International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Evaluation of the Feasibility of Biogas Production from Leftover Foods of Bahir Dar University Students' Cafeteria

Alemayehu Gashaw[1], Solomon Libsu[2], R.B. Chavan[3]

[1]Department of Chemistry, Faculty of Natural and Computational Science, Bule Hora University, Bule Hora, Ethiopia
[2]Faculty of Natural and Computational Science, Department of Chemistry, Bahir Dar, Ethiopia
[3]Department of Textile Technology, IIT Delhi, India

Abstract: ***The aim of this research is to generate biogas, an alternative and viable source of energy for household consumption in particular, from substrate consisting of leftover foods collected from Bahir Dar University students' cafeteria and cow dung, taken in a weight ratio of 7:3. The production of biogas from the substrate was attempted using plastic digesters of 150 L, 20 L, and 1.8 L capacity under anaerobic conditions. The leftover foods were collected from the student's cafeteria while cow dung was fetched from the University's ranch. The production of biogas was monitored over a period of 60 days. Parameters such as pH, temperature, total solids, volatile solids, and ash and moisture contents of the raw and digested sludges were determined using standard methods. The average volume of biogas produced from three separate digesters, each volume of 1.8 L, was measured using water displacement method and was found to be 5.6 ml of biogas per gram of substrate. Injera with shiro stew, vegetable sauce and injera with peas kik stew have higher %VS/TS suggesting their usefulness as desirable substrates for biogas generation. The flammable gas was observed from laboratory scale digesters, on 45th day after charging the waste. As shown in the result, reduction of total solids and volatile solids of food waste was observed after digested sludge was treated for solid analysis. This indicates that, the raw substrate charged in the digester was degraded to produce biogas. Food waste has a highest organic content and biodegradability, so it is a useful substrate for biogas production.***

Keywords: Leftover foods; Biogas; Anaerobic Digestion; Bio-methanation, Bahir Dar University

1. Introduction

The depletion of non-renewable energy sources such as petroleum invokes the need to search for other locally available renewable resources. These renewable energy sources need to be developed in parallel with the exhaustion of energy sources of fossil origin (Tahvildari and Motamedi, 2010). In recent years, the ever-increasing demands for energy, coupled with the shortage of fossil fuels almost all over the world have created a renewed interest for utilizing renewable energy sources (Kavitha and Joseph, 2007). The search for alternative renewable energy sources is needed not only for replacement of fossil fuels, but also to meet environmental protection demands (Imri and Valeria, 2007). Biogas generation and its utility as an alternative renewable source of energy is increasingly gaining attention, particularly among the developing countries (Abdulkareem, 2005).

Issues pertaining to global warming and climate changes are receiving unprecedented attention among the scientific as well as political spheres both at national and international levels (Yohannes, 2010). Climate problems resulting from the green house effect, ozone depletion, etc. have all contributed to the recognition of the value of anaerobic digestion of organic wastes as an alternative renewable source of energy. Anaerobic digestion or bio-methanation may be defined as an important biological process that converts organic matter in the absence of oxygen to a gaseous mixture, popularly known as biogas (chiefly composed of methane and carbon dioxide) and leaves stabilized residue (fertilizer) (Vindis et al., 2009; Prakash and Singh, 2013).

Biogas so produced can be used for cooking purposes, light and electricity production and as an alternative vehicle fuel (Harris, 2008). Use of biogas for cooking purposes leads to substantial reduction in the amount of firewood consumption. This results in reduced deforestation thereby making significant contribution towards environmental protection. Presently, utility of biogas as a viable source of energy is seen to be taking root in many parts of the country. A case in point is Bahir Dar Town's Felege Hiywot Hospital where biogas generated from a mixture of human excreta, cow dung and leftover foodstuffs is used for cooking purposes.

