Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.3, No.6, 2013

Effects of Buffering and Urea on the Quantity and Quality of Biogas From Banana Leaves as Alternative Renewable Energy Resource.

Ekwenchi, M.. M[1]. and Yaro M. N[2]*.
1. Department of Pure and Industrial Chemistry, University of Jos – Nigeria
2. Department of Chemistry, Federal University, Dutse, Jigawa State -Nigeria.
* E-mail of the corresponding author: yaro_n @yahoo.com

Abstract

Buffer solutions of different molar concentrations (O.1.M, 0.2M, 0.3M, .4M and 0.5M) were prepared using buffer salts (Na_2HPO_4 and $NaH_2PO_4.H_2O$). The pKa of the buffer salts was determined from the ionization constant, Ka (7×10^{-8}) of the phosphoric ions (HPO_4^{2-} and $H_2PO_4^-$) of the buffer salts using the relation, pKa = -log Ka. The pKa of the buffer salts obtained was further used in Headerson-Hasselbaltch's equation, pH = pKa + log [base]/[acid], where the volumes ($125cm^3$ each) of the prepared buffer solution of required pH (6.8, 7.0, 7.2, 7.4 and 7.6) were prepared. Slurries were prepared using 20g banana leaves in $125cm^3$ of the prepared buffer solutions. For the investigation of the effect of buffering on biogas yield and its composition, 0.1M, 0.2M, 0.3M, 0.4M and 0.5M buffer solutions (pH 7.0 each) were used in making the slurry; for the investigation of the effect of pH of buffer solution on the quantity and composition of biogas, buffer solutions of pH (6.8, 7.0, 7.2, 7.4 and 7.6) were separately used in making the slurry; for the investigation of the effect of addition of urea (as nutritive additive), 0.1g, 0.15g, 0.20g, 0.25g and 0.30g of urea, were respectively added into the five (5) replica slurries prepared from 20g banana leaves and $125cm^3$ distilled water, which were labeled A,B,C, D and E and; for the investigation of the combined effect of buffering and addition of urea, 0.1g, 0.15g, 0.20g , 0.25g and 0.30g of urea (as additive), were respectively added into another five (5) replica slurries prepared from 20g banana leaves and $125cm^3$ of 0.2M buffer solutions of pH 7.4, which were also labeled A,B,C,D and E. Compositional analysis of the biogas produced was also carried out by passing the gas collected (biogas) through concentrated NaOH solution (10M) and a solution of $(CH_3COO)_2Pb$ in a 3 molar CH_3COOH, where CO_2 and H_2S were, respectively absorbed from the biogas. The work revealed that, the use of buffer solution at certain molar concentrations (0.1M – 0.3M) and pH (7.0 – 7.4); the use of urea ($0.1g/125cm^3$ – $0.25g/125cm^3$) equivalent to $0.8g/dm^3$ – $2.0g/dm^3$ and; the use of the combination of buffer solution and urea, each enhanced biogas yield. The compositional analysis carried out, revealed that the biogas (secondary biofuel) produced was of good fuel value (60 – 68.78% CH_4) and low environmental hazards (CO_2 below 40% and H_2S below 0.5%).

Keywords: Biogas; buffer solution; urea; molar concentration; ionization constant (pKa) of phosphoric ions; pH of slurry.

1. Introduction

The awareness of the imminent depletion of fossil fuels coupled with the global energy crisis all over the world has stimulated interest in the search for alternative energy sources. The potential alternative energy sources which have received much attention all over the world nowadays are water current, wind power, geothermal power, nuclear power, solar energy and organic wastes as pointed out by Garba *et al* (1996), Naturally, each of these has its own shortcomings, but solar energy and organic wastes are the most reliable alternative source of energy for third world countries (Nigeria inclusive) because they are by far more readily accessible to inhabitants of rural areas from the available biomass resources in their immediate environment.

