International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

# Study on Process and Design Optimization of Biogas through Processing the Food Waste in Anaerobic Digester

Bala Krishna Inguva[1]
Department of Chemical Engineering,
Chaitanya Bharathi Institute of Technology,
Telangana.

Kiranmai Palcham[2], Manasa Kamidi[3]
Department of Chemical Engineering,
UG students,
Chaitanya Bharathi Institute of Technology,
Telangana.

***Abstract*- A report by the FOOD WASTE INDEX by UNEP estimates 931 millions of food waste was generated in 2019. The food waste alone causes 10% greenhouse gas emission .Demand for renewable energy has increased due to the depletion of fossil fuels .Anaerobic Digestion is a complicated biodegradable process involving a several bio chemical reactions in the absence of oxygen. In INDIA, the total potential of BIO-GAS production from various organic wastes is about 40,734 $Mm^3$/year. The optimum studies were presented to improve the bio gas yield and production rate. This Review paper presents the overview of the parameters effecting and improving the biogas production from food waste through Anaerobic Digestion. The optimum value for HRT was found in the range of 25-30 days. The optimum value of OLR is around 2-3 gm VS/ L/day. The optimum temperature range is 25-30 degrees centigrade.**

***Keywords— Food Waste;Anarebic digestion; renewable energy; factors for biogas maximization***

## I..INTRODUCTION

According to the reports of WMO there are 90% chances for the global temperature to increase above 1.5 degree centigrade above pre industrial level in the next five years from now. It also states that 1.5 degree centigrade could be crossed permanently in decade or two. The Intergovernmental panel on climate change (IPCC) warned that 1.5 degree centigrade will be the menacing milestone in planet's warming. Higher temperatures cause more melting of ice, higher sea levels and extreme changes in the climate. one of the causes for this rise in the temperature is release of greenhouse gases into the atmosphere mainly water vapours, nitrous oxide, carbon dioxide, methane. It is estimated that 1/3rd of the food is wasted across the world. The United Nations Environmental Programme (UNEP) estimated 931 million of the food waste was generated in 2019 in THE FOOD WASTE INDEX report published in 2021 where contribution of households is 63% , contribution of foodservice is 26% and retails contribute 3%.we can eliminate the green house gas emission to 6% - 8% if we can stop wasting the food. One way to eliminate the food waste is to process the food waste biologically for producing the useful products from the wastes. Anaerobic Digestion (AD) process is the conversion of organic wastes into useful products like bio gas renewable energy without supply of oxygen. Also, the demand for the renewable energy has increased due to the depletion of fossil fuels. Producing the renewable energy which has potential applications from biodegradable waste helps to overcome the energy crisis and eliminate the solid, food waste.

Anaerobic digestion is a biological process that has been prevailing long ago and is considered to be a useful tool where we can generate renewable energy and byproducts. Significant research interest has arisen recently in this field. AD is four stage process containing hydrogenesis, acetogenesis, acedogenesis, methogenesis .Operational control parameters like alkalinity, VFA(volatile fatty acids), pH and process performance parameters characterized by volatile solids, biogas production, and methane content, were studied to monitor the anaerobic co-digestion. Though we are aware of Bowenpally Market in Hyderabad which is successful in producing the bio-gas through processing Food-waste in Anaerobic digester but to what extent the process is efficient and the parameters included in design and processing is not known in detail. A detailed study of parameters on the process and design of biogas through food waste in anaerobic digestion is presented in this paper.

## II. LITERATURE REVIEW

Anaerobic digestion is a complicated biodegradable process involving a several bio chemical reactions in the absence of oxygen. It is concerned about the design considerations, analysis of gas production, substrates and inoculums utilization, uses and impacts of biogas by process parameters [1]. It enhances the reactions happening during the process and design aspects like temperature, pH, nature of digester, composition of food waste, organic loading rate, retention time, mixing, C/N ratio, waste particle size, moisture content , pre-treatment of food waste which are involved in optimization. Anaerobic digestion has been proven superior to land filling, incineration. The above highlighted factors effect the efficiency of anaerobic digestion process. The outcomes from [2] reveal that there is a variation in the outcome of the optimum operational values of the main parameters from one biogas plant to another. Additionally, we have to eliminate the negative conditions while operating a biogas plant. Anaerobic digestion process stability is affected by many factors (e.g., the conditions inline and surrounding the reactor, material of construction, the reactor's design, the operational parameters, etc.).There is a requirement for sustainable,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

stable, efficient biogas production. To achieve this we have to determine the parameters effecting the process and control them to maximize the biogas production [3]. A design technique for sizing an anaerobic digestion follows various parameters involved in the process of anaerobic digestion and also the fabrication of the bio digester for different kinds of substrates. Challenges are faced in the design changes such as eliminating the dead volume and sizing the plant appropriately. It has been determined that a numerous factors effecting the design and operation of anaerobic digesters must be considered to ensure the maximum efficiency and cost-effectiveness of a digester considering the respective operating conditions [4]. There exists a gap in the optimization of process and design aspects to improve the yield of the bio-gas through processing the Food Waste in Anaerobic Digester to face the growing energy challenges.

