Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.8, 2013

Factors Affecting Biogas Production during Anaerobic Decomposition of Brewery effluent- wastewater in a Fluidized Bed Digester.

Okonkwo P.C [1*] Aderemi B.O [1] Okoli C.S [2]
1. Department Of Chemical Engineering Ahmadu Bello University Zaria. Nigeria.
2. Department Of Chemical Engineering University of Uyo. Nigeria
* Email of the corresponding author: chemstprom@yahoo.com

Absract
This work determined the dependency of biogas and carbon (iv) oxide production on microbial concentration X (Cfu/l), hydraulic retention time (HRT), ratio of total volatile fatty acid (TVFA) and total alkalinity K, during anaerobic decomposition of brewery effluent wastewater in a fluidized-bed reactor system. The volume of biogas and carbon (iv) oxide produced were monitored as the treatment time progressed. For brewery waste water volume of 2 litres treated in the bioreactor, the volume of biogas rich in methane, produced in this work was described as s-curve with initial volume of biogas produced as 0.003l at 4h HRT and maximum volume of 0.0045l at 8 h HRT.Similarly,0.0033l of carbon(iv)oxide was recorded at 2 h HRT and it achieved its maximum of 0.0042l at 8 h HRT. Total microbial count was conducted on the reactor sample water. The maximum concentration of the gases recorded at 8 h HRT corresponded to the favourable operating environment and good system stability ratio (VFA/Alkalinity)<0.5 achieved.
Key words: Anaerobic decomposition, brewery wastewater, fluidized-bed reactor, Biogas, carbon (iv) oxide.

1.0 Introduction

The increased consumption of energy all over the world has led to a drastic increase to the rates of all hydrocarbon based fuels. In addition to this , hydrocarbon based fuels has a finite source that will not be able to meet the increasing fuel needs in the world. With the fossil fuels emitting excessive carbon dioxide and other gases, they prove to increase the incidence of global warming in the world. So to meet the energy needs of the world and to control global warming, scientists and researchers all over the world are working at creating new fuels. Biogas has been found to be a promising alternative fuel.

Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material, and crops(http://www.nnfcc.co.uk/publications/nnfcc) . Biogas comprises primarily of methane(CH_4) and carbon dioxide(CO_2) and may have small amounts of hydrogen sulphide(H_2S), moisture and siloxanes. The composition of biogas varies depending upon the origin of the anaerobic digestion process. Landfill gas typically has methane concentrations around 50%. Advanced waste treatment technologies can produce biogas with 55 - 75% methane(http://www.oaktech.environmental.com/junper:htm) , and for reactors with free liquids 80- 90% methane composition can be achieved.

Biogas can be utilized for electricity production(http://www.alfagy.com/index) , in a CHP engine where the waste heat from the engine is conveniently used for heating the digester, cooking, space heating, water heating and process heating. If compressed , it can replace compressed natural gas for use in vehicles where it can fuel an internal combustion engine or fuel cells. Processes that have potentials for generation of biogas such as waste treatment processes therefore deserve to be optimized so that the economics of the process will be improved upon. This study it is hoped will provide some technical bases for optimal operation of such plant as the energy mix of the entire process will be more efficient.

In a typical brewing processes , about 1113liters of raw water is required to produce 159 liters of beer. In general, about 65% of the total water used in the brewery process ends up as wastewater while small quantity of water is boiled –off during kettle boil or captured in the spend grain(Ockert and Poter 2001). Of concern, brewery effluents are generally characterized by high biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and suspended solids (SS). Breweries produce typically 2-6hl of wastewater per hl produced beer. The Chemical Oxygen Demand(COD) of this wastewater varies between 2000 and 6000ppm, with a BOD(Biological Oxygen Demand/COD ratio of 0.5-0.7. The COD consists mainly of easily biodegradable organic compounds such as sugars, ethanol and soluble starch(Driessen and Vereijken 2003). Anaerobic treatment is a proven and energy efficient way to clean brewery wastewater. Low energy use, a small reactor surface area, lower chemical usage and no sludge handling costs are advantages of this technology over aerobic alternatives. Furthermore biogas is produced during anaerobic treatment, which can be used by the brewery as a renewable energy source to replace part of fossil fuel use

Microbial population, volatile fatty acid (VFA)/ alkalinity(alkalinity) ratio i.e K (vfa/ alkalinity) and hydraulic retention time (HRT) have been demonstrated in a number of studies to have great influence on the volume of methane(CH_4) and carbon (iv) oxide (CO_2) produced during anaerobic decomposition process.(Ozturk et al 1989) treated brewery effluent wastewater in an anaerobic fluidized-bed reactor and reported 75% COD-to-CH_4 Conversion in 1968hr HRT(Sanchez et al 2005),on treating piggery wastewater in UASB, demonstrated that the concentration of CO_2 increased up to 61.3l when the value of K increased up to 0.5. Similar behavior was observed in the acidogenesis of dairy and gelatin-rich wastewater using UASB Yu and Fang 2002) and (Yu and Fang 2003).