Biomass has been defined as the natural biologically storage of energy (Solar) and other materials in complex organic substances primarily by gross photosynthesis as reported by Zuru *et al* (2001). The biomass resources of Nigeria are wood, forage grasses and shrubs, human and animal excretion, aquatic biomass and wastes arising from forestry and, agricultural, municipal and industrial activities. The biomass reserve of Nigeria has been estimated at about 9.0 x 102 MJ as reported by Garba (1998) while the total world mass of forest is put at 1,600 billion tones as reported by Ramage & Seurlock (1990). When biomass are used directly for energy, they are called primary biofuels. On the other hand, if the biomass resources are converted to fuels through bioconversion processes, the derived fuels (biogas, ethanol e.t.c) are referred to as secondary biofuels a explained by Loughton (1990). The inefficient use of primary biofuels in most developing countries (Nigeria inclusive) has caused many ecological problems such as deforestation, desertification, erosion and reduced biodiversity as reported by Kgbathi(1997). Moreover, the adverse health problems associated with the indoor pollution from biomass use (as primary biofuel) include respiratory diseases chronic lung diseases and cancer as report by Smith (1991). Thus, the used to develop efficient methods of using the available biomass resources in our environment for fuel generation is imperative. Fortunately, the use of secondary biofuels has proved more efficient with biogas emerging as the most attractive option nowadays. Unfortunately, the actual biogas yield from biomass resources through bioconversion process is much lower than expected, the shortfall is attributed to the inadequate supply of minerals nutrients among other factors required by the micro-organisms to grow, multiply and efficiently act on the substrate feedstock for biogas production as explained by Zuru *et al* (1997). For this reason, attempts to improve the biogas yield from biomass resources of different origin (plants and animals) through bioconversion process have been made. For instance, Guiot *et al* (1988), have reported improved growth of methanogens due to the supply of appropriate mixture of Ni^{2+}, Co^{2+} and Mo^{6+} Singh *et al* (1992), added different concentrations of Na^{+}, Mg^{2+}, Fe^{2+}, Al^{3+}, Sn^{2+} and Cd^{2+} salts into the slurry of *Ecphoria crissipes* and investigated the effects of these salts on the cumulative gas yield of the substrate. They found that, Na^{+} and Al^{3+} salts had no adverse effect at low concentration but caused a significant increase in gas production rate at concentration above 500mg/kg of waste; Fe^{2+}, Mg^{2+} and Cd^{2+} showed inhibitory effects and; Sn^{2+} stopped the gas production completely. Machido *et al* (1996), investigated the effect of Ca^{2+}, Ni^{2+} , Mo^{6+}, Co^{2+} and B^{3+} ions on the production of biogas from cow dung slurry. They observed that, the gas yielded in the digesters containing Ca^{2+}, Ni^{2+}, Mo^{6+}, Co^{2+} and B^{3+} were 3.44%, 1.72%, 1.72%, 8,34% and 7.14%, respectively of that yielded by the control digester. Similarly, Zuru *et al* (1997), studied the effect of addition of Ca, B and Co salts on biogas production from cow dung. The work revealed that the salts added had neither inhibitory nor enhancing effect on the total gas yield, but they stimulated early gas production. In addition to the aforementioned efforts and many others made by different researches towards promoting biogas production from different substrates, this research is aimed at investigating the influence of buffer solution and urea on the quantity and composition of biogas (secondary biofuel) from banana leaves as alternative and environmentally – friendly renewable energy resource.

2. Materials and Methods

2.1 Chemical/Reagents

The chemicals/reagents used for this research were disodium hydrogen phosphate (Na_2HPO_4), ethanoic acid (CH_3COOH), lead ethanoate {$(CH_3COO)_2Pb$}, Sodium dihydrogen phosphate monohydrate ($NaH_2PO_4.H_2O$), Sodium hydroxide (NaOH) and urea ($CO(NH_2)_2$). The chemicals/reagents were general purpose reagents of good analytical grade, products of BDH Chemicals LTD, Poole-England.

