Volume-11,Issue-4(Apr-19)
ISSN (O) :- 2349-3585

The Potential of Biogas from Apple Juice

Udara S. P. R. Arachchige[1], Kohilan Rasenthiran[2], Lakshan M.A.L[3], LakshithaMadalagama M. K[4], PrabhathPathirana P.R[5], SakunaSandupama P.W[6]
Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka

Abstract – This study examines the biogas and energy generation potential from apple juice, optimum factors and inhibitors for the biogas generation process. Instead of apple waste apple juice used for the experiment by assuming apple juice and apple waste compositions are approximately equal. In this report consider about biogas generation amount, flow rate, other factors are affecting the biogas generation, and energy derives from biogas. Moreover, simulated the biogas potential, flow rate, pH & VFA etc.Then compared experimental results with simulated data. Small syringes used as reactors and gas holder. In this experiment considered the effect of the biogas potential with mixing effects and without mixing. According to the yield calculation data, identified 5% is given the maximum yield. According to the 5% sample simulated data, identify the optimum conditions and used simulated results to calculate the energy potential from biogas. pH, VFA, organic load are the main important factors affect to the biogas production. pH should be around 7 for better gas production.The temperature at 35 ± 1.0 C was kept for better gas production. UASB is the best reactor for biogas generation because of the smallest volume. Average gas production from apple waste is 35ml/1 ml feed and CH4 production is approximately 60% of the total gas production. Finally calculated the energy potential from methane as 417.7kWh.

I. INTRODUCTION

High energy demand directly linking to the prices of fossil fuel and environmental pollution. Developed and industrialized countries most concerned about clean energy technologies, while the developing countries still prioritizing fossil fuel based energy generation for manufacturing and energy infrastructure. However the evolution of low carbon energy systems and advanced energy technologies needed to meet the sustainability goals at the first level of priority [1]. Global warming resulted from the fossil fuel based industrial emissions of greenhouse gases; especially carbon dioxide has received widespread attention with the concentration of CO2 in the atmosphere reaches 400 ppmv[2]. Therefore, the fast moving of sustainable energy generation is in high priority to maintain a better environment. The biogas generation from wastes, residuals, and energy crops will play a vital role in future. Biogas is versatile renewable energy which can be used to replace fossil fuels in gas-fired power plants, and heat generation sector as well as in the transportation sector. The anaerobic digestion process of biogas generation offers significant advantages over other forms of bioenergy production. It has been identified as one of the most energy-efficient and environmentally beneficial technology for bioenergy production [3]. Anaerobic digestion process can be defined as organic substrates are degraded in the absence of oxygen due to enzymatic and bacterial activities. The fermentation process produces biogas that can be used as a fuel source for cooking purposes and energy generation sector. The sludge generated by the fermenting process can be used as an organic fertilizer in agriculture [4]. The main aim of the present study is to quantify the biogas production from apple juice. The waste from fruit and vegetable processing industries has been used for the production of biogas by the anaerobic digestion process. During this process, the complex polymers are first hydrolyzed enzymatically into simpler substances and then the resulting matter is converted to Volatile Fatty Acids (VFA's) by acidogenic bacteria. These VFA's are further converted to acetates by acetogenic organisms. At the final stage, methanogenic organisms will utilize acetates and produce biogas (Fig. 1). This study examines the energy generation potential from biogas derived from apple juice. This experiment was done to find the optimum conditions for biogas generation such as substrate to inoculums ratio, pH etc. It is also wanted to find the optimum gas production using apple waste as a raw material. In the end, calculated the

All rights reserved by www.ijrdt.org

energy potential from biogas using apple waste.

II. OBJECTIVES

In this project, the primary aim was to test the following hypothesis.

Hypothesis 1: Apple juice is a suitable biogas feed and it can be used to fulfil the energy demand in apple juice factory.

Hypothesis 2: Effect of mixing to biogas yield.

Hypothesis 3: Oxygen, NH4 and H2 inhibition to the CH4 production.

Same time investigate the influence of initial conditions on the process using computer-aided simulation tool Aquasim 2.0.

III. THEORY

Modelling of the net energy production of the anaerobic fermenter is important for reliable decision making on the efficiency of anaerobic digestion processes. By using the Anaerobic Digestion Model No. 1 (ADM1) the simulation of biogas production and estimation of operating conditions are possible [5].

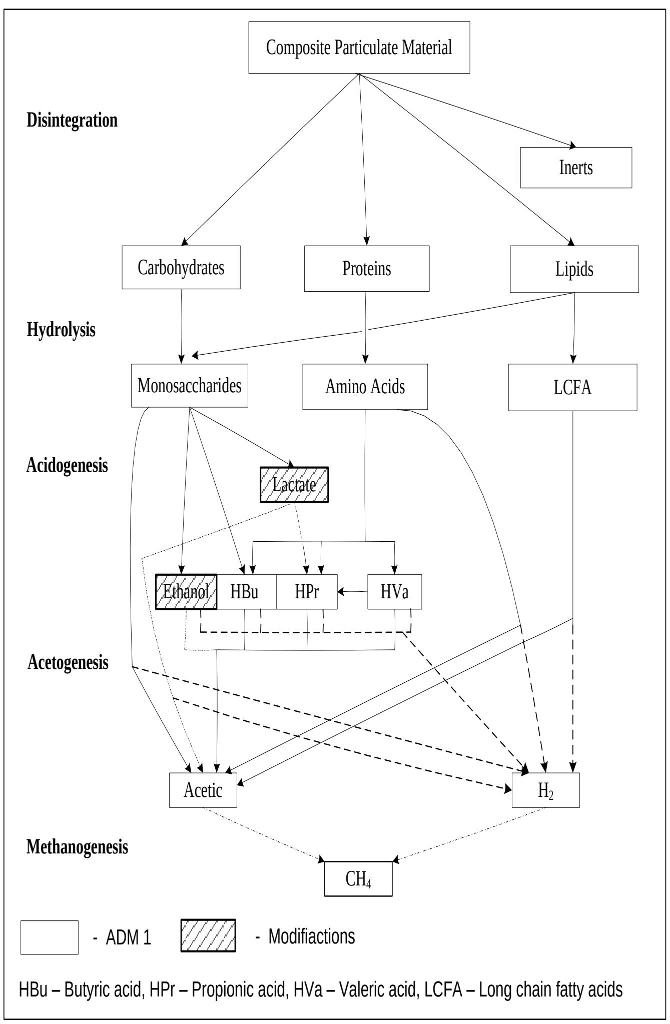

Fig. 1. Diagram of ADM1

There are three main steps involved with overall anaerobic oxidation of a waste.

