٠٦١ ملي لتر بمتوسط يومى قدره ٥٦٢,٤٧ مليلتر/يوم خلال فترة مكوث وصلت الى ٥٧ يوم مقارنة مع ٢٢٥٢٥، ٢٤٧٩٥، و ٢٣١٥١ ملي لتر بمتوسط يومى قدره ٣٩٥,١٧, ٤٣٥، و ٤٠٦,١٦ ملي لتر/يوم للمخمرات أ ، ب، د. على الترتيب.

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