In this study, brewery effluent wastewater decomposition in an anaerobic fluidized bed reactor was studied for biogas and carbon (iv) oxide generation potential. The aim of this research is to study the effect of microbial population, vfa/alkalinity (K) and HRT on the production of biogas reach in methane and carbon (iv) oxide during anaerobic decomposition of brewery effluent wastewater in a fluidized-bed reactor system. The biogas produced from the waste water treatment can be integrated into the energy mix of the brewery and this will ultimately improve the economics of brewing processes.

In this study, anaerobic fluidized-bed reactor system was chosen to treat brewery effluent wastewater as a result of presence of biomass concentration upon a carrier material which allows for faster utilization of BOD per unit volume than any other type of biological treatment process. This system enables high biomass hold-up to be attained for good system efficiency and stability with low hydraulic-retention time for good system economy . Unlike the conventional biofilm system in which the growth support media are fixed in space either by gravity or by direct attachment to the reactor wall, the anaerobic fluidized bed system retains the growth support media in suspension by drag forces exerted by the up flowing wastewater. The distribution of the retained biomass is relatively uniform because of the completely mixed conditions maintained and the continuous biofilm sloughing process which counterbalances the accumulation of biomass due to growth, therefore ,anaerobic fluidized-bed system can be considered as a continuous-flow and completely-mixed microbial system.

In the optimized internal environment of a reactor, large organic molecules are converted chiefly into methane and carbon (iv) oxide by the action of bacteria. Under ideal conditions and in the complete absence of free oxygen, this ultimately proceeds to yield fully reduced methane (CH_4) and fully oxidized carbon (iv) oxide (CO_2).The reality of this breakdown at the microscopic level is chemically very complex involving hundreds of potential intermediary reactions and compounds. In addition, many of these reactions each have further need of specific synergistic chemical, catalysts or enzymes.

In very general term however, it is possible to simplify the overall biochemical reaction to (Metcalf and Eddy 1991);

Organic matter $\longrightarrow$ $CH_4 + CO_2 + H_2 + NH_3$ (1)

Four stages of anaerobic digestions are hydrolysis, acidogenesis, acetogenesis and methanogenesis. This stagewise decomposition and the participating microbes are illustrated in Figures 1 ,2 and 3.

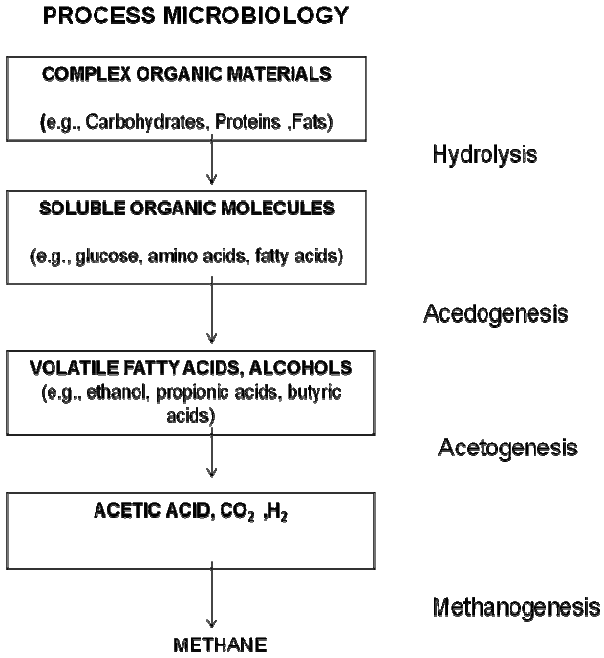

Figure 1. Metabolic Bacteria Groups Involved in Anaerobic Digestion of Organic Wastes