- Hydrolysis
- Fermentation(Acidogenesis&Acetogenesis)
- Methanogenesis

Hydrolysis

The first step is hydrolysis. Hydrolysis of particulate biodegradable material is carried out by facultative bacteria. Carbohydrates are broken down to simple sugars. Proteins are broken down to amino acids and lipids are broken down to long chain fatty acids. The hydrolysis of lipids is the rate-limiting step. At this point no COD reduction takes place. It just shifts from solids into the liquid phase.

Fermentation

In the fermentation process, amino acids, sugars, and some fatty acids are degraded further. The principal products of fermentation are acetate, hydrogen, CO2, and propionate and butyrate. The propionate and butyrate are fermented further to produce hydrogen, CO2, and acetate too.

TABLE 1: PRODUCTS FROM GLUCOSE DEGRADATION

Products	Reaction	Reference
1 Lactate	$C_6H_{12}O_6 \rightarrow 2CH_3CHOHCOOH$	5,6,7
2 Ethanol	$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$	5
3 Butyrate	$C_6H_{12}O_6 \rightarrow CH_3CH_2COOH + 2CO_2 + 2H_2$	5,6
4 Acetate	$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2$	5,6,7

The lactate is subsequently degraded to propionate and acetate. Stoichiometric reactions of lactate acidogenesis are presented in below.

TABLE 2: PRODUCTS FROM LACTATE DEGRADATION

Products	Reaction	Reference
1 Propionate	$CH_3CHOHCOOH + H_2 \rightarrow CH_3CH_2COOH + H_2O$	6,7
2Acetate and propionate	$3CH_3CHOHCOOH \rightarrow 2CH_3CH_2COOH + CH_3COOH + H_2O + CO_2$	6,7

ISSN:-2349-3585 |www.ijrdt.org

3 Acetate	$CH_3CHOHCOOH + H_2O \rightarrow CH_3COOH + CO_2 + 2H_2$	5,6,7

Acidogenic bacteria start working on the amino acids, sugars and long chain fatty acids. The process is a fermentative reaction, where both the electron donor and electron acceptor are organic compounds, leading to the formation of intermediate compounds (volatile fatty acids), such as propionic and butyric acid. Acetogenic bacteria start metabolizing the intermediary metabolites - volatile fatty acids - converting them into acetic acid, carbon dioxide, and hydrogen. Anaerobic oxidation at this point is inhibited by hydrogen gas. With the high hydrogen gas partial pressures the reaction becomes thermodynamically unfeasible, resulting in an increasing amount of volatile fatty acids (VFA) in the surrounding liquid phase.

Methanogenesis

For successful operation of anaerobic digestion, there is a need to continuously remove hydrogen (this is what methanogens do). Methanogenesis is the last step in microbial biogas production. There are two groups of Methanogens; all of them are obligate anaerobes. One group - H2-oxidizing methanogens - reduces CO2 using H2 as the electron donor to form methane. The second group of methanogens cleaves acetic acid into methane and CO2. About 2/3 of the methane produced, comes from this reaction. Nearly all volatile organic matter entering a digester will end up as methane. Small amounts will be incorporated in newly formed biomass.

IV. Methodology

In this experiment, 60ml medical syringes were used as small scale anaerobic digesters and gas holders. Apple juice and inoculum were added to the syringes according to the ratios given below. The inoculum was taken from a wastewater treatment plant sludge outlet (filtered sample) Fig. 2. The five different apple juice feed samples tested with parallels. Two samples used as fixed reactors (without mixing) and two used with laboratory shaker (with mixing). The 30 ml inoculum is added to each reactor (syringe). See Table 3 for detailed information.

TABLE 3: QUANTITATIVE DOSIN OF APPLE JUICE AND INOCULUM IN THE REACTORS

Sample no.	Residue content (weight-%)	Parallels	Inoculum(ml)	Apple residue, leachate (ml)
1	0	2	30	0
2	1	2	30	0.3
3	2	2	30	0.6
4	5	2	30	1.5
5	10	2	30	3.0

All syringes were prepared for biogas production according to the following procedure.

1. The pH of inoculum and apple juice was measured.
2. 30 ml inoculum was sucked up into each and every syringe.
3. Apple juice was sucked up according to the above table.
4. The air in the syringe was removed by pressing it through the needle.
5. Placed the stopper at the needle point to close the syringe.
6. Checked if the syringe is gas-tight by pulling the piston, no air sucked into the syringe indicates that the system is gas tight.
7. Place the syringes on a test tube rack and other set placed on the shaker and placed both sets in the incubator.
8. The temperature at 35 ± 1.0□ C was kept for better gas production.
9. Daily gas production in each syringe was recorded with temperature data.