2.2 Apparatus

The apparatus used were the common laboratory glass wares, electric beam balance, mesh, oven, pestle and mortar pH metre, PVC tube and stirrer.

2.3 Sample Collection and Treatment

The banana leaves were collected from a group of banana plants planted by Kano Agricultural and Rural Development Authority (KNARDA) in Bichi town, Kano State – Nigeria. The banana leaves were fresh and mature at the time of collection. The sample (banana leaves) was oven-dried at 37°C for four (4) hours ground using pestle and mortar and sieved to a mesh size less than 250µm using mesh of a well defined porosities for different particles sizes.

2.4 Preparation of Reactants (Slurries)

The slurry used in the control digester was prepared by dissolving 20g of the treated sample with 125cm^3 distilled water in a reactor (250cm^3 Buchner flask) and thoroughly stireed for homogeneity. The pH of the slurry was measured using pH metre. For the preparation of slurry using buffer solution, the pKa of the buffer salts was first determined using the relation, pKa = - log Ka. The determined pKa was further used in Headerson Hesselbalch equation, pH = pKa + log [conjugate base]/[acid], from which the volumes of the buffer salts (acid and base) that were mixed and formed a buffer solution of required molar concentration and pH (See Appendix I). The slurry was prepared by dissolving 20g of the treated (prepared) sample and 0.9g of yeast in 125cm^3 of the prepared buffer solution in 250cm^3 Buchner flask. For the investigation of the effect of concentration of buffer solution on biogas yield and its composition, different molar concentrations (0.1M, 0.2M, 0.3M, 0.4M and 0.5M) of buffer solution of equal pH (7.0) were used in making the slurry. For the investigation of the effect of pH of buffer solution on the quantity and composition of biogas, different pH (6.8, 7.0, 7.2, 7.4 and 7.6) of buffer solution were used in making the slurry. In order to investigate the effect of urea on the quantity and composition of biogas, a slurry was prepared by dissolving 20g of the prepared sample in 125cm^3 distilled water in a reactor (250cm^3 Buchner flask). Five (5) replica slurries were prepared into which 0.1g, 0.15g, 0.20g, 0.25g and 0.30g of urea, were respectively added. For the investigation of the combined effect of buffering and addition of urea on the quantity and composition of biogas, a slurry was prepared by dissolving 20g of the prepared sample in 125cm^3 of 0.2M buffer solution (pH 7.4) and placed into a reactor (250cm^3 Buchner flask). Five (5) replica slurries were also prepared into which 0.10g, 0.5g, 0.20g, 0.25g and 3.0g of urea were respectively added. The reactors (250cm^3 Buchner flasks) into which the prepared slurries were placed for each of the investigations (effect of buffering, effect of urea and the combined effect of buffering and urea) were labeled A, B, C, D and E and each was connected to a gas collecting apparatus (an inverted 500cm^3 measuring cylinder filled with brine) using a PVC rubber tube (50cm long and 8.5cm internal diameter), which was positioned up right in the measuring cylinder. The digesters were made in duplicate.

2.5 Experimental Set up

The digesters were made air-tight according to the procedure described by Uba & Garba (2001). The digesters were immersed about 1/3 in water bath operated at 33^{o}C and, the degradation process was allowed to continue for 15 days according to the degradation method adopted by Yaro (2011) with few adjustment in the quantity of the slurry, size of the digester and duration of the reaction. The collection of the gaseous degradation product (biogas) was carried out according to the collection method adopted by Gumel & Yaro (2012). The volume of the gas collected from each digester was measured by water displacement method as described by Ekwenchi & Yaro (2010). The mean (average) volume of gas collected from each digester was evaluated and recorded at fixed daily intervals for 15 consecutive days.