## III. OBSERVATIONS:

There is a need for Process and design optimization for expansion of the biogas plants to meet the ever growing energy needs and methane due to its potential application. When we look into the countries like Germany, Europe they are far ahead. There are a huge number of Bio-gas plants established making better economic production of bio gas over there. In India, though it is an ancient methodology, it is limited to its expansion because of various factors effecting the production of bio-gas. Although the process was found in India, we are not producing the bio-gas efficiently. There are many issues faced during its operation. This has been a research topic now-a-days to overcome the deficiency of non-renewable energy resources. This process ensures to employ the use of renewable energy resources and eliminate the waste generated organically from food. Not only food, it can further treat the municipal sludge, waste water, industrial effluents and so on. Our observations present some of the factors that are gone through to find maximize the bio-gas production rate and scale up bio gas plant. Upon a detailed literature review, factors can be categorized into the following.

### *A. Reactor Design:*

The criteria for selection of a reactor for bio gas includes nature of substrate, substrate retention time, mesophilic, thermophilic temperature, combination of substrate taken in the digester and the size of the digester tank other considerations include material of construction employed in the design. It has various parameters to be considered.

Depending on the dry matter content of the substrate considered, if the dry matter content is greater than 12% it is classified as dry digestion and if the dry matter composition is less than the 12% then it is classified as wet digestion. Various experimental studies have shown that wet digestion can produce faster and efficient results than dry digestion. The wet digestion process of raw manure (cow dung with sewage sludge) with water with 11.3% TS resulted in 3.3-9.0 liter per Kg VS for the first days .later as the bio-gas started to decrease after 15 days. The methane production at this stage was 1.7-2.8 liter per Kg VS. After 36 to 42 days, the bio-gas production resulted in3.5-4.6 liter per Kg VS [6]. Experimental studies conducted on dry digestion of agricultural straw resulted in the methane potential with 0.21-0.3 N $m^3$ / kg VS for high amount of total solids. From the results, it is concluded that wet digestion provides efficient results [7]. However, dry AD ensures technical problems with high content of Total Solids in the reactor, where careful attention is taken for operational steps unlike the wet AD to achieve optimised stable processes.

Material feeding: It is also important how we feed the biogas digester. Feeding frequency effects the process performance and microbial activity in anaerobic digesters. From the results conducted by an experiment observed significantly high methane yields and biogas produced 20% more methane on average from the frequently feed digester at higher OLR than continuously feed digester.[7]

+Process Phase: There are two types depending on the process phase in the AD. Those are single stage process and multistage process.

Single stage process is where all the four stages of AD process are carried out in a single reactor. However, conditions within the reactor will not be optimal for the various groups of microbes influencing the biogas and methane potential.

Multistage process is where each of the stages in the AD process is carried out in two different digesters. Here it is easy to operate and maintain and offers more optimal conditions to the methanogenic bacterial population resulting the better yield of biogas. However it costs more than the single stage process i.e. installation and operational costs are more.

### *B. Mixing*

It is one of the important factor to ensure the homogeneity of substrates, temperatures inside the reactor. Slurry rheology is considered to be very important in designing the equipment for mixing to eliminate the scum formation, floating, settling in the reactor. There are various kinds of mixing technology available now a days and also various methods like gas sparging, impellor mixing, slurry recirculation. Ghanimeh et al. [8] experimental study has stated that continuous mixing at 100 rpm produced 0.6 methane l/g VS and with no mixing during digestion it was 0.45 methane l/g VS. Further mixing intensity with 50rpm produced 26-41% higher methane content than the 80 rpm mixing intensity. From the above studies we conclude that optimum mixing would be around 50-70rpm for frequently feed digesters.

### *C. pH*

Anaerobic digestion has significant effects n this parameter. The optimum pH in for the methanogenic stage in the anaerobic digester was found to be in the range of

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

6.8 to 7.2. The activity of methanogens was observed to be inactive at higher or lower pH other the optimum range . More over the pH was observed to be dependent on the substrate composition and the type of microorganism used in it. However, the AD process can tolerate a range of 6.5 to 8.0.The maximum methane and $CO_2$ concentrations (by volume) inside the produced biogas were 68% methane and 32% $CO_2$ for wheat substrate at pH 7 and 36 degree centigrade for 65 days [9].