Bahir Dar University has a large number of resident students (to the tune of 15000) per year. Substantial portion of these students reside and have their meals in the Main Campus. As a result, we have huge quantities of organic wastes including leftover food stuffs and human excreta, all of which may be used as substrates for anaerobic biogas generation. In light of this, Bahir Dar University is an undisputedly attractive site for generating and utilizing biogas as a viable energy source.

Bread, injera, pasta, rice, meat (generally beef and mutton), and various vegetable types along with different kinds of stews/sauce and marmalade are among the major ingredients of foods served to students of Bahir Dar University. Therefore, a lot of leftover food stuffs were generated from the students' cafeterias during a regular academic year and summer time. Leftover foods are remnants or scraps of foodstuffs that remain unused after each meal is served. These sizable quantities of leftover foods and other organic wastes from students' cafeterias of Bahir Dar University and various households' enterprises within the premises of the University can be advantageously used for biogas production. Conversion of such organic wastes into biogas also alleviates health related problems including foul smell that ultimately results from their unattended stay in the environment.

The conversion of complex organic compounds, which are found in organic wastes, into methane and carbon dioxide requires different groups of micro organisms and is carried out in a sequence of four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. During hydrolysis, complex organic matters such as carbohydrates, proteins and lipids converted into soluble organic molecules such as sugars, amino acids and fatty acids by the action of extracellular enzyme, i.e. cellulase, amylase, protease and lipase. Hydrolytic bacteria, which hydrolyze the substrate with these extracellular enzymes, are facultative anaerobes (Fang, 2010; Zagorskis et al., 2012). In the second stage (acidogenesis), the products of the hydrolysis such as sugars, long-chain fatty acids and amino acids are converted into acetate, other volatile fatty acids (VFAs), alcohols, hydrogen and carbon dioxide by acid forming bacteria. Acidogenesis leads to different products including glucose (Parawira, 2004). In acetogenesis, the acetate forming microorganisms convert alcohols, volatile fatty acids such as butyric acid, propionic acid and valeric acid other than acetic acid to CO2, hydrogen and acetic acid (Zamudio, 2010). Finally methanogenic bacteria use hydrogen and acetate (most important substrate) and produce methane and carbon dioxide (Balasubramaniyam et al., 2008).

This work aims to evaluate the feasibility of biomethanation of leftover foods for energy generation. Specifically, it helps to promote biogas production and its utilization in Bahir Dar University and communal households, contribute towards attempts to minimize deforestation, to contribute towards attempts to maintain environmental cleanliness and to initiate the use of biogas so generated for heating purpose in laboratories.

2. Materials and Methods

Biogas production in this study was attempted using various ratios of leftover food stuffs mixed with 30% of cow dung. In this work, two different types of digesters were used, namely discontinuous reactors or batch digesters with a total of five reactors (Figure 1 & 2) and one flow technique digester (Figure 3). All these digesters were operated under ambient temperature (25 – 29 oC), that is, mesophilic temperature (25 – 45 oC). The mesophilic batch experiments were performed in 1.8 L plastic bottles and 20 L plastic tank. All the digesters used in the present work were air-tight.

Figure 1: 1.8 L plastic bottle digesters.

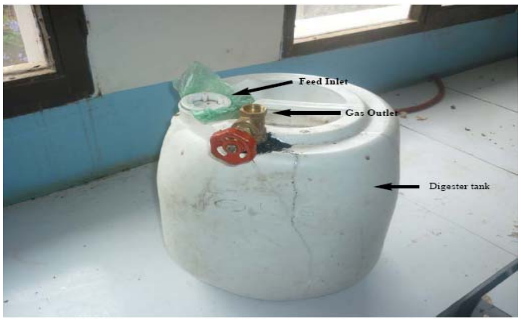

Figure 2: 20 L plastic batch digester

The digester used in this study was a 150 L daily-fed anaerobic plastic digester (Figure 3). It was fixed with mixing tank by 50 cm metal pipe having a diameter of 3.81 cm. The mixing tank is used for agitating and homogenizing the mashed leftover foods and cow dung together.

Figure 3: Pilot scale digester fixed with mixing tank.