2.6 Evaluation Procedure

In order to evaluate the composition of the biogas generated, the techniques adopted by Yaro (2011) were used, The carbon (IV) oxide (CO_2) content of the biogas was removed by passing through concentrated Sodium hydroxide (IM), where the CO_2 was absorbed from the gas (biogas) according to the following equation:

$$2NaOH_{(aq)} + CO_{2\,(g)} \longrightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$$

The H_2S content of gas was removed by absorption using lead ethanoate solution in 3M ethanoic acid $\{(CH_3COO)_2Pb/CH_3COOH\}$ according to the following equation:

$$(CH_3COO)_2Pb_{(aq)} + H_2S_{(g)} \longrightarrow 2CH_3COOH_{(aq)} + PbS_{(s)}$$

The percentages of the secondary biofuel (CH_4), CO_2 and H_2S in the biogas were evaluated as follows:

$$\%CO_2 = \frac{VCO_2}{Vbiogas} \times 100$$

$$\%H_2S = \frac{VH_2S}{Vbiogas} \times 100$$

$$\%CH_4 = \frac{Vbiogas - (VCO_2 + VH_2S)}{Vbiogas} \times 100$$

Where V = Volume (cm^3)

3. Results

The results of all the investigations carried out are shown in Tables 1, 2, 3 and 4 below:

Table 1, 2 and 3 show the mean total volumes of biogas (cm^3) collected, from 20g of banana leaves, which were anaerobically digested at 33^{o}C over a period of 15 consecutive days under the influence of the concentration of buffer solution, pH of buffer solution and addition of urea, respectively. Table 4 shows the quantity and composition of biogas generated through anaerobic fungal degradation of 20g of banana leaves at 33^{o}C for 15 consecutive days under the combined influence of buffer solution and urea.

4. Discussion

The results of the effects of concentration of buffer solution, pH of buffer solution, addition of urea and the combination of buffer solution and urea are shown in Tables 1, 2, 3 and 4, respectively.

From the results (Table 1 and 2), it could be seen that, at certain ranges of concentration (0.1M – 0.3M) and pH (7.0 – 7.4) of buffer solution, there was remarkable increase in gas production when compared with the control digester in which distilled water was used. The increase in gas production may be attributed to the presence of Na^+ and P^{-5} in the buffer salts, which served as inorganic nutrients (fertilizers) for the fermentative bacteria and stimulated their growth and activities. This is accordance with the findings of Singh *et al* (1992) & Airehrour (1994). The increase could also be attributed to favourable conditions (in terms of suitable pH) into which the fermentative microbes were rendered. This is because fermentative microbes require a neutral or mildly alkaline environment for their proper growth and metabolic activities as pointed out by Ariane (1985). On the other hand, the use of buffer solution (in terms of both the effects of concentration and pH) each brought about a slight decrease in the percentage of CH_4 (secondary biofuel) content of the biogas and a slight increase in the percentages of CO_2 and H_2S (associated contaminants of the secondary biofuel). The increase in CO_2 may be connected to the oxidation of carbon content of the substrate by the oxygen content of the buffer salt as pointed out by Gumel & Yaro (2012) while the increase in H_2S may be associated with the drastic degradation of sulphur containing amino acids and proteins content of the substrate, as pointed out by Harrison & de Mora (1996).The increase in H_2S may also be associated with the reduction of sulphate ion (SO_4^{2-}) mediated by sulphur containing compounds in the substrate feedstock as reported Ahmad (2000). The changes in the percentage composition of the biogas has no significant impact on the good fuel quality of the secondary biofuel formed. This is because the percentage of CH_4 in the biogas is still up to 60 and, that of CO_2 is below 40 and, for a biogas be of good fuel value (high calorific value) and low environmental harzards, the CH_4 content must exceed 60% and, the CO_2 content below 40% as pointed out by Ekwenchi & Yaro (2010).