*D. Hydraulic Retention Time (HRT)*

This is an operational parameter whose importance reveals the conversion of total solids into Bio-Gas. It affects contact of substrate and micro-organisms which favours the high treatment efficiency .However, low HRT causes washout of the substrate i.e., active microorganisms escape from the reactor thereby reducing the efficiency of substrate degradation. So, studies revealed that low HRT with slight acid pH leads to high production of Hydrogen . At this time when you increase HRT, fermentation of hydrogen gets shifted to the methanogenesis. Thereby, increasing the methanogenic activity and resulting in high yield of methane gas potential [14].The optimum range of HRT is around 25-30 days.

*E. Organic Loading Rate:*

It is the important parameter which has its effects on the all other parameters included in the AD process. It is the amount of feed that has been fed to the reactor per unit volume per unit time. Studies show that increasing the substrate concentration increases OLR thereby, improving biogas production but high concentrations of substrate may inhibit the system or even cause changes in the microbial pathway leads to anaerobic degradation process. From the studies on the digestion of FW with no addition of co-substrates, the maximum yield of specific methane was found to be 363 mL /g VS/d at organic loading rate (OLR) of 2.8 per g VS / L / d, and found the occurrence of failure at OLR of 3.5 g VS /L /d [12].The optimum OLR would be around 2-2.5 g VS / L / day.

*F. Temperature*:

This is the major parameter to begin the process. Anaerobic digestion can be performed at ambient temperature 25°C, mesophilic (25 - 45 °C) and thermophilic (greater than 45 °C) conditions. A low temperature is not favorable for the activity of the acidogenic and methanogenic phases, while temperatures above 25 ◦C were more favorable to high biogas production. The two factors which impact the biogas production in anaerobic digester are the sub layer temperature and the process temperature [17]. The results illustrated that [16] biogas production in the methanogenic phase is maintained at relatively higher levels in the temperatures ranging from 25-35°C. It is found that the methane content is higher than 50% at a temperature above 25 °C.

Merits of thermophilic temperature:

- Decreased retention time helps in rapid and effective digestion.
- Digestion is improved with utilization of Solid sub layers
- complete destruction of undesired pathogens as well as seed weed
- High feasibility of liquid isolation from solid fractions

*G. C/N Ratio*

It is a relevant factor in AD process. When the C/N ratio is high in the substrate, methanogens consume nitrogen more rapidly for their protein reuirements to build themselves. This results in low methane production however with low C/N ratio, nitrogen is present in the form of ammonia inhibiting the metabolism of methanogens due to its toxicity[20]. The authors have concluded that maximum methanogenesis occurs at C/N ratio of 30:1. However some others concluded that it varies for different substrate concentrations. So, the optimum C/N ratio for high methane gas production can be in the range 20-30:1[11].

*H. Nutrients*

Addition of Micro supplements like iron, cobalt, nickel, molybdenum to the Bio-gas digester helps in transformation of physiochemical processes. Nutrients are responsible for maintaining the suitable environment for sustainability of microorganisms inside the digester. Nutrients added which involving in mineralization and reduction of multivalent ions in substrate (e.g. $SO_4^{-2}$, Fe III $(OH)_3$) helps to increase pH, also the addition of Fe III-ions helps in removal of hydrogen sulfide ($H_2S$). The precipitation of $Fe^{2+}$ phosphates in the substrate releases protons thus reducing the pH in the acetogenesis stage of AD process. Further the reaction between $Mg^{2+}$, $NH_4^+$ and $PO_4^{3-}$ ions (to form struvite) causes the release of $H^+$ ions inside the digester which can converted to methane by increasing the HRT. It has been mentioned that bioactive substances, such as phytohormones (e.g. gibberellins, indole acetic acid), nucleic acids, monosaccharides, free amino acids, vitamins and fulvic acid, etc., helps the plants in promoting their plants and tolerance to environmental stress. [18]

*I. Energy Potential of BIOGAS*

In INDIA, the total capacity of BIO-GAS production from various organic wastes is about 40,734 Mm^3/year. The country has capability installation of about 12 million household type biogas plants. From the records of 2014, nearly 4.75 million of biogas plants have been already established contributing to the 40% of total potential. Studies have estimated that India can produce power of about 17000 MW using biogas which is 10 % of country's energy requirement .In India, most biogas plants constructed are popular and technically supportive for the digestion of animal waste. While considering the other organic wastes like kitchen waste, municipal solid waste, agricultural waste, processing industries waste etc. they were successfully employed for generating biogas and challenging the studies on optimization of parameters. There are various technologies prevailing now for generating the electricity from biogas on household and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

industrial level. On the whole, we need to expand the energy potential of biogas.