2.1 Biogas Collecting and Measurement Unit

In this work, the downward displacement of water was used to measure the quantity of biogas generated. In a typical experiment, an inverted graduated burette filled with water was dipped in a 500 mL beaker approximately half-filled with water: into the inverted burette was inserted a U-shaped glass tube that was connected to a tube coming from the plastic bottle digester as shown in Figure 4.

Figure 4: Measurement of biogas volume by water displacement technique.

2.2 Preparation of Leftover Foods Mixed with Cow Dung for Biogas Production

Scraps of leftover foodstuffs (Figure 5) were collected from students' cafeteria located in the Main Campus of Bahir Dar University daily for a week. From the collected foodstuffs, indigestible wastes such as bones were discarded. The leftover foods collected from the students' cafeteria were mashed and shredded to about 2-5 mm in size and mixed with the same amount of tap water. To this was then added 30% of cow dung with the view of improving and stabilizing the anaerobic digestion process. In addition, cow manure buffer is able to overcome the effect of volatile fatty acids present in digester due to lipids that can occur in food waste (Fang, 2010).

A. Bread leftover

B. Mixed leftover foods

C. Leftover of injera

D. Cooked rice

E. Cooked pasta with tomato sauce

Figure 5: Different types of leftover foods collected from students' cafeteria

2.3 Analytical Procedures

All collected biodegradable leftover food samples were analyzed for total solids (TS) and volatile solids (VS). In addition, the effluent was also analyzed for TS and VS (Abubakar and Ismail, 2012).

2.4 Total Solid (TS)

Total solid and moisture content in the leftover foods and cow dung were determined in a typical experiment as follows: 25 g of each leftover food was transferred to a pre - weighed evaporating dish, and weighed altogether and recorded. It was then dried at 105°C in a drying oven for 24 hours. The dish with its contents was then cooled in a dessicator and weighed using an electronic weighing balance (Mettler Toledo, Model AT250, Switzerland). The expression for calculating moisture content on wet basis is shown below (Equation 1) (Zaman, 2010; Eze and Agbo, 2010).

% Moisture content = $(w - d)/w \times 100$ (1)

Where, w = initial (wet) weight of sample
d = final (dry) weight of sample

The increase in weight over that of the empty dish represents the total solids. The total solids in percentage of wet sample are calculated as per Equation 2 (Zaman, 2010):

%Total solids = $A - B/C - B \times 100$ (2)

Where, A = weight of dried residue + dish (g)
B = weight of dish (g)
C = weight of wet sample + dish (g)

2.5 Volatile Solids (VS)

The residue from the total solids determination is ignited to constant weight at 550°C for 2 hrs. Then, the sample was removed from the furnace, cooled in a dessicator and weighed. The remaining solids represent the fixed total, dissolved, or suspended solids while the weight lost on ashing is the volatile solids. Total volatile solids are determined as per Equation (3) (Eze and Agbo, 2010).

%Volatile solids= Total solid – (weight of ash/ Weight of wet waste) × 100 (3)

The reduction of solids (TS and VS) in the food waste after the treatment was calculated as the difference of solids concentration in influent minus the accumulation of solids in the reactor.

2.6 pH determination

This was determined using digital pH meter (Jenway mode). Electrodes were thoroughly wetted and prepared according to the manufacturer's instructions. Instruments were standardized with standard acetic acid buffer solution of pH 4.0. The reading was taken when equilibrium, as shown by the absence of drift, was established.

2.7 Biogas Improvement

There are methods to reduce the amount of non-combustible gases such as carbon dioxide, hydrogen sulfide and moisture present in the biogas. The method which is suitable for reducing the amount of carbon dioxide in the biogas is passing the gas through calcium hydroxide (lime water) solution. Besides, the amount of moisture content is also reduced by using calcium chloride crystal since it is dehydrating agent. This was attempted using a distilling flask containing an aqueous solution of lime. As shown in Figure 6, the flask was connected to the gas outlet of the digester. After treatment with lime, the biogas was allowed to reach a Bunsen burner, after crossing small glass tubing containing anhydrous calcium chloride, so that its combustibility would be tested.

