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Research Article

Production of biogas from Co-Digestion of Goat Manure and Watermelon (Citrullus lanatus) Fruit Peels under Anaerobic condition

Temesgen mitiku[1], Tidnekachew kifle[2]

[1,2]Dambi Dollo University, College of Natural and computational Sciences, Department of Biotechnology, P.O. Box: 260, Dambi Dollo, Ethiopia
E-mail: temuabebew@gmail.com

ABSTRACT

Biogas is an alternative sources of energy that produced by bacteria spp particularly methanogenic through the bio-degradation of organic material under anaerobic conditions. The main objective this study was biogas production from co-digestion of goat manure and watermelon peels under anaerobic digestion and although to analyze different physico-chemical parameters of substrates. Biodigestes; The 1st Biodigester (A) contain, 100% GM and 0% WP, the 2nd Biodigester(B) contain 70% GM and 30% WP, the 3rd Biodigester(C) contain 50% GM and 50% WP, the 4th Biodigester(D) contain 30% GM and 70% WP and the last 5th Biodigester(E) contain 0% GM and 100% WP. The experiment was done in mesophilic condition (38ºc) using batch fermentation type from microbiology and central laboratories of Haramaya University. All physico-chemical parameters were measured and the result shows in each substrate there was significantly varied between previous to and after digestion. The gas production was measured started from first day of the fermentation and stop until it stop any more gas production using water displacement method for 30 days of retention time in the Biodigester. Since, the rate of biogas production was started in the third day of the experimental observation in all Biodigester and becomes 0 ml after 23 day of the retention time.

Key words: *Biogas, anaerobic digestion, co-digestion, mesophilic condition*

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INTRODUCTION

Globally, the demands of energy consumption are continuously increasing from time to time with the increasing of human populations. Nowadays, they are getting great focus worldwide because of concerns to sustain energy security, climate change and the need to support local agriculture (Maria, 2008).

Biogas is a fuel that can substitute firewood for food preparation, lighting heating or others purposes. Biogas are considerably reduces the greenhouse-gas emission compared to the emission of landfill gas to the atmosphere (Aremu and Agarry, 2013). Biogas is a renewable energy source through anaerobic digestion, and link of bacteria cooperated on the way to acquire anaerobic digestion through different phases like transformation and decomposition of Organic matters into biogas (Ofoefule *et al*., 2010).

About 80% of the world's energy consumption still originates from combusting fossil fuels (Goldenberg and Johansson, 2004). So, energy production from biomass, which is called bio-energy, this alternative is the key (Schamphelaire and Verstraete, 2009). There are wide ranges of raw material that can be used in anaerobic digestion to produced biogas, like wastes from households, animals, agricultures, etc. Utilization of biomass like weeds for the production of biogas offers some advantages. Besides helping as a waste management strategy, the cost for raw material is cheap, available in high quality and the biogas yield is relatively the same as biogas produced from manure waste (Deublein et al., 2008). The use of firewood has negative effects both socially and environmentally.

Deforestation is a very big problem in developing countries like Ethiopia where, people cut trees for fire wood, construction and expansion of arable land. As big forests are destructed in untenable way, the effect on the surroundings including earth wearing away lead to decreasing soil fertility, land slide, etc. will become considerably noticeable (Asnake *et al.,* 2006). Use of manure as fire wood for source of energy is also harmful for human health since the smoke arising from the burning cause air pollution. Thus, the situation calls for the use of an eco-friendly substitute for energy source (Dawit, 2011). Any kind of Biomass that contains organic matters like carbohydrate, fat, protein and so on can be used as a raw material for biogas production. In higher institutions productions of wastes like fruit peels, food waste, different animal wastes are highly available for the production of biogas. Among those in Haramaya University, there is a huge amount of solid animal excreta from cattle, pig, goats, sheep, and the poultry farm. In addition, a large quantity of different fruit peels are disposed off daily from households and/or fruit market areas of Bate, Harar, Jigjiga, Dire Dawa towns etc. Indeed, biogas production from different organic materials like *Moringa stenopetala* seed cake powder (Eyasu, 2008), poultry litter (Ebrahim, 2006), Khat (*Catha edulis*)