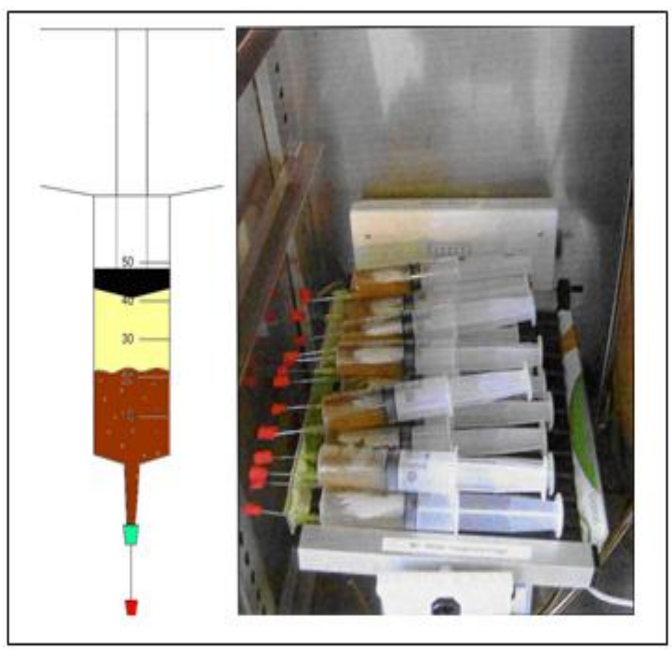

Fig 2. Biogas reactor with samples placed on a rack

ISSN:-2349-3585 |www.ijrdt.org

Aquasim

According to the inoculum volume and type of the reactor (batch or CSTR) simulations of the flow rate, pH, VFA, biomass etc. were carried out with Aquasim 2.0 software. AQUASIM allows its users to define the spatial configuration of the system to be investigated as a set of compartments, which can be connected to each other by links. Moreover it allows users to perform simulations using different models, to assess the identifiability and to estimate the values of model parameters (using measured data), and to estimate prediction uncertainty. The simulation process was repeatedly checked to fit the theoretical model into the experimental data and to estimate initial conditions of the reactor.

Analytical Methods

pH meter is used for measuring the pH of the inoculum and apple juice. Gas production in each day was removed to provide the space for next day gas production. Then total gas volume calculated according to the volume of gas removed and measuring value.

V. Simulation Studies

Simulation studies based on biogas generation is considered in this section.

Batch Reactor

Biogas yield variation with % feed indicated in following Fig. 3.

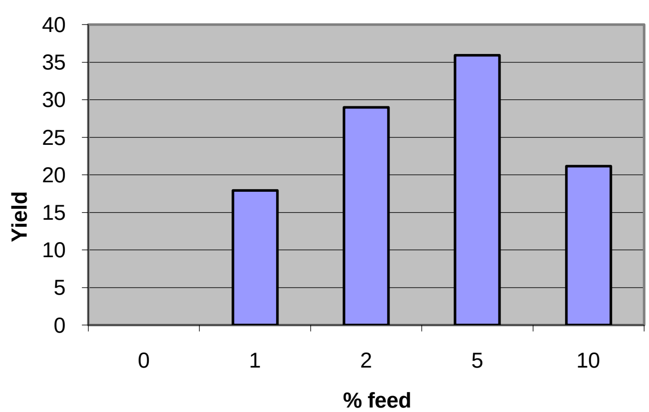

Fig 3. Biogas yield vs. feed%

Biogas production yield for 5 samples is represented in the above graph. According to the graph, 5% feed give the maximum yield (Average values of four samples were used).The maximum yield around 35ml biogas/ml feed. Average biogas volume with the amount of feed variation indicated in the following Fig. 4.

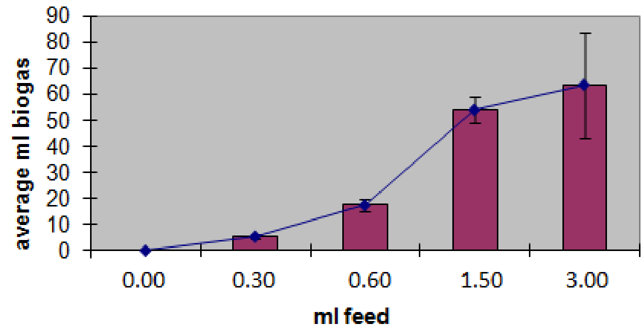

Fig 4. Total Biogas produced from different feed% samples

According to the above Figure 4, 10% feed gives the maximum gas production volume. The maximum biogas production is around 60ml and its related to the 10% feed sample. But yield is high in 5% feed sample. So 5% feed sample is selected as the best feed sample for biogas production. And that sample data used for simulation. The reasons for selecting 5% feed is given below.

- 5% feed sample gives the maximum yield.
- 10% represent the overloaded state.(Not enough biomass)
- If we used 10% instead of 5% energy and production cost is higher.

Accumulated gas production

Accumulated biogas variations for experimental and simulated figures are given below in Fig 5.

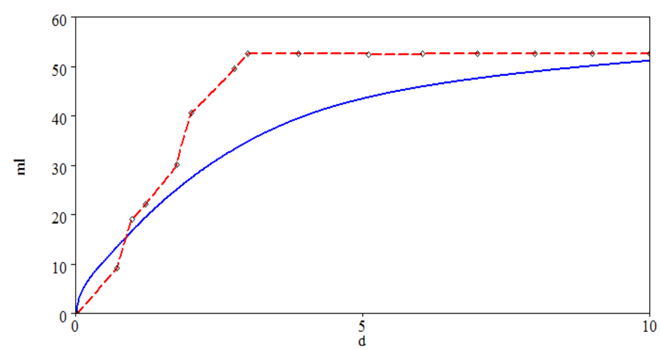

Fig 5. Accumulated biogas generation (- - - experimental; — simulated results)

The Blue colour solid line represents the simulated accumulated gas production and red line represented the experimental accumulated gas production. According to the shape of the lines, both follow the same pattern. After 3 days of the period, gas production has stopped. The reason may be, not enough foods for further gas production. According to the simulation graph, after 10 days period gas production has stopped. Experimental data represent some deviations from

ISSN:-2349-3585 |www.ijrdt.org

the simulated graph. But both figures are approximately equal. So our experiment followed the theoretical biogas production procedure.