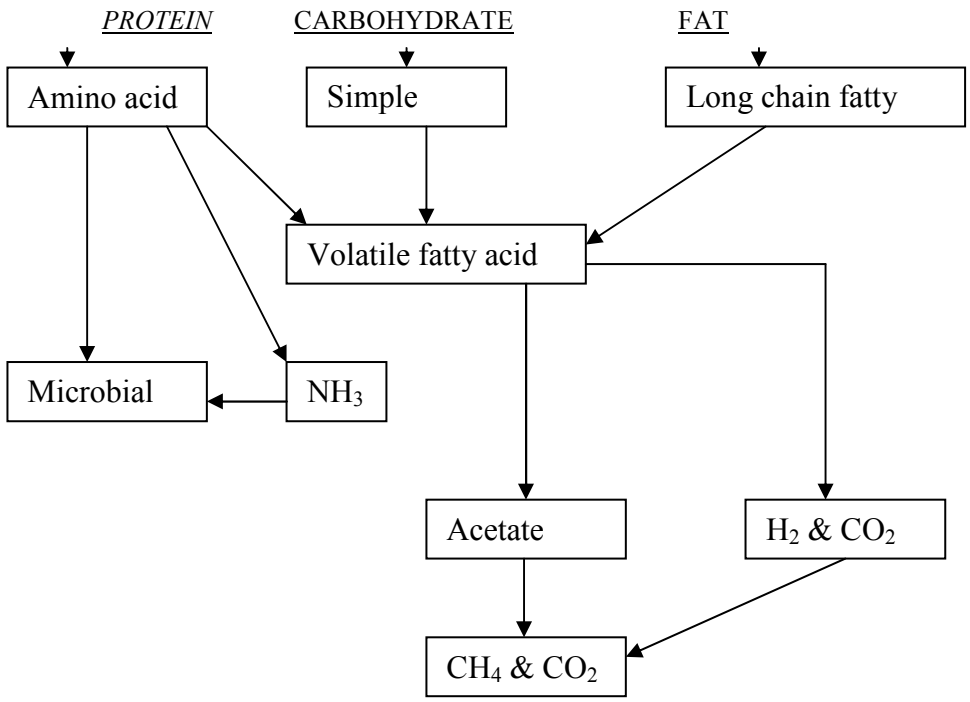

Figure 2. Process Routes For Anaerobic Microbial Degradation of Organic Matter

In a biological process, in which, decomposition of organic matter occurs without oxygen, two processes occur during anaerobic decomposition. First, facultative acid forming bacteria use organic matter as a food source and produce volatile (organic) acids, gases such as carbon dioxide and hydrogen , stable solids and more facultative organisms. Second, anaerobic methane formers use the volatile (organic) acids as a food source and produce methane gas, stable solids and more anaerobic methane formers. The methane gas produced by the process is usable as a fuel. The methane former works slower than the acid former, therefore the pH has to stay constant consistently, slightly basic, to optimize the creation of methane. One needs to constantly feed in sodium bicarbonate to keep pH slightly basic.

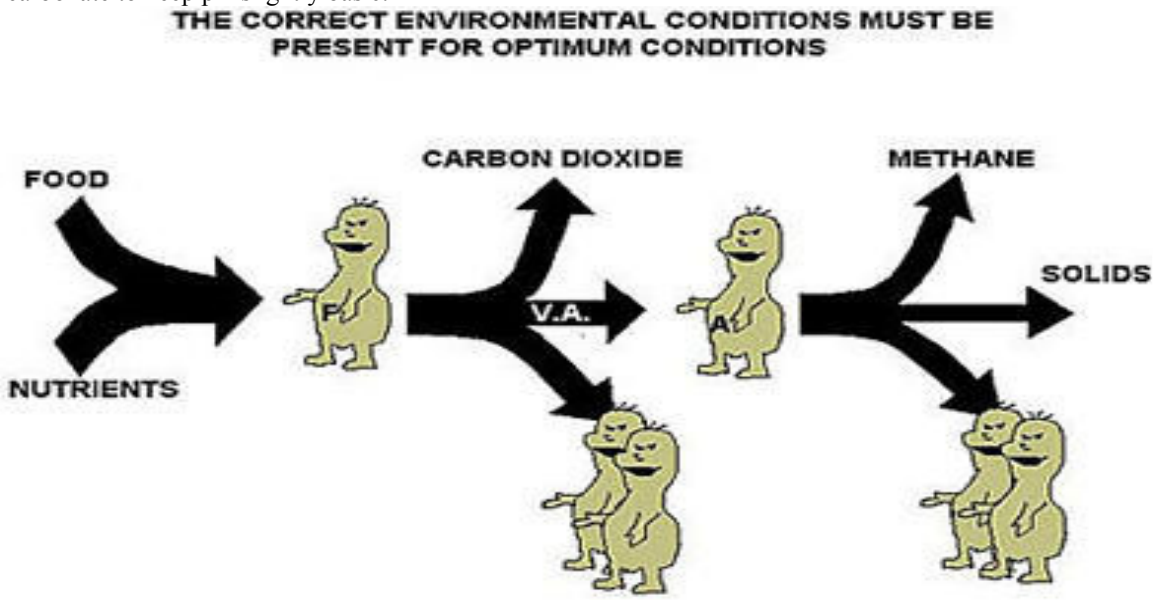

Figure 3 Stages of Biodegadation Waste Water

1.1 Hydrolysis

During hydrolysis, complex insoluble organic polymer such as carbohydrate, cellulose, proteins, fats are broken down and liquefied by the extra cellular enzymes produced by hydrolytic bacteria. This makes them more easily available for use by acidogenic bacteria of the next stage. In general, proteins present in the waste are converted to amino-acids, fat into long chain fatty acids and carbohydrates into simple sugars. The liquefaction of complex

compound especially cellulose to simple soluble substance is often the rate limiting step in digestion since bacteria action at this stage proceeds more slowly than in acidogenesis and methanogenesis.

The rate at which hydrolysis takes place is governed by substrate availability, bacterial population, density, temperature and pH. It is widely considered that there are three effective temperature ranges for anaerobic digestion each of which has its own favored group of bacteria and its own set of characteristic advantages and disadvantages.