*J. Monitoring of Operational Parameters*

The monitoring of the operational parameters in the bio gas plants can be achieved through on-line and off-line monitoring analyzers. The fast and automated control is the key factor for online monitoring analyzers. On a real time basis, several parameters can be monitored at the biogas plant. Off-line monitoring is carried out in the laboratory taking the samples and performing defined test for each of the samples to analyze the parameters. In 2013, Germany equipped their Biogas plants with the online monitoring system for fast and easy monitoring of parameters. There is growing demand for the online monitoring systems to analyze immediate results of the parameters on the AD process.

*K. Cost*

This is one of the important economic parameter used to estimate the methane production potential and perspective of costs associated with energy that will profit us. The simulation results on economic and financial simulation showed that benefit of cost is dependent on two economic variables:

- The feed structure costs and the price of associated energy.
- The loan repayment for the installation.

Make sure to look at the most likely and the worst case scenarios for profits.

*L. Co-Digestion*

It is one of the promising step in the enhancement of methane generation and improves the quality of the substrate. It also enhances the C/N ratio for better microbial activity in the digester. Fitamo et al. concluded that co-digestion of grass, garden waste; food waste with municipal sludge enhanced the production of methane by 35–48%, decreasing hydraulic retention time (HRT) to 15 days. Callaghan et al. observed the improved methane yield from 230 to 450 L $CH_4$ /kg VS by increasing the proportion of the FW to 50% from 20% in co-digestion with cattle slurries and chicken manure.

*M. Pre-Treatment*

It enhances the speed of hydrolysis of the substrate. There are different kinds of pre-treatment- Mechanical, thermal, biological, ultrasound pretreatment. Ultrasonic pre treatment had produced good results on comparison with the other models.

It is simple technology with minimal cost having positive impact on the biogas plants which are not operating optimally. Ultrasound disintegrates microbiological biomass and cannot disintegrate lignocellulosic material (Onyeche et al., 2002). The cell disruption sets hydrolytic enzymes to liberate and helps in increasing the hydrolysis rate of biomass (Klingspor & Sörensen 2012).

*N. Enhancement of Methane gas by removing the contaminants using Adsorption and Absorption:*

The biogas contains combustible methane ($CH_4$)-(60-70%),Non-combustible carbon dioxide ($CO_2$)-(30-40%), along with traces quantities of others such as nitrogen (<1%), siloxanes (0–0.02%),halogenated hydrocarbons carbon monoxide ,oxygen, hydrogen sulfide and water vapours ($H_2O$, 5–10%).

The results showed from [23] showed that CaO solutions can reduce the concentration of $CO_2$ below 6%, And also $H_2S$ can be reduced to 96% on treating the raw biogas with $FeCl_2$, FeO, $Fe_2O_3$, and activated carbon. The water vapours present in the raw biogas can be reduced by treating it with Na2SO4 and silica gel to 0.2 to 0.7 %.

## IV. SUMMARY/CONCLUSION

In order to increase the bio gas potential to meet the increasing demand of energy supply for generating electricity, as a BIO-FUEL there is a need for optimization in the AD process for high Bio-gas production and methane potentials. The OLR, HRT, pH, Total solids content, Temperature, C/N ratio are the parameters effecting the BIO-GAS production, maintaining them at the optimum range with respect to the substrate composition results in a good yield of methane potential and improved quantity of biogas. On the other side, the parameters like co-digestion, pre-treatment, enhancement of biogas by adsorption and absorption improve the bio-gas production. The suggested and optimized value for OLR is 2-3 g VS/ L /day with HRT of 20-30 days. For the removal of contaminants in the bio-gas, treating raw gas with the CaO solutions helps in reducing $CO_2$ composition in it to below 6%. And treating with the $FeCl_2$, FeO, $Fe_2O_3$, helps in removal of H2S to 96% and on treating with $Na_2SO_4$ and silica gel in reducing the water content in the raw bio gas to 0.2 to 0.7%.

## V. FUTURE SCOPE

This review mainly focuses the study on the parameters of process and design aspects in the Anaerobic Digestion of food waste along with other substrates outside the experimentation leaving the experimental studies. Work on the experimental optimization studies to eliminate the drawbacks by the operational parameters like C/N ratio, Temperature, percentage of Total solids their stability levels and online monitoring of the equipment connecting with IOT can be done.