Gas production rate

Gas production flow-rate for experimental and simulated results are given in Fig 6.

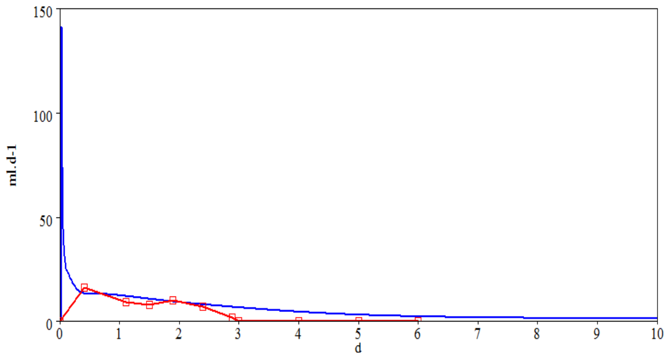

Fig 6. Batch reactor biogas production rate simulated & experimental data

In the graph above is represented the same sample (5%) gas flow rate values for 10 days period. Redline (symbols) represented the experimental gas flow rates and blue colour (line) represents simulation results. According to the experimental graph at the beginning gas production is increasing and then the rates are decreasing after showing the peak rate. After 1.5 days again the gas production rate is increased. Then after 3 days, the gas production flow rate become zero. According to the simulated figure, initially shows a high production rate and then decreasing. After 0.5 days again flow rate increased and after two days period flow rate decreased and after 10 days close to zero value.

Biomass

Reactor biomass concentration variation is given below in Fig 7.

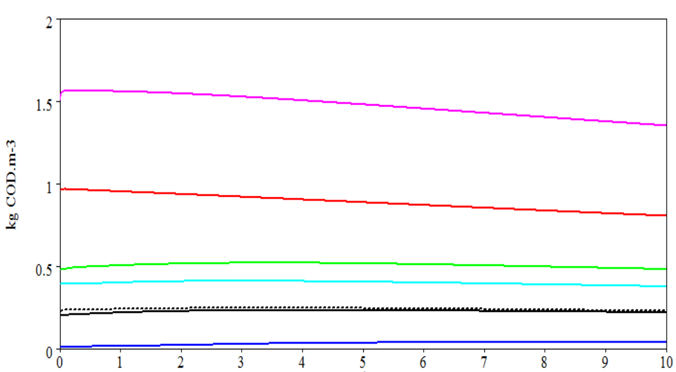

Fig 7. Batch reactor simulated results for reactor biomass concentration

The above Fig. 7 represents the biomass variation in the reactor. According to that, X_su and X_pro are decreasing slowly and others are stable. Purple line and red line indicated biomass concentration for sugar (X_su) and propionate (X_pro) respectively.

Adjusted gas rates

Simulated adjusted gas volume figure for a batch reactor is given below. In this figure indicating the percentage amount of various gas production.

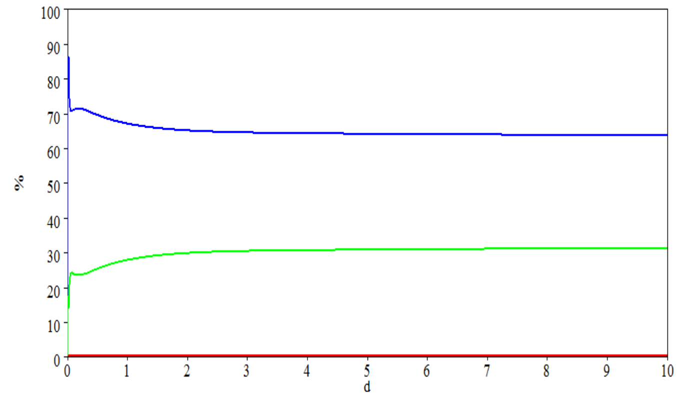

Fig 8. Batch reactor simulated results for adjusted gas percentages

The above Fig. 8 represents the gas production percentages. Blue colour represents the CH4, the Green colour line represents the CO2 and red colour represents the H2. There are around 70% methane gas is produced and remaining is CO2 gas. There is no H2 gas production in this step.

VFA

This graph (Fig. 9) represents the VFA variation with a time period.VFA is considered as one of the best indicators for the biogas production process.

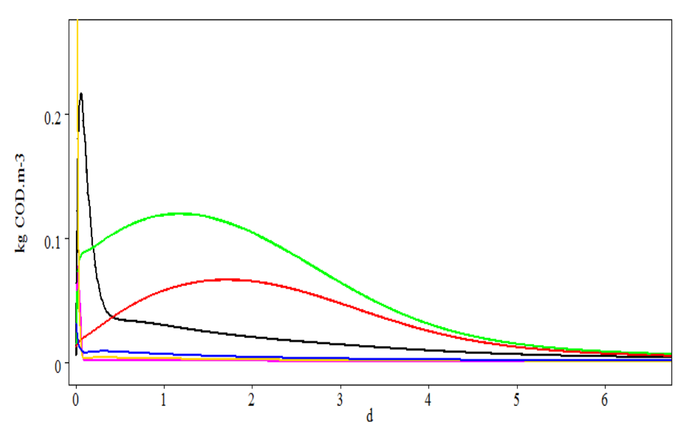

Fig 9. Batch Reactor simulated results for reactor VFA concentrations

ISSN:-2349-3585 |www.ijrdt.org

According to Fig 9, VFA of butyric and valeric VFA concentrations are increasing until 1.5 days and shows peak value (green and red colour). Then both graphs decreasing following the same pattern.VFA concentration of acetate graph is decreasing. But other graphs do not represent a significant effect. So it can be said that butyric and valeric VFA play an important role in the biogas production process.

pH

pH variation in the reactor is given below in Fig 10. pH is one of the most important parameters for biogas production.