These ranges are;

Cryophilic: $< 20^0C$

Mesophilic :($20^0C – 45^0C$)

Thermophilic: $>45^0C$

1.2 Acidogenesis

Acidogenesis sometime splits into acidogenesis and acitogenesis. It is characterized by the production of acetic acid from monomers released in the preceding stage and volatile fatty acids (VFAs) which are derived from protein, fat and carbohydrate component of the feed stock. The main products of this stage are acetic, lactic and propinoic acid. The pH falls as the level of these compounds increase. Carbon (iv) oxide and hydrogen are also evolved as a result of catabolism of carbohydrates with the additional potential for the production of methanol and / or other simple alcohols. The proportion of different by–products produced depends on the environments, to some extent, and more largely on the particular bacterial species present.

1.3 Acetogenesis

Organic acids, alcohols and ketones can be transformed to acetate, carbon (iv) oxide and hydrogen gas by acetogenic bacteria in an anaerobic digestion of wastes. Acetogenic bacteria convert fatty acids (e,g. propionic acid, butyric acid) and alcohols into acetate, hydrogen and carbon(iv) oxide, which are used by the methanogens. Hence, ethanol, propionic acid and butyric acid are converted to acetic acid by the following reactions:

$$CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 2H_2 \quad (2)$$

$$CH_3CH_2COOH + 2H_2O \longrightarrow CH_3COOH + CO_2 + 3H_2 \quad (3)$$

$$CH_3CH_2CH_2COOH + 2H_2O \longrightarrow 2CH_3COOH + 2H_2 \quad (4)$$

1.4 Methanogenesis

This involves the production of methane from the raw material produced in the previous stage. This is brought about by obligates anaerobic whose growth rate is overall slower than the bacterial responsible for the preceding stages.

The methane is then produced from a number of simple substrates; acetic acid, ethanol or carbon (iv) oxide and hydrogen. Of these, acetic acid and the closely related acetate are most important, since about 75% of the methane produced is thus derived according to the equation(Wheatley 1990) :

$$CH_3COOH \longrightarrow CH_4 + CO_2 \quad (5)$$

Methane forming bacterial may also use methanol as

$$CH_3OH + H_2 \longrightarrow CH_4 + H_2O \quad (6)$$

or may use carbon (iv) oxide and hydrogen

$$CO_2 + H_2 \longrightarrow CH_4 + 2H_2O \quad (7)$$

Hydrogenotrophic methanogenesis:

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2HO_2 \quad (8)$$

Acetoclastic methanogenesis:

$$CH_3COOH \longrightarrow CH_4 + CO_2 \quad (9)$$

Despite the fact that the production of methane yields a useful fuel source, the action of the associated methanogenic bacteria plays a vital role in maintaining the wider break down process by converting volatile fatty acid (VFAs) into methane and associated gases. Any trend towards an increase in VFA concentration thus decreases pH.

In this way, the acid/base equilibrium is naturally regulated, at least in part and the attendant potential for biochemical inhibition and / or bacterial population distribution provided by the acidification of the reactor environment is largely removed.

Methanogenes are pH sensitive, the required range being mildly acidic (6.6-7.2) and problems are likely to be encountered if the pH falls much below 6.4. More over, should this stage not progress properly, the required stabilization of the waste will not progressively be achieved and the volatile fatty acids produced prior to the methanogensis phase will have serious implication with regard to final use or disposal of the same materials derived.

2.0 Materials and Methods

2.1 Instrumentation and Equipment

The anaerobic fluidized-bed reactor shown in Figure 3.1 consists of frustum - like shaped glass material column with a total working volume of 2l. The reactor column has total height of 1.45m with a progressive increase in internal diameter from 42 mm at the bottom to 60 mm at the top. The effluent recycle port was located at 550 mm from the top with the diameter of 22 mm. Below the effluent recycle port, is a solid trapper made of fine diffusible filter cloth located inside the reactor, about 290 mm from the bottom of the reactor. This enclosure prevents excessive washout of solids and it maintains good bacterial flocs and conducive environment for better degradation of organic matter in the reactor. Twenty gram activated carbon of size range (75-300) µm were used to serve as support material for microbial concentration in the reactor. About 12 l capacity laboratory tanks were used as effluent collection tank and feed tank respectively. The feed tank was mounted on hot iron plate with thermostatic settings to maintain the range of temperature (34^0C-38^OC) which was needed for the work (mesophilic temperature). The upper section of the reactor contains a conical-shaped gas-liquid separator to allow the biogas produced to vent-off into a carbon (iv) oxide absorption unit. The carbon(iv) oxide is absorbed by bubbling the gas through 2M solution of $Ca(OH)_2$ in a 500l flat bottom flask. The biogas rich in methane gas passed into an inverted graduated cylinder, where it was collected through downward displacement of water. Sample ports were located along the reactor length through which reactor contents were collected for analysis .The reactor length was lagged to minimize loss in temperature of the content to the environment .The pump was located very close to the reactor feed entrance point to minimize head loss. .