Figure 6: Set up for biogas improvement technique.

3. Result and Discussion

3.1 The composition of leftover foods

The leftover foods employed in this work consisted of bread, injera, cooked pasta or noodle, cooked rice and mixed leftover foods (**Table 1**).

Table 1: Composition of leftover foodstuffs

No	Component	Percent by weight (% w/w)
1	Bread	13.428
2	Injera	17.016
3	Cooked pasta/noodle	5.62
4	Cooked rice	6.349
5	Mixed leftover food	57.58
	Total	100

3.2 Characterization of leftover foodstuffs and leftover food mixed with cow dung

The solids analysis such as total solids and volatile solids of different leftover food stuffs and their moisture contents using 25 g of sample are shown in **Table 2.**

Table 2: Characterization of leftovers foodstuffs and mixed leftovers with cow dung

Component	Moisture content (%)	Total solids (%)	Ash (%)	Volatile solid (%)	VS/TS (%)
Bread	43.43	56.57	12.89	43.68	77.21
Injera	61.13	38.74	6.78	31.96	82.50
Cooked pasta	77.14	22.86	3.424	19.436	85.02
Tomato sauce	66.48	33.52	5.36	28.16	84
Injera with peas kik stew	73.56	26.44	2.4	24.04	90.92
Injera with shiro wat	77.36	22.64	1.8	20.84	92.05
Injera with meat stew	74.07	25.93	5.646	20.284	78.20
Injera with lenticle kik stew	72.39	27.61	5.69	21.92	79.40
Mixed leftover foods with cow dung	64.64	35.36	7.88	27.48	77.71
Vegetable sauce	84.12	15.88	1.48	14.40	90.68
Cooked rice	68	31.38	9.9	21.48	68.45
Bread with malmalade	44.28	55.72	8.96	46.76	83.92
Cow dung	84.72	15.28	3.28	12	78.53

From **Table 2**, injera with stews made of meat, peas, and vegetable sauce have high percentage of volatile solid content relative to total solid. According to **Steffen *et al.* (1998),** the biodegradable organic matter content ranges from 70 to 95 percent of the dry matter content for effective production of biogas. On the other hand, the substrates with dry organic matter content less than 60% are rarely considered as substrates worthwhile for anaerobic digestion **(Eyalarasan *et al.*, 2013).** Accordingly, all substrates in **Table 2** are considered as good substrates for anaerobic digestion and hence for biogas production even if the cooked rice has the lowest percent of VS to TS.

3.3Combustibility of Biogas

The combustibility of the biogas generated in a 1.8 L digester was tested on 45th day of digestion period by using a Bunsen burner that was connected to the gas outlet of the digester. A short-lived blue flame was observed at the mouth of the burner confirming presence of methane in the biogas.

3.4 Environmental factors

i. Temperature

Temperature is a very important factor having influence on the composition of microorganism population and the intensity of their activities. If the temperature is higher, organic matter is degraded more rapidly and microorganisms use nutrients quicker **(Sibisi and Green, 2005; Baltrenas and Kvasauskas, 2008).** The digesters used in this work were all placed in a laboratory and hence were protected from experiencing sharp falls in the temperature. The digester temperature, which generally ranged between 26-29^{0}C, is within the mesophilic temperature range **(Huy, 2008).** Though the digester temperature in this work is within the mesophilic range, it is still way below the optimum range thus making difficult the degradation of wastes containing high oil content in a short digestion time **(Swampnavahini *et al.*, 2010).**