waste (Tesfaye, 2007), banana peels (Belayhun Assegid 2014) and others was performed in Ethiopia. Nevertheless, no investigate has conducted so far the result of the co-digestion goat manure and watermelon fruit peels on biogas production. Watermelon fruit peel is a waste that may be used as good potential source of biogas production. This research was means to evaluate watermelon peel for biogas production in sole and combined with goat manure in different proportions.

MATERIALS AND METHODS

Conducted Area

The research was conducted from Haramaya University main campus in Microbiology and Central Laboratory. The university is found around 510 kilometer away from the capital city of Ethiopia in east part. The University is geographically located at latitude of 9°26' N, longitude of 42°03'E and an altitude of 1980 m.a.s.l. The mean annual temperature is 17°C (Google earth, 2013) and (FAO, 1990). The whole experiments in this study were conducted in microbiology and central Laboratory by constructing model lab-scale anaerobic digesters.

Substrate Preparation

Four kilogram of fresh goat manure was collected from Haramaya university goat farms and ten kilogram of waste watermelon peels was also collected from Jigjiga town in Somali regional state of Ethiopia and 5 L inoculum was obtained from Haramaya university abattoir and sieved them through a cloth of 0.5 mm sieve diameter to separate solid content from slurry. The inoculums was stored at the oven by maintain the temperature of 38 ºC for one week to increase the population of methanogenic bacteria in numbers (Lo Niee- Liew, 2011).

The collected goat manure was also sun-dried for two days and the fresh watermelon peels was chopping by using cutter to reduce their size, in order to increase water evaporation rates and sun-dried for one week because it has high moisture content by its nature and after dry crushed mechanically. Finally, the resulting ground material was sieved using 0.5 mm mesh size sieve to obtain powdered samples of uniform particle size.

Design of the Experiment

The experimental design was completely randomized design using batch mode of 0.5 L Biodigester in 5 x 3 replicated from two substrates, i.e, goat manure (GM) and watermelon peel (WP). Each of the Biodigester was charged once from the mixture or solo of substrates throughout the experimental periods (30 days). The

temperature of Biodigester environment was keep by oven at mesophilic (38°c (Knottier, 2003)).

The pH value of each Biodigester was also adjusted from 6.8 to 7.2 before anaerobic digestion taken place because the methanogenic bacteria require optimum pH value for their active metabolic activity (Rajeshwari et al., 2000).

The experiment was conducted in a batch mode of fermentation using a series of 5 plastic bottles under digesters in the laboratory scale.

Table 1:-Mixing ratios of digesters

Biodigester	%GM	%WP
A	100	0
B	70	30
C	50	50
D	30	70
E	0	100

Biogas Production Setup

Three plastic bottles set in sequence in such the first fill slurry; the middle acidified brine solution and the last unfilled intended for accumulated the salt water solution that was barred out from the second Biodigester. The salt water solution was prepared by addition of 500g of sodium chloride in to distilled water and mixed it awaiting a supersaturated solution was formed and added 3 drops of sulphuric acid used a dropper to prevent the dissociation of biogas in the water. Each Biodigester be linked each other using a thin plastic pipe. The digesters were equipped with tightly sealed accessories for the role of manage the way in and out of unwanted and desire gas from the bottle (Teame *et al*, 2014). The tube connecting the first bottle to the second bottle was fitted just above the slurry in the first bottle to help gas collection. Thus, the biogas produced by fermentation of the slurry was driven from the first bottle to the second bottle that contained a brine solution so as to displace a volume of the brine solution equivalent to the volume of biogas produced. From this setup, daily desire outcome was calculated by water dislocation method with brine solution (Itodo et al. 1992).