2.2 Experimental procedure

The reactor was initially filled with 20 g activated carbon (75-300 µm), and then the 168 h acclimatized seed sludge (100 ml) was added .The anaerobic seed used in this work was collected from lagoon process system treating brewery wastewater. Brewery wastewater obtained from Sona System Associates Business Management Limited (SSABM) located at Kudenda Industrial Area, Kaduna, Kaduna State, Nigeria, was charged raw into the feed tank. The study employed a fluidized-bed digester, with liquid volumetric flow rate of 1.7 x $10^{-6}m^3/s$, superficial velocity of 0.0012 m/s and 0.00026m/s of the minimum velocity required to fluidized 20g activated carbon bed of height 0.03m with 0.384 voidage in a recycling manner prior to continuous operation, to improve in homogenization of temperature, flow rate and the acclimatization of the cells in the digester, thereby enables the cell attached to the solid supports material. The pressure drop across the fluidized-bed was calculated to be 1.848 N/m^2.

The reactor length was lagged to prevent loss in temperature to the surrounding. The pH was adjusted to neutral point, and then the reactor was operated by pumping the feed from the feed tank continuously at volumetric flow of 6.28 l/h in all the experiment, the biogas produced was vented-off the reactor through the gas-liquid separator where carbon (iv) oxide was absorbed in a 2M solution of Ca(OH) and the biogas rich in methane gas was collected over water in a measuring cylinder through downward displacement of water. 1M sodium hydroxide solution was added periodically to maintain the pH range of 6.8 to 7.2 in the reactor. In each run, the same concentration of the feed was used at a particular hydraulic retention time (HRT). This continued for different HRT at the same initial feed concentrations and at the same feed flow rate. The samples analysis were taken periodically and Lagrange interpolation technique was applied to the experimental data to bridge the gap between the period of system shut-down and the continuous process. All the chemical analyses of the parameters (chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), suspended solids (SS), dissolved solids (DS), total solids (TS), alkalinity, volatile fatty acid, nitrate, phosphorous and oil & grease) were done according to the standard Methods(11) (APHA, AWWA, WPCF).

2.3 Determination of Bacterial count

The total count was performed using plate-count method . Three serial dilution of 1ml of sample water with 9ml of brine to make 10ml in each case was prepared. From the third diluted sample,0.1ml was pippetted into freshly prepared nutrient agar medium in a Petri dish, with the help of wire loop, which is sterilized in Bunsen flame and cooled in between streaks, the primary inoculums was spread out at an angle of 120^0-130^0 over 4-5 segments in a petri-dish. The innoculated plates were incubated for 24 h with the base of the plate faced upward at 37^0 in an incubator (Gallenhamp,GA-216). After 24 hours, the number of colonies grown in the agar plate was counted, and the colony forming unit were calculated from Colony forming unit per mil

$$\left(cfu/_{ml}\right) = \frac{Number\ of\ colonies\ x\ dilution\ factor}{volume\ of\ the\ innoculum} \quad (10)$$

Note: Volume of the inoculum used = 0.1ml
Dilution factor = 10^3
The count was done for the sample from the reactor (X) and that of the reactor effluent (Xe)

Initial number of the bacteria seed inoculated = 0.94 x 10^9 cfu/l

2.4 Determination of volatile fatty acid

Volatile fatty acid was determined using distillation method.

Two hundred ml water sample was centrifuged for 5 min at 3000 rpm.Hundred ml of the resulting supernatant liquor was measured into 500 ml distillation flask. 100 ml distilled water was added together with three clay chips (anti-bump material). Finally, 5 ml concentrated tetraoxosulphate (vi) acid was added and the whole mixture was stirred thoroughly such that acid did not settle at the bottom of the flask. The flask was connected to distillation assembly and was distilled at the rate of about 5 ml per min. The first 15 ml of the distillate was discarded and exactly 150 ml of the distillate was collected and titrated with 0.1N Sodium hydroxide using phenolphthalein indicator.

The volatile fatty acid is given by: $$VFA(mg/l) = \frac{ml\,(NaOH) \times N \times 60000}{ml(Sample) \times f} \quad (11)$$

Where N= Normality of Sodium hydroxide

f = Recovery factor

3.0 Results and Discussions

The raw waste water from SSABM, located at Kudenda industrial area, Kaduna State, Nigeria was analyzed in accordance to the Standard Methods and the compositions of this wastewater are summarized in Table 1 . During the continuous treatment process, the effluent waste water was collected and analysed in accordance to standard methods. The composition of the reactor effluent and some reactor parameters are in Table 2.