ii. Changes in pH During Fermentation

Immediately after charging the food waste, the pH of the digester was 6.01 (day one) but as fermentation took place the pH value of the slurry dropped to 5.61, which is weakly acidic, on the fifth day of the fermentation as shown in **Figure 7**. The pH lowering at the early stage of the digestion of waste may be attributed to the fact that initially the acidogens were breaking down the organic matter (easily degradable) which produces volatile fatty acids. The leftover foods employed in the present work contain lots of oils which are biodegraded into glycerol and long chain fatty acids (LCFAs). LCFAs are slowly degraded under anaerobic conditions and, when present even in millimolar concentrations, they (LCFAs) can inhibit the growth of anaerobic microorganisms, including acetogenic bacteria and methanogens **(Stabnikova *et al.*, 2005)**. Until 40th day of digestion time, the pH of the digester was seen to decline rapidly (**Figure 7**). The occurrence of this longer acidity period may be due to formation of fatty acids as degradation products.

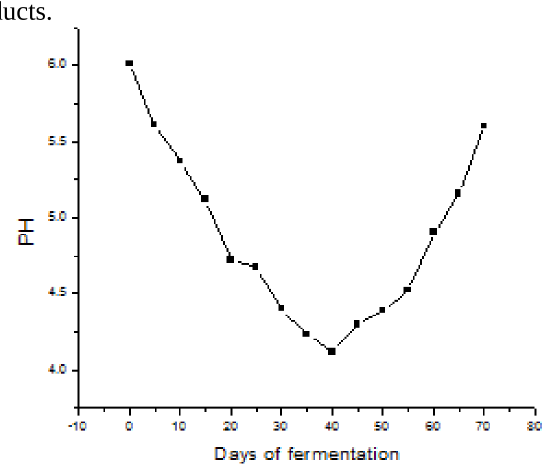

Figure 7: Variation of pH during the digestion period.

As a result, the acidity of the medium increased and the pH fall below 5. This low pH value allowed very little activity of methanogenic bacteria and is apparently responsible for releasing of carbon dioxide as the main product from the food wastes **(Lin *et al.*, 2011).** Methanogenic bacteria will cease activity or die when conditions in the digester are not right. When methane-forming bacteria die, the acid-formers may continue to grow and produce high concentrations of volatile acids, leading to a decrease in the pH of the digester contents. In contrast, there is a pH rise starting on 45th day of fermentation. This may be due to the degradation of proteins to release ammonia which brings about alkalinity **(Gerardi, 2003)**. This also creates a favorable condition to increase the methanogenic archeas population to generate methane by bringing the pH toward the neutral value. The optimum pH for methanogenic bacteria is 6.8 – 7.2 **(Budiyono *et al.*, 2010).** The pH tested even after 70 days of digestion time was found to be pH 5.6, a value outside the optimum range. This showed that buffering capacity of the digestate present was not enough and thus inhibits anaerobic process. This led to low or no biogas production.

iii. Biogas Measurement

Measurement of the volume of biogas generated by water displacement method was done within three days after the 45th day of fermentation. The gas measured was generated from slurry composed of 350 g leftover foods (22.22 g cooked rice, 19.62 g cooked pasta, 59.56 g injera, 46. 99 g bread) mixed with 150 g cow dung, which gives a total weight of substrate as 500 g. The substrate so prepared was taken in 500 g of water. Totally above 2.8 L (0.0028 m^3) of biogas was produced from 500 g food waste mixed with cow dung (5.6 ml of gas per g of substrate).

iv. Total Solids and Volatile Solids Reduction of Food Waste

Anaerobic digestion in this study attained a steady state on 60th days of start-up process. During the steady state, the efficiencies of total solids and volatile solids reduction of the digester was calculated. The results are presented in **Table 3**.