From Table 3, it could be seen that addition of urea at a certain range of mass concentration ($0.1g/125cm^3$ – $0.25g/125cm^3$) enhanced biogas generation. The enhancing effect of urea on biogas yield may be connected to the fact that urea contains elements needed for fungal (bacteria) growth for instance, the presence of amine (-NH_2) in the urea serves as source of nitrogen (N), which is needed by the fermentative microbes for their growth as pointed out by Garba (1988) while the presence of Ketone (>C=O) serves as source of carbon (C), which is required by the fermentative microbes for energy supply and generation of secondary biofuel (CH_4) from substrate feedstock as pointed out by Obinwanne (1999). The effect of urea on the composition of biogas also caused in a slight decrease in CH_4 and an increase (slightly) in CO_2 and H_2S. The slight increase in CO_2 content of the biogas observed may be attributed to the release of CO_2 during the hydrolysis of urea in the slurry. This is in line with the statement of Murry (1977), which says that, urea hydrolyses in the presence of enzyme (urease) and yields CO_2. The increase in CO_2 could also be associated with the formation of H_2CO_3 from hydrolysis of urea, which decomposes instantaneously to CO_2 and H_2O as pointed out by Yaro (2011). The increase in H_2S content of the biogas due to the addition of urea may be attributed to drastic degradation of sulphur containing compounds in the substrate feedstock by the fermentative fungi as reported by Harrison and de Mora (1996). Just like in the case of the effect of buffering, addition of urea has no significant effect on the quantity of the biogas produced (as fuel) because the CH_4 content of the biogas was above 60%, with CO_2 content below 40%.

Table 4 showed that the use of the combination of buffer solution and urea at certain concentration and pH greatly enhanced biogas generation with significant change in composition of the biogas when compared with the respective effects of buffering and addition of urea separately (when they are not combined). The relative increase in the quantity of biogas observed due to the collective effect of buffering capacity and addition of urea was connected to the : presence of Na^+ and P^{-5} ions in the buffer solution which served as fertilizers and, stimulated the growth and activities of the fermentative bacteria as reported by Singh *et al* (1992) & Airehvour (1994); the presence of $–NH_2$ and >C=O groups in the fertilizer, which served as sources of nitrogen and carbon, respectively as pointed out by Obinwanne (1997) and; the favouruable pH condition of the slurry as pointed out by Ariane (1985). On the other hand, the drastic change in the composition of biogas due to the combined effect of buffering and urea may be attributed to the chemical nature of the substrate feedstock, buffer solution and urea added. For instance, the increase in CO_2 may be connected to the: oxidation of carbon content of the substrate feedstock by the oxygen content of the buffer solution as pointed out by Gumel & Yaro (2012); hydrolysis of urea in the presence of enzyme (fermentative bacteria), which release CO_2 as pointed out by Murray (1977) and ; decomposition of H_2CO_3 formed during fermentation into CO_2 and H_2O as pointed out by Yaro (2011). The increase in H_2S may be connected to the degradation of sulphur containing amino acids and proteins in substrate feedstock as pointed by Harrison & de Mora (1996) and reduction of sulphate ion (SO_4^{2-}) mediated by sulphur containing compounds as pointed out by Ahmad (2001). Of all the changes in the composition of the biogas, the biogas obtained was of good fuel value and low environmental hazards because the CH_4 content of the biogas was up to 60% and the CO_2 and H_2S contents, were respectively below 40% and 0.15%.

5. Conclusion

From the quantity ($681cm^3$) and the percentage composition of the biogas (60% CH_4, 39.57%, CO_2 and 0.43% H_2S) generated under the collective influence of buffer solution and urea, it can be concluded that, the use of buffer solution and urea at certain ranges of concentration and pH level, enhances biogas generation with good fuel value and low environmental hazards from banana leaves.

6. Acknowledgement

The authors wish to appreciate the contribution of the staff of Kano Agricultural and Rural Development Authority (KNARDA) Bichi for supplying the sample (banana leaves) used for the research.

References

Ahmad, U. (2000):Nutrients determination of biogas from three different aquatic weeds. Unpublished M.Sc. thesis, submitted to the Department of Pure and Applied Chemistry, Usmanu Danfodiyo University, Sokoto – Nigeria Pp.50-52.