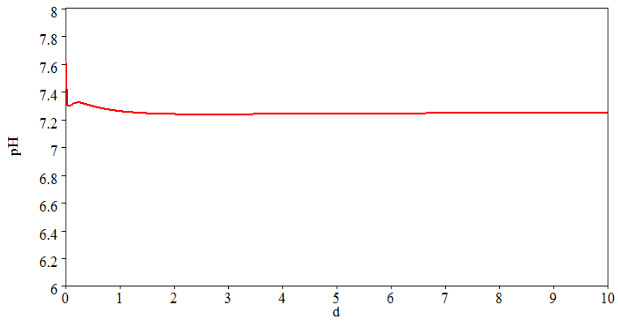

Fig 10. Batch reactor simulated results for pH

According to Fig 10 above, pH value is stable around 7. So this pH is good for the biogas production process. pH is considered as the other main factor represent the biogas production capability instead of VFA figure.

Continuous Stirred-Tank Reactor (CSTR)

Here we consider flow rate as a 2 m3 and hydraulic retention time (HRT) 10 days. So the volume of the reactor is 20 m3.

Gas flow rate

Gas flow rate variation in CSTR is given below in Fig 11.

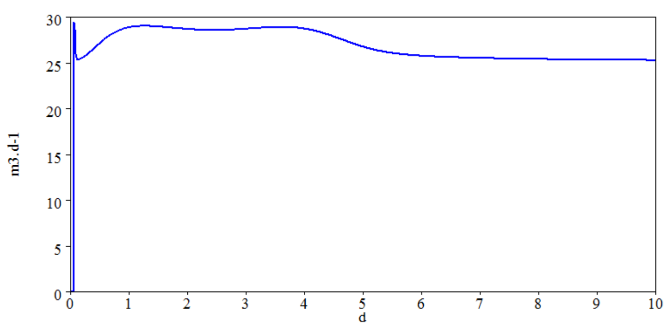

Fig 11. CSTR simulated gas flow rate

Above Fig 11, represents the biogas production flow rate of CSTR biogas reactor. In CSTR, feed is continuously supplying. If it is considered, HRT as 10 days, reactor size is 20 m3. According to Fig 11, initially, the gas flow rate is increasing drastically and then stable around 25 m3/day. There are a lot of advantages and disadvantages related to the CSTR reactor (Further discussed in discussion part).

Adjusted gas volume

Simulated adjusted gas volume figure for the CSTR reactor is given in Fig 12. In this figure, it is indicating the percentage amount of various gas production.

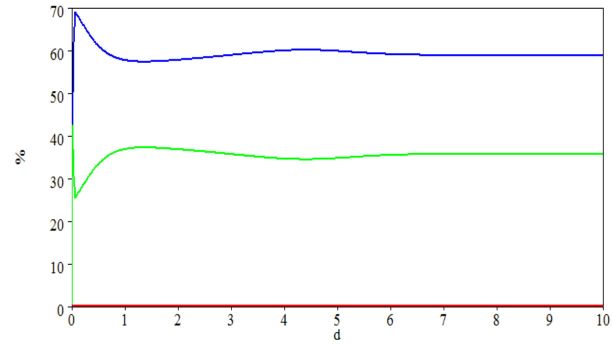

Fig 12. CSTR simulated results for adjusted gas volume

According to Fig 12, CH_4 gas percentage around 60% (blue), and CO_2 percentage around 40% (green).There is no effect on H_2 (red) production. When calculated the amount of energy generated, CH_4 percentage is considered.

Inhibitors

Simulated Fig 13 for Inhibitors related to the biogas production process is given below.

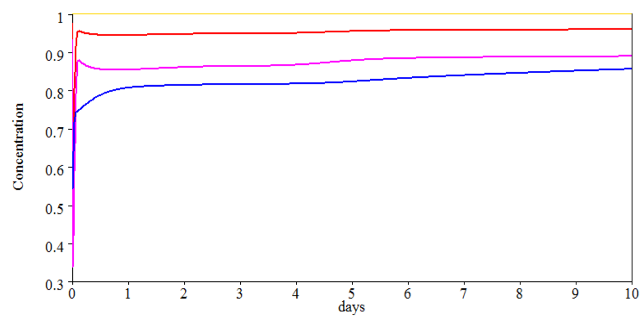

Fig 13. CSTR simulated results for inhibitors concentration

According to Fig 13, indicated the very low effect of inhibition for apple waste biogas production process. The Red colour indicated the CO_2, purple colour line indicated the H_2 and blue colour indicated the NH_3. The concentration of all inhibitors are very small and negligible (0.9 kg COD/m3). Therefore inhibitor action on apple waste biogas production is negligible.

UASB (Up-flow Anaerobic Sludge Blanket)

UASB reactor can be used to reduce the reactor volume of CSTR reactor. In this method solid sludge recirculation back

ISSN:-2349-3585 |www.ijrdt.org

to the reactor. HRT of this reactor can be assumed as 2 days. It becomes the reactor volume of 4 m3.

Gas flow

Gas flow rate variation in the UASB reactor is given below in Fig 14.

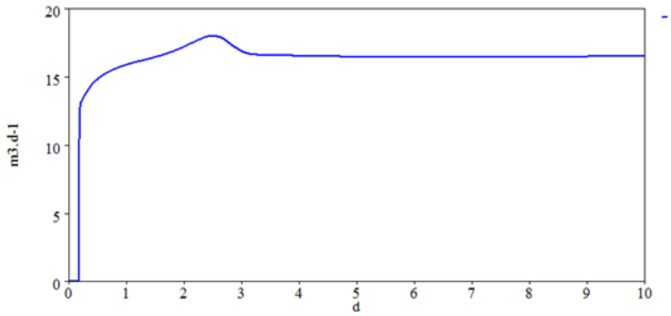

Fig 14. UASB simulated results for gas flow

This Fig 14 represented the gas production flow rate of UASB reactor. According to Fig 14, the gas flow rate increased and then decreased gradually. Initially the gas flow rate increasing very fast and then stable around 17 m3/day. In this reactor, the gas production rate is less than the CSTR reactor, but the reactor size is smaller than the CSTR reactor. So it beneficially effects on the investment cost.