Measurement of Biogas

Yetilmezsoy and Sakar, (2008) point out, the amount of gas produced was measured by water displacement method using brine solution. The daily gas production was recorded over 30 days for all Biodigester until any gas production was stopped. The daily gas produced means that the daily acidified brine solution displaced to the third plastic bottle. The volume of biogas produced is equal to the volume of brine solution displaced from the second bottle to the third plastic bottle.

Analysis the Physico-chemical Characteristics of the Substrates

Total solids

Samples that contain a solid after the water there in it is evaporated at about 105°C in oven are total solid. The processes to find out the total solid of the substrates as follows; spotless crucible be dehydrated intended for three hour inside oven at 105^{O}C, cooled in desiccators and weighed immediately before use by digital balance. Then, 10 gram of the two substrates i.e goat manure and watermelon waste peel was weighed separately using a digital balance and placed on a dried crucible and again weighed evaporating dish and the substrate together. Then, the dish (crucible) was placed inside an oven safeguard at 105^{O}C. The percentage of the total solid was calculated using the formula indicated in APHA (1999) as follows

%TS= MDS/MFSx100

%TS= total solid, MDS= mass of dried sample, MFS= mass of fresh sample

Volatile solids (VS)

The volatile solids content of the samples were determined by transferring the dried samples into muffle furnace, heating at 550ºC for 3 hours and weighing after cooling at room temperature. The proportion of volatile solids was calculated by using the following equation (APHA 2540 E, 1999).

$$\%VS = \frac{MDS - M(ash)}{MDS} \times 100$$

Where

%VS	volatile solid
MDS	mass of dried sample
M (ash)	mass of ash

Moisture content

The most commonly used method to determine moisture content is that oven-dying method. In this study moisture content was determined as the percentage of initial weight of the material lost through heating. To achieve this, 10g of each sample has been dehydrated separately in an oven at 105^{O}C for one day and weighed. It calculated using the formula (Elias, 2010):

$$\%\ MC = \frac{w-D}{W} \times 100$$

Where

MC	moisture content
W	initial weight of sample (g)
D	weight of sample after drying at 105ºC for 24 hrs

Determination of pH

The pH of the Biodigester was maintained between 6.8 and 7.2 by adding buffer solution (Yadvika *et al.,* 2004). In the case of before anaerobic digestion, the sample was diluted using distilled water before

inoculation with rumen fluid and an electrode was inserted into samples of substrate.

Organic carbon

The carbon content of the substrates was obtained from volatile solids data using an empirical equation as reported by Badger *et al*., 1979 and Barrington *et al*., 2002. % carbon =%vs/1.8

Liquid content

The total amount of liquid (distilled water and rumen fluid) that was added to the Biodigester was determined by the following formula (Ituen *et al*., 2007).

8%=(MFTS)/(A+B)

Where: MFTS= mass of fixed total solid,
A= mass of fresh sample added
B= mass of water and inoculums to be added to get 8% TS suspension in the digester.

Table 2 Biodigester and the content of each digester, used in the anaerobic co-digestion on three replications.

Biodigester	TS of GM (g)	TS of WP (g)	VS of GM (%)	VS of WP (%)	V. water added (ml)	V. Inoculum1s added (ml)	Fresh G.M added (g)	Fresh W.P added (g)
A	23.5	0	60	0	168.8	100	25	0
B	16.45	6.3	46.7	20	159.4	100	17.5	7.5
C	11.75	10.5	33	33	153.12	100	12.5	12.5
D	7.05	14.7	21.9	51.1	146.9	100	7.5	17.5
E	0	21	0	77.6	137.5	100	0	25

A = (100% GM and 0 %WP), B= (70%GM and 30%WP), C= (50% GM and 50%WP) D = (30% GM and 70%WP) and E = (100%WP and 0% GM).

Data Analysis

After the completion of the whole laboratory process the data was analysis of variance by means of SPSS 20. Fishers Least Significant difference was used to explore statistical significance between the different Biodigester, paired samples T-test was used to investigate statistical significance within a Biodigester. Difference between means was considered statistically significant at $P<0.05$.