Airiehour, T. A. (1994): Anaerobic Biodegradation of lignocelluloses from water hyacinth using specific fungus (curvalaria spp). Unpublished M.Sc thesis submitted to the Department of Pure and Industrial Chemistry, University of Jos – Nigeria. Pp. 21-25.

Ariane, V. B. (1985): A Chinese biogas Manual: Popularizing technology in the countryside, intermediate Technology publication, London Pp.24.

Ekwenchi, M. M. & Yaro, M. N (2010): Gaseous Fuel production by Fungal degradation of banana leaves *CHESEARCH Journal 1* (1) : 28-32.

Garba, B; Zuru, A. A. & Sambo, A .S. (1996): Effect of slurry concentration on Biogas production from cattle dung. *Nigerian Journal of Renewable Energy* 4(2) : 38-43.

Garba, B. (1998): Studies on the Chemical Composition of biogas and Kinetics of its production at varying temperature, unpublished Ph.D thesis in the Department of Pure and Applied Chemistry, Usman Danfodiyo University, Sokoto – Nigeria. Pp.28.

Ginot, S. R., Gonar, S. S. & Kennedy, K. J. (1988): Nutritional environmental factors contributing to Microbial aggregation during up flow anaerobic sludge bed-filter (SBF) reactor start-up anaerobic Digestion: 45-54.

Gumel, S. M. & Yaro, M. N. (2012): An evaluation of the increased atmospheric pollutants due to the use of urea and buffer solution for maximum gaseous fuel generation from water hyacinth. *Biological and Environmental Sciences Journal for the Tropics* (BEST) 9(3): 30 – 33.

Harrison, R. M. & de Mora, S. J. (1996): Introductory Chemistry for the environmental Sciences (second edition), published by the syndicate of the Cambridge University, UK. Pp. 183 – 184.

Kg bathi, D. L. (1997): Introduction in Biogas Energy policy in Africa, Selected case studies, D.L. Kg bathi, D.O. Hall, A. Hategeka & M. B. M Sekhwela (Editors). Zed book Ltd; London. Pp. 1-9.

Loughton, M. A (1990); Renewable energy sources Barking: Elsevier Science, Amsterdam.

Machido, D. A, Zuru, A. A & Akpan, E .E. (1996): Effects of some inorganic nutrients on the performance of cow dung as substrate for biogas production. *Nigerian Journal of Renewable Energy* 43(2): 38-43.

Obinwanne, V. E. (1999): Determination of local level in three locally produced beverages, namely: Pito, burkutu and Palm wine. Unpublished B.Sc. Project, submitted to the Department of Chemistry, University of Jos – Nigeria. Pp 1-3.

Muray, P. R. S. (1977): A modern comprehensive text for Schools and Colleges (second edition) published by Heimann Educational Books Ltd, 48 Charles Street, London. Pp 270 – 271.

Remage, J & Scurlock J. (1990): Biomass, in: Boyle, G. Renewable Energy Power for sustainable future, Oxford University Press, London. Pp 137 – 182.

Singh, S. K., Amarika, S. & Pandy, G. N. (1992): Effect of additives on bioconversion of biomass into methane. Proceeding of the 2nd World Renewable Energy Congresss 3 (1): 1460 – 1469.

Smith, K.R: (1991): Health Effects of biomass smoke: a brief survey of current literature, Background Paper No.4 Honolulu, Environment and Policy Institute of the East-West.

Uba, A. & Garba, B. (2001): Effect of some inert Polymeric materials on biogas generation. *Nigerian Journal of Renewable Energy* 9 (1 & 2): 60 – 63.

Yaro, M. N (2011): Studies on biogas and bioliquid production by fungal degradation of banana *Musa sapientum)* leaves. Unpublished Ph. D thesis in the Department of Pure and Industrial Chemistry, University of Jos – Nigeria. Pp. 88 – 102.