Table 1. Summary of Characteristics Results of Raw Sample

PARAMETER	VALUE
Chemical oxygen demand(COD) (mg/l)	7137.67
Biological oxygen demand(BOD_5) (mg/l)	2177.85
Total solid (TS) (mg/l)	4075.33
Total dissolved solid (TDS)(mg/l)	2969.33
Total suspended solid (TSS) (mg/l)	1106
Phosphorous (mg/l)	51.13
Nitrate (mg/l)	58.8
Ph	5.17
Oil &Grease (mg/l)	0.00008

Table 2. Summary of Effluent Parameter Values

HRT(τ) (h)	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alkalinity(mg/l)	99.36	533.33	967.32	1038.66	1110.00	1126.30	1142.59	1153.0	1163.4
VFA(mg/l)	342.44	486.22	630.00	581.06	533.91	548.59	563.26	579.02	594.78
K(Vfa/Alkalinity)	3.40	0.91	0.65	0.56	0.48	0.49	0.49	0.50	0.51
Biogas (l)	0.00	0.017	0.033	0.036	0.039	0.042	0.045	0.036	0.033
CO_2 (l)	0.033	0.032	0.031	0.032	0.033	0.038	0.042	0.036	0.030
X_e (Cfu/l)X10^9	1.89	1.29	0.69	1.38	2.06	1.69	1.32	2.04	2.76
X (Cfu/l)X 10^9	2.05	2.13	2.20	2.24	2.28	2.36	2.44	2.54	2.32
U(mg COD/Cfu.hr)x10^{-7}	1.71	1.88	1.93	2.47	2.86	2.56	2.37	2.14	2.88
Ug(CH_4 /Cfu.h)x10^{-9}	0.00	2.71	5.10	5.46	5.80	6.05	6.27	4.82	4.84

3.1 Effect of HRT on Volume of Biogas and Carbon (iv) Oxide Produced

The performance of anaerobic reactor can be assessed by monitoring the volume of biogas rich in methane and carbon (iv) oxide produced. In this case, production of methane, being the last phase of any anaerobic digestion of organic waste, is the slowest step. Figure 4 shows the variation of biogas rich in methane and carbon (iv) oxide gas generated as the treatment time increases. From the figure above, no methane gas was detected in the first 2 h HRT treatment period. This observation had long been described by other researchers[13], though COD reduced was partially significant. The volumetric methane production can be described as S-curve corresponding to biofilm (bacterial accumulation with production of bio-polymer) formation, In this case, significant amount of carbon (iv) oxide was produced as product together with volatile fatty acids with no methane gas as represented in Figure 3 . From figure 3, the first phase with zero volume of methane after 2 h HRT, then the second phase with progressive increase in volume of methane up to 0.045 l, at 8 h HRT. This was achieved as a result of converting the volatile acids and some intermediates products to methane and carbon (iv) oxide by methanogenic

bacteria as it can be shown in figure 3, and reaction equation 9. Finally, the last declined phase with volume of methane being 0.033l at 10 h HRT. This experience was as a result of low production of volatile acid at this point which serve as major substrate for the methane forming bacteria as shown in Table 2.

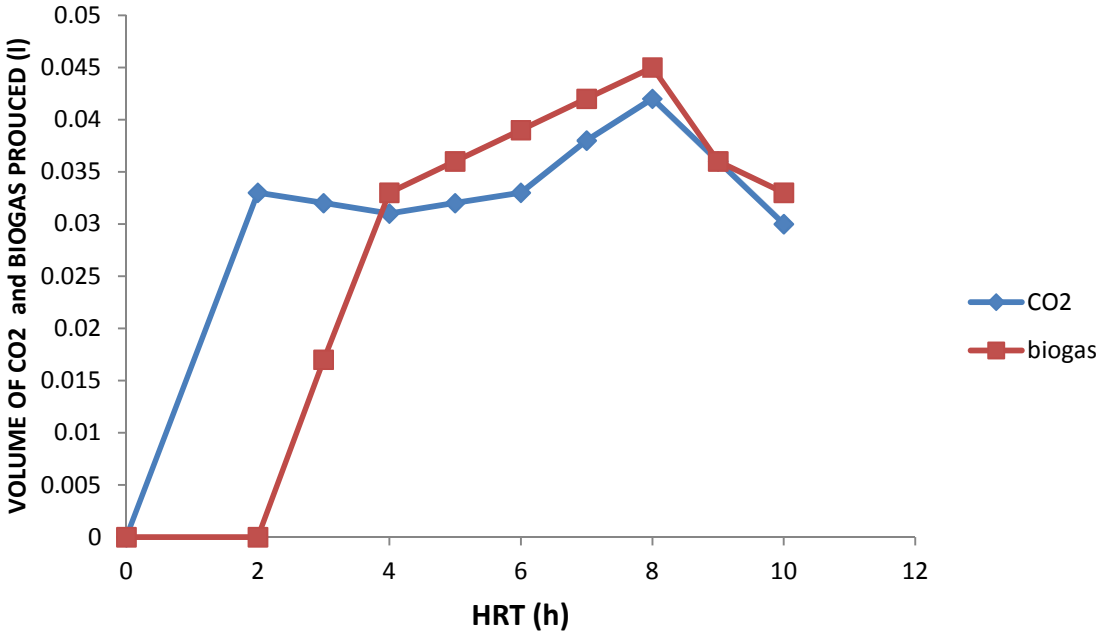

Figure 4: Variation of Biogas and Carbon (iv) Oxide Gas With HRT

3.2 Effect of HRT on Microbial Concentration in The Reactor (X)

Figure 4 shows a clear picture of cell growth as the treatment time increases in the anaerobic reactor.Before the treatment operation began,the anaerobic microbes(seeds) were sourced from locally made lagoon unit treating brewery wastewater.The microbes were acclimatised for 168 h at 37^{O}C to cultivate high population of anaerobic microbes which engaged in waste degredation.From figure 5.4, 0.94 X10^{9} Cfu/l was introduced in the reactor to initiate the treatment operation. After 2 h , the microbial concentration was observed to be 2.05 X10^{9} Cfu/l. It was observed that as hydraulic retention time increases,the cell concentration increases as well, until at 10 h HRT, the cell concentration decreased.The decrease in cell concentration may be as a result of death.This condition can make cells to loose attachment strength.This condition lead to high concentration of effluent cell wash-out (Xe) at 10 h HRT as shown in Table 2.