RESULTS AND DISCUSSION

The physico-chemical parameters of the substrates

PH Value

In this studied the physico-chemical parameter of the substrate were measured before and after anaerobic digestion was takes placed in each Biodigester and evaluated their values. Among those parameters, PH was an important for assessed the efficiencies of anaerobic digestion. To achieve the optimum biogas production in each Biodigester the initial pH value of the input mixture substrate was adjusted between 6.7 and 7.2 because methanogenic bacteria need their own optimum PH values (Marchaim, 1992). According to experimental result indicates that among five Biodigester the maximum PH value was recorded from 100% goat manure (6.94±0.03) in before anaerobic digestion was takes placed; this values as by itself an optimum range for methanogenic bacteria to proceeding normal metabolic activity and high yield of biogas. However, the minimum PH value was also recorded from 100% watermelon peel (6.09±0.03) before anaerobic digestion; this value was not optimum so it required other agents to increase PH value until reach the preferable ranges methanogenic bacteria. According to the experimental result, goat manures has optimum PH value to methanogenic bacteria for perform active anaerobic digestion however, the waste watermelon peel and other two mixtures have no optimum PH value alone for anaerobic digestion process because methanogenic bacteria needs almost neutral PH environment conditions to perform their normal activity. Since, after completion of anaerobic digestion the PH value were significantly increased in each Biodigester. The data shows in below table (4) the maximum PH value was increased from digester E (6.09 ±0.03 to 8.14±0.04) the results may due to high accumulation methanogenic bacteria and their waste products can be contributed for this value through a digestion of biological materials inside the Biodigester(Gerardi, 2003) and the minimum increased was also recorded from digester A (6.94±0.03 to 7.41±0.05) perhaps the result present of small number of methanogenic bacteria and low toxic products in this digestion.

Table 3: Contrasting the value of PH between before and after anaerobic breakdown of each Biodigester (mean ± SE, n=3)

Biodigester	first PH	last PH
A	6.94 ± 0.03^{Ab}	7.41 ± 0.05^{Ea}
B	6.53 ± 0.04^{Cb}	7.75 ± 0.02^{Da}
C	6.78 ± 0.01^{Bb}	7.93 ± 0.02^{Ca}
D	6.23 ± 0.04^{Db}	8.06 ± 0.02^{Ba}
E	6.09 ± 0.03^{Eb}	8.14 ± 0.04^{Aa}

Means represent by unlike upper case letter in column are significantly different at $p<0.05$ between Biodigester. Means followed by different lower case letters in row are

significant increased at p<0.05 for paired samples T-test within Biodigester. A contains 100%GM, B contains 70%GM and 30%WP, C contains 50%GM and 50%WP, D contains 30%GM and 70%WP, and E contains 100% WP. GM= goat manure and WP=watermelon peels.

The initial PH values of each mixed Biodigester were 6.94±0.03, 6.53±0.04; 6.78±0.01, 6.23±0.04 and 6.09±0.03 from the digesters were labeled A to E respectively. According to experimental result shows that most of the Biodigester have below optimum PH value for the growth of targeted methanogenic bacteria in batch fermentation. However, after anaerobic digestion was completed the PH value were significantly increased 7.41±0.06, 7.75±0.02, 7.93±0.04, 8.06±0.02 and 8.14±0.04 from Biodigester A to E respectively perhaps, this value attributed may due to the making of alkaline complex such as ammonium ion and other toxic substances through the digestion in the Biodigester(Gerardi, 2003).

In all testing pH value of the rumen fluid was moderately superior to the raw material (pH=7.37) and it could be contributed to the increased of the pH values in each Biodigester. The comparison of pH values in each Biodigester between the two phases are increased after anaerobic digestion was takes placed; this is due to the accumulation ammonia ion during digestion of protein in the Biodigester. As a results of the substrates which rich in protein was good buffer capacity due to production of ammonia (Verma, 2003).

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