Gas production amount

Simulated adjusted gas volume figure for UASB reactor is given in the following Fig 15. In this figure indicating the percentage amount of various gas production.

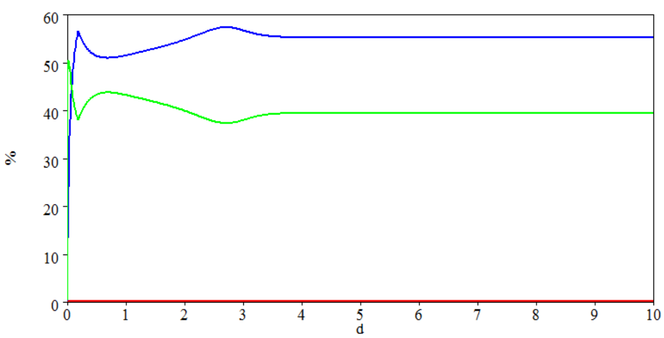

Fig 15. UASB simulated results for adjusted gas volume

According to Fig 15, the blue colour represents the CH4 production percentage, green colour represents the CO2 production percentage.CH4 production percentage around 55%. When compared with CSTR there is no big difference with CH4 percentage. In this reactor pH stable around 7.So reactor conditions are good for biogas production.

Overloaded

This Fig 16, related to the overloaded conditions simulated results for the pH of the reactor.

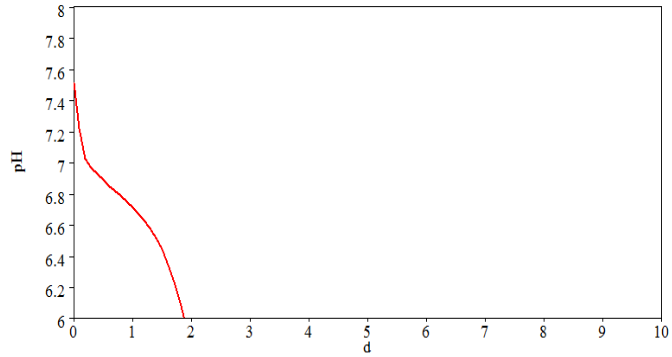

Fig 16. Simulated results for overloaded condition (pH)

According to Fig 16, pH decreasing drastically when overloaded conditions happen. Then this pH is not providing a better environment for Methanogenesis bacteria. According to the overloaded conditions reactor, VFA variation is given below.

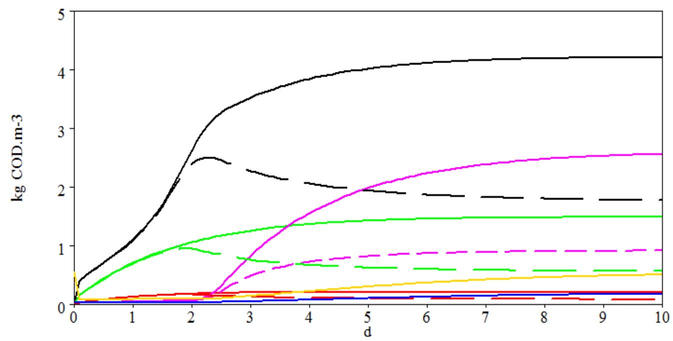

Fig 17. Simulated results for overloaded condition (VFA)

In this Fig 17, acetate VFA level is increasing and both butyric and valeric VFA levels are also increasing. All acidic VFA levels increasing mean again acid level increasing and pH level goes down. So lower pH is not good for Methanogenesis bacteria. It causes to reduce biogas production.

VI. Discussion

According to the experiment, different apple juice compositions fed to the syringe and measured gas production daily. 10% sample indicated the maximum gas production (Fig 4). But the yield was high in 5% sample (Fig 3). Therefore, 5% sample was selected as the best sample for simulation studies. Because of the yield is the important thing when considering large scale biogas production. A number of bacteria are involved in the process of anaerobic digestion. Anaerobic organisms digest the initial volatile organic matter, which undergoes four-stage microbial processes converting it to intermediate molecules including sugars, hydrogen & acetic acid before finally methane - biogas is produced. The

ISSN:-2349-3585 |www.ijrdt.org

substrate mix fed to the digester results in a specific biogas composition and biogas yield. pH, VFA, organic load are the main important factors considering about biogas production.

pH and volatile fatty acids

Volatile fatty acids (VFA) level variation was shown to be a good parameter describing anaerobic digester process stability. VFA concentration will change according to the changes in hydraulic loading, organic loading or temperature. Bacteria involved have different requirements regarding the biochemical environment. Acid-forming bacteria are much more tolerant of low pH concentrations than methanogens. Acidogenic bacteria metabolize still at high levels at pH 4.5 whereas methanogens face decreasing rates at pH 6.0. Fatty acid concentration and subsequent pH levels in anaerobic digesters play a vital role in operating a biogas system. Production of VFAs leads to a decrease in pH. Normally the drop in pH is counterbalanced and buffered by the formation of alkalinity through CO_2 production.