## REFERENCES

[1] Muzaffar Ahmad Mir, Athar Hussain, Chanchal verma, Shashi Dubey (2016), Design considerations and operational performance of anaerobic digester: A review

[2] Abdullah Nsair, Senem Onen Cinar, Ayah Alassali, Hani Abu Qdais and Kerstin Kuchta, 2020, Operational Parameters of Biogas Plants: A Review and Evaluation Study .

[3] M.Edwin, S. Joseph Sekhar, Design considerations of anaerobic digester for producing biogas loaded with cow manure.

[4] Jay N Meegoda, Brian Li , Kush Patel , Lily B Wang , 2018 A Review of the Processes, Parameters, and Optimization of Anaerobic Digestion.

[5] Daniel P. Duffy, 2017, The Costs and Benefits of Anaerobic Digesters

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

[6] Yanran Fu, Tao Luo , Zili Mei, Jiang Li, Kun Qiu and Yihong Ge, 4th December,2018, Dry Anaerobic Digestion Technologies for Agricultural Straw and Acceptability in China –A Review.

[7]. Anette T. Jansson ,Regina J. Patinvoh, IIona sarvari Horvath and Mohammad J. Taherzadeh,14th May 2019, Dry Anaerobic Digestion of Food and Paper Industry Wastes at Different Solid Contents-Research Article.

[8] Hirota, Kosuke Hironaga, Zhihao Tu, Isao Yumoto, 31st July 2020, Comparison between wet and semi-dry anaerobic biogas diester under thermophilic and mesophilic conditions: Methane productivity and analysis of microbiota - Academic Journal.

[9] Carissa Jordan Kayla Kell , April 2019, Anaerobic Co-Digestion of Fruit Juice Industry Wastes with Lignocellulosic Biomass.

[10] Buta singh, Zolatan Szamosi,Zoltan Simenfalvi, 30th March,2020,Impact of mixing intensity and duration on biogas production in an Anaerobic digester: A Review.

[11] Kine Svensson, Lisa Paruch, John Christian Gaby, Roar Linjordet, December,2018, Feeding frequency influences process performance and microbial community composition in anaerobic digesters treating steam exploded food waste – case study.

[12] Adrian Eugen Cioabla, Loana lonel, Gabriela - Alina Dumitrel and Francisc popescu,6th June 2012, Comparative study on factors affecting anaerobic digestion of agricultural vegetal residues.

[13] Tugba Ke skin, Haris Nalakath, Abu backar,Kubra Arslan,Nuri Azbar,2019, Bio-hydrogen from solid wastes.

[14] L.jian - jun Dong, L. Xiao Shvang Shi, 2017, Effect of Hydraulic Retention Time on Anaerobic Digester of wheat straw in the semi-continuous stirred tank reactor

[15] Swati Hegde and Thomas A. Trabold , 2019 ,Anaerobic Digestion of Food Waste with Unconventional Co-Substrates for Stable Biogas Production at High Organic Loading Rates.

[16] Shiwei Wang , Fang Ma , Weiwei Ma, Ping Wang, Guang Zhao and Xiaofei Lu ,2019, Influence of Temperature on Biogas Production Efficiency and Microbial Community in a Two-Phase Anaerobic Digestion System.

[17] Gurinderpal Singh, V.K. Jain and Amanpreet Singh,2017, Effect of Temperature and other factors on Anaerobic Digestion Process, responsible for Bio Gas Production.

[18] Kurt Muller , Torsten Muller,2012, Effects of anaerobic digestion on digestate nutrient availability and crop growth: A review.

[19] Maurizio Carlini ,Enrico Maria Mosconi ,Sonia Castellucci, Mauro Villarini and Andrea Colantoni , 2017, An Economical Evaluation of Anaerobic Digestion Plants Fed with Organic Agro-Industrial Waste.

[20] C. keske, 2011, Determining the Economic Feasibility of Anaerobic Digestion in Colorado: Guidelines for Animal Farm Producers.

[21] James M Aarthi, 2016, Evaluating the Economic Feasibility of Anaerobic Digestion of Kawangware market.

[22] Lucy F. R. MONTGOMERY, Gunther BOCHMANN, 2014, Pre Treatment of feed stocks.

[23] Muhammad Rashed Al Mamun and Shuichi Torii, March,2017, Enhancement of Methane Concentration by Removing Contaminants from Biogas Mixtures Using Combined Method of Absorption and Adsorption