3.3 Effect of Microbial Concentration on The Volume of Carbon (iv) Oxide and Biogas Produced

From Figure 3, four categories of microbes working in a synergic relationship are involve in transformation of complex organic materials to methane.During waste digestion,carbon (iv) oxide is produced as a result of microbial conversion of voliatile fatty acids (butyric acid,propionic acid) and alcohols into acetic acid with more microbial cells reproduced as shown in Figure 1 and Figure 2. The effect of microbial concentration (X) in the reactor on the volume of carbon (iv) oxide and Methane produced can be shown in Table 2. Here, at the first 2 hr HRT,the anaerobic cells fed on solublised organic matter to produce carbon(iv) oxide, volatile acids and more anaerobic cells (see Figure 2).Hence ,the microbial population in the reactor increased. In this case, no methane was observed. As the hydraulic retention time increases,volatile acids and ethanol were converted to acetic acid which later consumed by methane formers to produce methane, carbon(iv) oxide and more microbial cells (see reaction equation 7 to 9 and Figure 2).Therefore, from Table 2, after 3 h HRT,significant amount of methane gas (0.017l) was observed.The volume of methane increased with carbon(iv) oxide and cell concentration up to 9 h HRT. At the end of 10 h HRT,cell population decreased with corresponding decreased in methane and carbon(iv) oxide production as represented in Table 2.The decrease in biogas and carbon(iv) oxide production might be due to decrease in microbial concentration in the reactor as shown in Table 2.

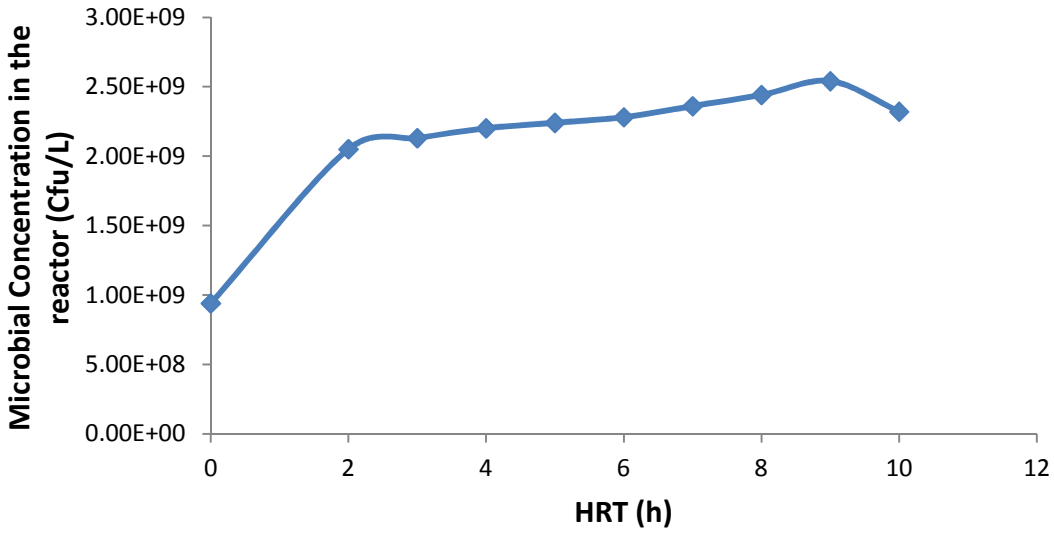

Figure 5: Effect of Hydraulic Retention Time (HRT) on Microbial Concentration in The Reactor (X)

3.4 Effect of K (VFA/Akalinity) Ratio on Volumetric CO_2 and Biogas Produced

Table 2 shows the effluent parameter results obtained under different experimental conditions studied. As explained earlier, no biogas in terms of methane gas was observed at 2 h HRT. The absence of methane may be as a consequence of the increase in volatile fatty acid (VFA) and a simultaneous decrease in the alkalinity causing a significant increase in K-value (VFA/akalinity). This situation has a strong influence on the biogas quality produced, hence significant amount of CO_2 was observed within this range of HRT. However, at 4 h HRT, there was a sudden increase in the alkalinity and a corresponding decrease in K-value, hence, 0.033 l biogas was observed. As reported by Fannin, when K-value is less than or equal to 0.5, the process is considered to be operating favorably without the risk of acidification. At 7 h and 8 h HRT, maximum concentration of gases were recorded since the concentration of alkalinity here overtook that of volatile acid, thereby brought the K-value down within the limit of stability (less than or equal to 0.5) as shown in Table 2. Beyond this limit, the system is said to be unstable and will be in danger of acidification which inhibits the methanogenes.