Organic load

The organic loading is one of the most important parameters operating an anaerobic digester. The organic loading provides information on nutrient supply levels of the microorganisms involved, overload or undersupply of the system as well as resulting technical and process control measures to be taken. Furthermore, it gives an indication of biological degradation of the substrates i.e. it describes the efficiency of the anaerobic digester. The organic load is defined as the amount of volatile organic dry matter entering the anaerobic digester over time. As an example: Irregular feeding intervals or overloading the digester leads to an imbalanced system. Acid-forming bacteria have a higher growth rate than methanogens. Therefore, they respond faster to changes in substrate concentration. Production of long chain fatty acids and acetic acid is increased immediately and leads to a drop in pH (Fig 16). Methanogens don't tolerate pH values below 6, have a much lower growth rate and cannot keep up as well in removing acetic acid and hydrogen. Anaerobic digestion systems are complex processes that often suffer from instability. Such instability can usually occur as a drop in the methane production rate, a drop in pH, a rise in Volatile Fatty Acid (VFA) concentration (Fig 17), finally causing a complete digester failure. The anaerobic process is more stable when the volatile fatty acid concentrations approach a minimal level, which can be taken as an indication that a sufficient methanogenic population exists and sufficient time is available to minimize hydrogen and VFA concentrations. The often rate-limiting step is the conversion of VFAs by the methanogenic organisms and not the fermentation of soluble substrates by the fermenting bacteria.

Buffer capacity

When biogas production was finished, the pH of the sludge was measured. This pH value is very low. According to the very low pH, produced biogas may not be methane. Because low pH values not well for Methanogenesis bacteria. So this gas may be more consists of H_2 and CO_2. Reasons for this situation (low pH value) can be assumed as follows. In the experiment, the inoculum was taken from a filtered sample of the wastewater treatment plant outlet. Then more buffering agents were lost to the filter cake. Therefore the buffer capacity of the filtrate is low and pH is low. So initial pH of the inoculum should be increased by adding buffering agents before feeding to the reactor or outlet of the wastewater treatment plant should not be filtered for inoculum.

Reactor Temperature

Constant process temperature is critical to successfully operate an anaerobic digester. An increase in temperature leads to increase bacterial activity with higher growth rates, faster metabolism and elevated nutrient demand. If the temperature falls below a certain optimum bacterial metabolism and subsequent biogas production decelerates. Methane production decreases or is completely stopped. At the same time, CO_2 levels rise. Acid-forming bacteria respond to an increase in temperature with accelerated growth and will outgrow the methanogenic bacteria. Rapid changes in temperature will result in similar effects as sudden increases in organic loading. Therefore a constant temperature is critical to the anaerobic digester. In our experiment temperature kept as 35 centigrade.

Biogas Plant design Simulation results can be used to determine the potential of biogas generation and energy generation from apple juice. According to the experimental value, approximately 35ml gas/ml feed can be assumed as a yield. Our calculation is done for the CSTR reactor.Various

ISSN:-2349-3585 |www.ijrdt.org

sized CSTR volumes were simulated by assuming different HRT values within this range and check the biogas production with simulated figures. An HRT 10 simulation result was used to get the best fit theoretical curve and that simulation and experimental data were used to scale up this complete mix biogas reactor.

At steady state,

Feed flow rate = $2m^3$/day

Yield = 35ml gas/ml feed

Yield $= \frac{35ml}{1\ ml\ feed} = \frac{x\ m3\ gas}{2\ m3\ feed\ /day}$

x = 70 m^3/day

According to the adjusted gas volume graph,

CH_4 composition = 60%

Amount of CH_4 production = 70 * 0.60 m^3/day

=42 m^3/day

At standard temperature and pressure (20 ˚C and 1 atm) methane gas has a lower heating value (LHV) of 35800 kJ/m^3. Lower heating value is the heat of combustion minus the heat of vaporization of any water vapour present.

Energy potential from methane=35.8 MJ/m^3 * 42 m^3/day

=1,503.6 MJ/day

1 kWh = 1kJ/s * 3600 s = 3600 kJ =3.6 MJ

Energy potential from methane (kWh)

$= \frac{1{,}503.6\ MJ/day}{3.6MJ/1kWh} = 417.7\text{kWh}$

Effect of mixing for biogas yield (Hypothesis two)

According to the experiment, there is no significant effect on mixing. Both group results are approximately equal. But theoretically, there is a good effect with mixing for biogas generation process (not for yield). Mixing is an important component within the complete mix digester technology helping to maximize homogeneous mixture. Mixers are specially designed according to fermenter volume and substrate properties like viscosity ensuring homogenous digester content and the rapid distribution of fresh substrate entering the digester. The constant agitation of the liquids enhances substrate and subsequently nutrient availability for the bacterial biomass. Bacteria have a sufficient food supply at all times. Anaerobic digestion takes place undisturbed. At the same time, mixing prevents the building of dead zones inside the digester and keeps fine particles in suspension and avoid the accumulated of biomass bottom of the reactor.

Inhibition action by NH4, O2 and H2 (Hypothesis three)

According to the simulated figures, there is no significant effect of inhibition for biogas production from apple waste. If the feed is more with protein composition, then it causes to produce NH3 and this affects to the biogas production. But apple waste is more with carbohydrates. Therefore the formation of NH3 is negligible.

Compare Batch, CSTR and UASB

A batch system is the simplest form of digestion. A batch reactor is good for small scale biogas generation. If the waste production time period is large, then the batch reactor can be used. Biomass is added to the reactor at the start of the process in a batch and is sealed for the duration of the process. Batch reactors suffer from odour issues that can be a severe problem when they are emptied. In the CSTR process, organic matter is continuously supplied to the reactor equipped with an impeller while the reactor effluent is removed (Fig 18). At steady state, the inlet flow rate and outlet flow rate should be equal; otherwise, the tank will overflow or go empty. It is economically beneficial to operate several CSTR in series.