Zuru, A. A., Abubakar, A.& Ekpekurede, A. (1997): A study of the effect of addition of calcium, boron, cobolt ions and the combination of three ions on biogas production from cow dung. *Nigerian Journal of Renewable Energy* 3 (1 & 2): 90-93.

Table 1: Effect of Concentration of Buffer Solution (pH 7.0) on the Quantity and Composition of Biogas Produced Over a Period of 15 Days.

Digester	Conc. of Buffer solution	Biogas yield (cm^3)	% Composition of biogas		
			CH_4	CO_2	H_2S
A	0.10	440.00	64.82	35.00	0.18
B	0.20	546.00	64.81	35.00	0.19
C	0.30	432.50	64.81	35.01	0.18
D	0.40	315.00	64.80	35.02	0.18
E	0.50	224.50	64.82	35.00	0.18
Control	Distilled water (pH 6.90)	365.00	68.78	31.10	0.12

*Key: Conc.= concentration

Table 2: Effect of pH of 0.2m Buffer Solution (pH 7.2) on the Quantity and Composition of Biogas Produced Over a Period of 15 Days.

Digester	pH of buffer solution	Biogas yield (cm^3)	% Composition of Biogas		
			CH_4	CO_2	H_2S
A	6.80	320.00	64.80	35.01	0.19
B	7.00	545.00	64.80	35.00	0.20
C	7.20	562.50	64.82	35.00	0.18
D	7.40	635.00	64.80	35.01	0.19
E	7.60	349.50	64.81	35.00	0.19
Control Distilled water (pH 6.90)		365.00	68.78	31.10	0.12

Table 3: Effect of Urea on the Quantity and Composition of Biogas Produced Over a Period of 15 Days.

Digester	Urea added (g)	pH of the slurry	Biogas yield (cm^3)	% Composition of Biogas		
				CH_4	CO_2	H_2S
A	0.1	7.10	460.00	63.98	35.19	0.35
B	0.15	7.30	582.00	63.98	35.68	0.34
C	0.20	7.40	595.00	63.87	35.77	0.34
D	0.25	7.50	456.00	63.97	35.69	0.34
E	0.30	7.80	322.00	63.85	35.79	0.36
Control	0.00	6.90	365.00	68.78	31.10	0.12

Table 4: Combined Effects of 0.2M Buffer Solution (pH 7.4) and Urea on the Quantity and Composition of Biogas Produced Over a Period of 15 Days.

Digester	Urea added (g)	pH of the slurry	Biogas yield (cm^3)	% Composition of Biogas		
				CH_4	CO_2	H_2S
A	0.10	7.60	473.00	59.94	39.63	0.43
B	0.15	78.0	632.00	60.00	39.58	0.42
C	0.20	7.90	681.00	60.01	39.57	0.42
D	0.25	8.20	402.00	60.00	39.56	0.44
E	0.30	8.20	206.00	59.95	39.62	0.43
Control	0.00	6.90	365.00	68.78	31.10	0.12

APPENDIX: PREPARATION OF BUFFER SOLUTION

Appendix I: *Preparation of 0.1M Buffer Solution (pH 7.0) Using Buffer Salts ($NaH_2PO_4.H_2O$ and Na_2HPO_4) of Ionization Constant (Ka) = 7 x 10^{-8}.*

The pKa of the buffer salts was evaluated from the given Ka as follows:

$$pKa = -\text{Log } Ka \quad \_\_\_\_\_\_\_\_\_\_\_\_ \quad (1)$$

$$\Rightarrow pKa = -\log 7 \times 10^{-8}$$

$$= -(-7.1549)$$

$$= 7.1549 \approx 7.155 \quad \_\_\_\_\_\_\_\_\_\_ \quad (2)$$

The volumes of acid (Va) and the volume of base (Vb) were obtained using Henderson-Hesselbelch's equation as follows:

$$pH = pKa + \text{Log}_{10} \frac{[\text{conjugate base}]}{[\text{ acid}]} \quad \_\_\_\_\_\_\_\_\_\_ \quad (3)$$