Table 3: The total solids and volatile solids of digested and undigested sludge

Component	TS (%)	VS (%)	VS/TS (%)
Raw substrate	35.36	27.48	77.71
Digested sludge after 60 days	13.36	7.72	57.8

The total solid reduction and volatile solid reduction of the substrate after 60th day of digestion time were calculated from **Table 3** to be 62% and 72% respectively. The efficiency in volatile solid reduction (VSR) of food waste (72%) and total solid reduction (62%) indicates that the largest portion of the organic content present in the food waste is converted to a gas. But more reduction of organic content can be made by longer retention time. Therefore, it could mean that the food wastes are easy to digest by anaerobic bacteria even if the longer retention time is needed due to several factors such as temperature. The reduction of TS and VS measured is an important parameter for measuring biodegradation, which directly indicates the metabolic status of some of the most delicate microbial groups in anaerobic system **(Steffen *et al.*, 1998)**. Volatile solid is an important parameter used to determine biodegradability, being the component which is directly converted to biogas **(Usman *et al.*, 2012).**

4. Conclusion

The pH of the digester declined till 45th day of fermentation and rises beyond pH of 5.6 on 70th day of digestion time. This indicates that food waste take a long retention time to reach on favorable condition for most methanogenic bacteria to replicate themselves to produce methane. In addition, due to its high organic content (highest percent of volatile solids) and biodegradability (reduction of volatile and total solids) of food wastes, the most appropriate treatment method for food waste mixed with cow dung is anaerobic digestion and hence convenient for biogas production.

The amount of cow dung used in this study is not enough to adjust the pH since there was a long acidity period in the digester. So, co-digestion of food waste with sufficient amount of cow dung may be sustainable and environmentally attractive method to treat and simultaneously convert such a waste mixture to a useful energy sources. According to this study, the highest amount of biogas (above 2.8 L) was produced from 500 g of food waste using water displacement method. Therefore, Bahir Dar University can generate the highest amount of biogas from a plenty of these leftover foods of students cafeteria by keeping some important parameters such as pH, temperature, and so on.

5. Acknowledgement

The authors gratefully thank the material and financial support of this work given by the ministry of education and Bahir Dar University, Ethiopia. Likewise, the first author's deepest gratitude goes to Mrs. Genet Abera for her financial support and edition of my work.

References

[1] Abdulkareem, A.S., (2005). Refining biogas produced from biomass: An alternative to cooking gas. Leonardo J. Sci., 7, 1-8.

[2] Abubakar, I.; Ismail, N. (2012). Anaerobic digestion of cow dung for Biogas production. ARPN J. Eng. App. Sci. 7(2), 169-171.

[3] Balasubramaniyam, U.; Zisengwe, L.S.; Meriggi, N.; Buysman, E. (2008). Biogas production in climate with cold winters. Online at www2.gtz.de/.../en-biogas-production-in-climates-with-long-cold-winters-2008.pdf. Accessed on 12/01/2011.

[4] Baltrenas, P.; Kvasauskas, M., (2008). Anaerobic recycling of organic waste and recovery of biogas. J. Environ. Eng. Landsc. 16, 178 – 183.

[5] Budiyono; Widiasa, I.N.; Johari, S.; Sunarso, (2010). The influence of total solid contents on biogas yield from cattle manure using rumen fluid inoculum. Energy Res. J. 1, 6 – 11.

[6] Eyalarasan, K.; Tewelde, S.; Yohannes, A.; Habteslasie, T.; Karthikeyan, K.(2013). Anaerobic co-

digestion of cafeteria wastes and cow dung mixtures for biogas production. Int. J. Eng. Res.Technol. 2(3), 1-5.

[7] Eze J. I.; Agbo K. E., (2010). Studies on the microbial spectrum in anaerobic biomethanization of cow dung in 10m3 fixed dome digester. Int. J. Physical Sci. 5, 1331-1337.

[8] Fang, C., (2010). Biogas production from food-processing industrial wastes by anaerobic digestion. PhD Thesis, Technical University of Denmark, Denmark.

[9] Gerardi, M.H., (2003). The Microbiology of anaerobic digesters, Wiley Interscience, pp. 1 – 85.

[10] Harris, P., (2008). Biogas Notes. Online at

[11] http://biogas.wikispaces.com/file/view/Biogas+Notes.pdf. Accessed on 23/11/2010

[12] Huy, N. Q.,(2008). Sequential dry batch anaerobic digestion of the organic fraction of MSW, Asian Institute of Technology, Graduate School of Environment, Resources and Development, Thailand.

[13] Imri, K.; Valeria, N., (2007). Experiments on the maximum biogas production. 7th International Multidisciplinary Conference, Baia Mare, Romania, 309-310.

[14] Kavitha, E.S; Joseph, K., (2007). Biomethanation of vegetable wastes. J. Inst. Public Health Eng. 3, 11-19.

[15] Lin, J.; Zuo, J.; Gan, L.; Li, P.; Liu, F.; Wang, K.; Chen, L.; Gan, H.,(2011). Effects of mixture ratio on anaerobic co-digestion with fruit and vegetable waste and food waste of China. J. Environ. Sci. 23, 1-15.

[16] Parawira, W., (2004). Anaerobic treatment of agricultural residues and waste water. Doctoral Dissertation, Lund University.

[17] Prakash E.V.; Singh, L. P. (2013). Biomethanation of Vegetable And Fruit Waste in Co-digestion Process. Int. J. Emerg. Technol. Adv. Eng. 3(6), 493-494.

[18] Sibisi, N.T.; Green, J. M., (2005). Floating dome biogas digester: perceptions of energizing a rural school in Maphephetheni, Kwazulu-Natal. J. Energy S. Afr. 16, 45-47.

[19] Stabnikova, O.; Ang, S.; Liu, X.; Ivanov, V.; Tay, J.; Wang. J.,(2005). The use of hybrid anaerobic solid-liquid system for the treatment of lipid-containing food waste. J. Chem. Technol. Biotechnol. 80, 455-456.

[20] Steffen, R.; Szolar, O.; Braun, R., (1998). Feedstocks for anaerobic digestion. Online on www.adnett.org/dl_feedstocks.pdf accessed on 20/04/2010.

[21] Swampnavahini, K.; Srinivas, T.; kumar, P.L.; Kumara, M.S. and Lakshmi, T., (2010). Leaf anaerobic digestion, Bioresources, 5, 391-392.

[22] Tahvildari, K.; Motamedi, S., (2010). Studying the environmental effects of using biogas energy in Iran. World Acad. Sci. Eng. Technol. 68, 1453-1456.

[23] Usman M. A.; Olanipekun O. O.; Kareem O. M. (2012). Biogas Generation from Domestic Solid Wastes in Mesophilic Anaerobic Digestion. Int. J. Res. Chem. Environ. 2(1), 200-201.

[24] Vindis, P.; Mursec, B.; Janzekovic, M.; Cus, F., (2009). The impact of mesophilic and thermophilic anaerobic digestion on biogas production. J. Achiev. Mater. Manufact. Eng. 2, 192-198.

[25] Yohannes, T., (2010). Biogas potential from cow manure – Influence of diet. MSc thesis, Swedish University of Agricultural Sciences. Uppsala.

[26] Zagorskis, A.; Baltrėnas, P.; Misevičius, A. (2012). Experimental biogas research by anaerobic digestion of waste of animal origin and biodegradable garden waste. Afr. J. Biotechnol. 11(100), 16586-16593.

[27] Zaman, N.Q., (2010). PhD thesis, University of Canterbury,.

[28] Zamudio Canas, E.M., (2010). Technical feasibility of anaerobic codigestion of dairy manure with chicken litter and other wastes. MSc thesis, University of Tennessee.

Author Profile

Alemayehu Gashaw Woldegiorgis was born in Ethiopia, Oromia, North Shoa Zone. He received his B.Ed. degree from Debre Birhan University, Debre Birhan, Ethiopia and M.Sc. degree from Bahir Dar University in Organic chemistry; His areas of research work are Evaluation of biogas production from leftover foods of Bahir Dar University students' cafeteria and has an ongoing project on Evaluation of biogas production from vegetable and Chat wastes which are mixed with cow dung. At present, he is working as a lecturer at Bule Hora University, Bule Hora, Ethiopia.