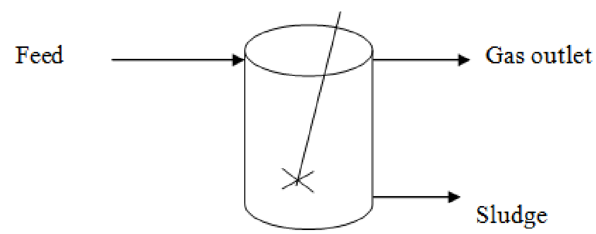

Fig 18. CSTR Biogas reactor

UASB reactor (Fig 19) uses an anaerobic process whilst forming a blanket of granular sludge which suspends in the tank. Feed flows upwards through the blanket and is degraded by the organisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. The blanket begins to reach maturity around three months. Small sludge granules begin to form whose surface area is covered in aggregations of bacteria. The UASB reactor is one of the reactor types with high loading capacity. UASB process is a combination of physical & biological processes. The main feature of the physical process is the separation of solids and gases from the liquid and that of biological process is the degradation of decomposable organic matter under anaerobic conditions. Reactor volume is smaller than CSTR.

ISSN:-2349-3585 |www.ijrdt.org

So investment cost is low and economically friendly [8].

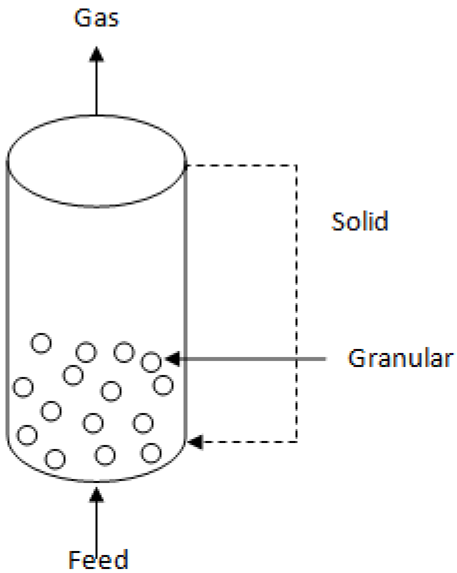

Fig 19. UASB Biogas reactor

The key feature of the UASB process that allows the use of high volumetric COD loadings compared to other anaerobic processes is the development of a dense granulated sludge.

VII. Conclusion

• UASB reactor is the best reactor for apple waste biogas generation. Because reactor volume is low (HRT is low).

• Mixing is not important for biogas generation and it does not affect the gas generation yield. But it is important to prevent the accumulating solid particles bottom of the reactor.

• pH, VFA, organic load are the main important factors considering about biogas production. pH should be around 7 for better gas production.

• The anaerobic process is more stable when the volatile fatty acid concentrations approach a minimal level.

• The temperature at 35 ± 1.0 C is better for gas production

• Initial pH of the inoculum should be high. If it is low, buffering agents should be added to the feed sample to increase the buffer capacity.

• Inhibition action for biogas production from apple waste is very low.

• Average gas production from apple waste is 35ml/1 ml feed ($35m^3/1\ m^3$ feed) and CH4 production is approximately 60% of the total gas production.

• Energy potential from methane 417.7kWh. And this energy generation is enough to fulfil the energy demand in Epleblomsten juice factory.

• Apple waste is good feed-source for biogas generation.

Recommendations for experiments

• It is important to do readings of the produced gas to operate at better conditions. To achieve proper reading it is important to notice that the results are influenced by the temperature and the way to do the readings. Press and pull the piston (and check if it goes back to the start position) before taking a biogas reading.

• According to formula PV=nRT, the temperature difference between the incubator temperature and room temperature make a significant effect on gas volume. So, when reading volume for headspace, it should be done as quickly as possible or read them in the incubator.

• It is highly recommended to measure the parameters such as pH, total COD, soluble COD in addition to gas volume & VFA analysis before doing the feeding.

Recommendation for plant

• To keep the process temperature stable tank walls are equipped with heating coils. Coils can be mounted onto the wall or are sometimes build as in-wall heating. Digester walls and floor are insulated in order to minimize temperature losses to the outside.

• Gas quality is continuously measured. The H2S content of the produced biogas is kept low by biological desulfurization inside the gasholder. If H2S levels are very high due to e.g. protein rich substrates chemical precipitation is needed to adjust gas quality.

• Elevated hydrogen sulfide concentrations can cause problems for the gas engines. Combustion leads to the formation of sulfur dioxide with increasing corrosion and a significant drop in pH of the oil and subsequent more frequent oil changes. 30% of the total hydrogen sulfide formed with anaerobic digestion passes over into the gas phase.

References

[1] D. Eric, Fossil Energy, Chapter 12, Cambridge University Press, 2012.

[2] U. S. P. R. Arachchige, " Carbon Dioxide Capture by Chemical Absorption: Energy Optimization and Analysis of Dynamic Viscosity of Solvents", Ph D thesis, University of South-Eastern Norway, ISBN: 978-82-7206-516-3, 2019.

ISSN:-2349-3585 |www.ijrdt.org

[3] H. Fehrenbach, J. Giegrich, G. Reinhardt, U. Sayer, M. Gretz, K. Lanje, J. Schmitz, KriterieneinernachhaltigenBioenergienutzungimglobalenMaßstab. UBA-Forschungsbericht 206:41–112, 2008.

[4] S. Zerrouki1 , R. Rihani , F. Bentahar, Biogas production from fruit juice wastewater, Proceedings Engineering and Technology, Vol 3, 185-188, 2013.

[5] Batstone et al, Anaerobic digestion model No 1 (ADM1), Water Science & Technology 45(10):65-73, 2002.

[6] D. Iván. Ramírez-Rivas, Anaerobic Digestion Modeling: from One to Several Bacterial Populations, Tecno. Lógicas., No. 31, julio-diciembre de 2013.

[7] I. Skiadas, H. N. Gavala, G. Lyberatos, Modelling of the Periodic Anaerobic Baffled Reactor (PABR) based on the retaining factor concept, Water Research 34(15):3725-3736, 2000.

[8] Metcalf and Eddy.(2003), Wastewater Engineering Treatment and Reuse.(Fourth Edition). Tata McGraw-Hill Publishing Company Ltd, 1005-1007.