3.5 Effect of Specific Substrate Utilization (U) on Specific Methane(Biogas) Production (Ug)

The conversion of any organic substrate to biogas rich in methane under anaerobic condition involves its conversion to a mixture of short chain organic acids (acetic acid) with the release of carbon (iv) oxide followed by the formation of methane by either splitting of organic acids or reduction of carbon (iv) oxide]. In Table 2, the specific methane production increased from zero with increase in specific substrate utilization up to 8 h HRT, where the specific substrate utilization ceased to increase , owing to the reason that methane formers at this point might have sourced for alternative substrate for the production of biogas rich in methane, that is, using carbon(iv) oxide and hydrogen as it can be seen in Equation 9. Finally, as the retention time was increased beyond 7 h HRT, specific methane production and specific substrate utilization decreased.

4.0 Conclusions

Bio- conversion of brewery waste water has good potentials in generation of green energy which can reduce over dependence on fossil fuels with its attendant problem of net generation of green house gases . The drive to check the global challenge of global warming and climate change will therefore direct focus attention to alternative sources of energy which are environmental friendly. Biogas offers such promising option of alternative energy resource.

The study showed the trend of variation of biogas produced during anaerobic decomposition of brewery waste with the process factors such as microbial concentration, X (Cfu/l),hydraulic retention time (HRT),ratio of total volatile fatty acid (TVFA) and total alkalinity ,K, during anaerobic decomposition of brewery effluent wastewater in a fluidized-bed reactor system. The production of biogas which is rich in methane was described as s-curved and was absent at the first 2 h of operation.

It was observed from the results that ratio of volatile fatty acid to alkalinity (k-value) above 0.5, has very great influence on the quality of biogas produced, therefore, maximum gases (carbon (iv) oxide and biogas) were found at the value of k, below 0.5 as 0.42 l and 0.45 l for carbon (iv) oxide and biogas respectively.

On the average from the experiments, 50 l of raw brewery wastewater was treated to generated 0.269 l of biogas and 0.313 l of CO_2,

The results obtained in this study can be used in optimization of operation of biodigesters for production of biogas which can be integrated in the energy supply mix of the brewery or the community. The CO_2 can also be processed for industrial uses.

References

American Public Health Association (1985)**, "**Standard methods for the examination of water and wastewater", *APHA, AWWA,WPCF*..

Biogas CHP engine fitted to Anaerobic Digestion Plant [Online] Available http://www. alfagy.com/index. Php(May 15 2010)

Cronin. C and K.V.LO.(1998), Anaerobic Treatment of Brewery Wastewater UsingUASB Rector Seeded with Activated sludge. *Bioresourecs Tech*. 64 .33-38.

Driessen W and Vereijken T.(2003) Recent Developments in Biological Treatment of Brewery Effluent . *The Institute and Guild of Brewing Convention Livingstone Zambia* March 2-7 2003

Fanin K.F (1987) *Start-up operation, Stability and Control In Anaerobic Digestion of Biomass*. Elsevier Lond UK 171- 195

Juniper Biogas Yield Comparison[Online] Available http://www.oaktech.environmental.com/junper:htm (May 15 2010)

Lawrence,A.W & McCarty, P. L.(1969) Kinetics of Methane Fermentation in Anaerobic Treatment. *Journal of.Water Pollution and Control Federation*, 41, 1-16

Metcalf Eddy Inc (2004), *Wastewater Engineering Treatment and Reuse* 4th ed. Mc. Graw Hill Publishing Company Ltd. 581-633, 1008-1018.

Ockert, Karl and Porter Fred .(2001), *Brewery Engineering and Plant Operation,* London Green Press Chapter 4.

Ozturk, I., Anderson, G.K. and Saw, C.B.(1989). Anaerobic Fluidized-Bed Treatment of Brewery Waste and Bioenergy Recovery, *Water Sci.Technology*.21, 1681-1684.

Sanchez, E., Borja, B., Travieso, L., Martin, A. & Colmenarejo, M. (2005) , Effect of organic loading rate on performance of a secondary upflow anaerobic sludge bed reactor treating piggery waste. *Bioresource. Technology*, 96, 335-334

Wheatly, A. (1990) , *Anaerobic digestion*, A Waste treatment technology. SCi, Elsevier, London, U.K .

Yu, H.Q., & Fang, H. H. P. (2002) Acidogenesis of dairy wastewater at various pH levels. *Water Sci. Technol.* 43 (10), 201-206 .

Yu, H.Q., & Fang, H. H. P. (2003) . Acidogenesis of gelatin-rich wastewater in an up-flow anaerobic reactor, influence of pH and temperature. Water Res. 37, 55-66, *Water Sci. Technol.* 43 (10), 201- 206 .

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