Since pH of the buffer salts = 7.0, equation (3) becomes:

$$7.0 - 7.155 + \text{Log}_{10} \frac{[HPO_4^{2-}]}{[H_2PO_4^{-}]}$$

$$-\,0.155 + \text{Log}_{10}\,\frac{[HPO_4^{2-}]}{[H_2PO_4^{-}]} \qquad (4)$$

By inverting the R.H. S of equation (4), we have

$$0.155 = \text{Log}_{10}\,\frac{[H_2PO_4^{-}]}{[HPO_4^{2-}]}$$

$$=> \quad \text{Log}_{10}\,\frac{[H_2PO_4^{-}]}{[HPO_4^{2-}]} = 0.155$$

$$=> \quad \frac{[H_2PO_4^{-}]}{[HPO_4^{2-}]} = 10^{0.155}$$

$$=> \quad \frac{[H_2PO_4^{-}]}{[HPO_4^{2-}]} = 1.43 \qquad (5)$$

But the mole ratio $\frac{\text{acid}}{\text{Base}}$ is given by $\frac{M_aV_a}{M_bV_b}$

$$:.\ => \quad \frac{[H_2PO_4^{-}]}{[HPO_4^{2-}]} = \frac{M_aV_a}{M_bV_b} \qquad (6)$$

By putting eqn. (5) into Eqn. (6), eqn. (6) becomes

$$\frac{M_aV_a}{M_bV_b} = 1.43 \qquad (7)$$

But for buffer solution, the molar concentration of acid must be equal to the molar concentration of base (i.e. $M_a = M_b$). For this reason, equation (7) becomes.

$$\frac{V_a}{V_b} = 1.43$$

$$\Rightarrow \quad V_a = V_b \times 1.43$$

$$\Rightarrow \quad V_a = 1.43\,Vb \qquad (8)$$

Since the volume of buffer solution used in preparing the slurry was 125cm^3,

$$=> \quad V_a + V_b = 125cm^3 \qquad (9)$$

By substituting the value of Va from eqn. (8) into Eqn. (9), eqn. (9) becomes.

$$1.43V_b + V_b = 125cm^3$$

$$2.43V_b = 125cm^3$$

$$:.\ V_b = \frac{125}{2.43}cm^3$$

$$V_b = 51.44cm^3 \qquad (10)$$

From eqn. (9), $V_a + V_b = 125cm^3$

$$:.\ V_a = 125cm^3 - 51.44cm^3$$

$$= 73.56cm^3 \qquad (11)$$

From eqns.(10) and (11), respectively 51.44cm^3 of base ($NaHPO_4$) and 73.56cm^3 of acid ($Na_2HPO_4.H_2O$), were respectively mixed and formed 125cm^3 of buffer solution (pH 7.0).

The same procedure was followed for determination of the volumes of acid (V_a) and volumes of based (V_b) for other molar concentrations (i.e. 0.2, 0.3, 0.4 and 0.5) and pH (6.8, 7.2, 7.4 and 7.6) of the buffer solution used.

This academic article was published by The International Institute for Science, Technology and Education (IISTE). The IISTE is a pioneer in the Open Access Publishing service based in the U.S. and Europe. The aim of the institute is Accelerating Global Knowledge Sharing.

More information about the publisher can be found in the IISTE's homepage:
http://www.iiste.org

CALL FOR PAPERS

The IISTE is currently hosting more than 30 peer-reviewed academic journals and collaborating with academic institutions around the world. There's no deadline for submission. **Prospective authors of IISTE journals can find the submission instruction on the following page:** http://www.iiste.org/Journals/

The IISTE editorial team promises to the review and publish all the qualified submissions in a **fast** manner. All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Printed version of the journals is also available upon request of readers and authors.

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar