A Review of Accelerated Bio-Methanation From Food Waste, Animal Waste and Garden Wastes

Vijaykumar Meti[1]
Assistant Professor
Department of Mechanical Engineering
Mangalore Institute of Technology and Engineering

Rolson Rebello[2], Roshan Chetan Habbu[3]
Under Graduate students
Department of Mechanical Engineering
Mangalore Institute of Technology and Engineering

Chetan Korde[4], R Ganeshkumar[5]
Under Graduate students
Department of Mechanical Engineering
Mangalore Institute of Technology and Engineering

***Abstract*:- Here we reviewing the acceleration of biomethanation from food waste, animal waste and garden waste. As the effect of urbanization the usage of fossil fuels is going on increasing and the organic solid waste also increasing. By producing biogas, we can overcome this crisis. By using aerobic and anaerobic two-phase digestion method we can enhance the biomethanation process and through this method, we can use food, garden and vegetable wastes effectively to produce gas. This method even helps to increase the concentration of volatile fatty acid and helps to reduce the volatile solids. By maintaining chemical oxygen demand, temperature and PH at the proper value we can even enhance the biogas production. By design and constructing efficient and compact high rate gas generation digester, we can save space, time and it will be economical. The biogas can be used as alternative fuel in IC engines, and Cooking fuel. By Using biogas, we can save fossil fuels fossil fuels (petroleum products) which are costly and exhausting soon.**

Keywords:- Aerobic digestion, Anaerobic digestion, Biogas, Food waste, Kitchen waste, Garden waste, dairy waste, VFA, Volatile Solids, COD

1. INTRODUCTION

Decades of rapid industrialization primarily dependent on diminishing fossil fuel reserves have brought about an alarming energy crisis of global proportions. Efforts in energy research now focus towards production from sustainable, affordable, and environmentally being sources. Biomass from kitchen waste, garden waste and agricultural products have been found promising substitutes for crude oil. However, the competition between biomass and high-value crops production remains a major drawback of large-scale utilization of biomass energy. Production of biofuels from biomass can be achieved through gasification, pyrolysis, Torrefaction and incineration from biomass.

Biogas is a gaseous fuel obtained from biomass by the process of anaerobic digestion (Fermentation). The infeed to the biogas plant Includes-Urban waste(garbage), Urban Refuse (Human excreta), Rural, agricultural waste, cow dung, animal waste from Butchery, etc. Biogas is a cheap secondary renewable energy. Close to 40% of methane emission takes is from the wetland ecosystem and 60% of the methane comes from human energy. Here, the infeed is mixed with water to assist anaerobic fermentation process. The biogas plant delivers methane-rich gas which has methane (CH_4), Carbon-dioxide (CO_2) and other impurities. Food waste if utilized can be a boon in producing many useful products such as renewable energy (RE), cooking gas and good manure.

By using above mentioned waste the accelerated Bio-methanation by the rapid anaerobic reaction can be attained with effective utilization of biogas produced from kitchen waste (food & vegetable), garden waste, agricultural waste and dairy waste, etc. This produced gas is used in I.C engine and heating application in the kitchen.

This particular study as lots of scopes as follows biogas production is a clean low carbon technology for efficient management and conversion of fermentable organic waste into clean and cheap and versatile fuel. This fuel is used in various category: Such as Fuel for cooking (Biogas chulha), driving IC engines for pumps and residue from biogas plants is used as manure.

Waste is simply being wasted and thrown into garbage than to landfill, which in turn act as open sources of anaerobic digestion causing the emission of greenhouse gases which has an impact on global warming. Hence, every individual’s right to know about the consequences which each one is ignorant about the impacts. Thus it’s an essential step for everyone, to go for reducing the global warming threats. Green technology and the concepts have to be understood and practised by every person to reduce the threats. Non-Conventional resources such as a bio-waste, solar, water harvesting, wind etc. are the source for renewable energy (RE) production. And the combination of all these sources which are available on premises would produce a sustainable energy.

Learn about methanogens Understand the chemistry behind the production of methane from food waste Identify the gas or gases produced during the reaction within a shorter interval of the time period.

2. LITERATURE REVIEW

[1] Shakira R. Hobbs, [et al.]. "Enhancing anaerobic digestion of food waste through biochemical methane potential assays at different substrate: inoculum ratios". Waste Management 71 (2018) 612–617.

Food waste has a high source of energy from that can produce methane through anaerobic digestion which is a useful energy. The amount of gas production is mainly depending on the various ratios of food waste which can find out via Biochemical Methane Potential assays (BMPs). In this paper, BMPs were conducted on food waste and inoculum ratios of 0.42, 1.42, and 3.0g chemical oxygen demand/g volatile solids(VS) are used to conduct experiment were inoculum material is Aerobic digester sludge (ADS).

The accurate and deep understanding of the performance of co-digestion with food waste is found out through effects of food waste to inoculum ratio. In this paper, they concluded that intermediate ratio of food waste COD to ADS VS i.e. 1.42g food waste COD/g ADS VS gives the more methanogenic yield with less lag time whereas high ratio of food waste i.e. 3.0g food waste COD/g ADS VS gives more quantity of methane but it has a higher lag period.

In this study, the various techniques that must be used for co-digestion of food waste are found out like maximizing methane production using proper ratio of food waste to inoculum and it even prevents the lowering of pH value. Even he concluded that the best ratio i.e. 1.42g food waste COD/g ADS VS will not be same for different combination food waste COD and ADS inoculum and he explained the method to find out the appropriate ratio.

[2] J. Mallick, [et al,]. "Biogas Generation from Leafy Biomass & Vegetable Wastes by Application of Ultrasound"

The biogas production through a biomethanation is a slow process and we all aware of that. In this paper, they explained about accelerating the biogas production. To accelerate biogas production ultrasound is used. They even did experimental studies in laboratory scale and pilot scale by using the cow dung and kitchen wastes with various dilution from 1:1 to 1:10. In this experiment, they provided ultrasound at a frequency of 43kHz from constant ultrasound generator every day for few minutes.

They concluded from an experiment that startup time to bio-methanation can be reduced and biogas generation can be doubled using ultrasound with proper care.

[3] Dupade Vikrant U, [et al.]. "Temperature, pH and Loading Rate Effect on Biogas Generation from Domestic Waste". IEEE - International Conference on Advances in Engineering and Technology-(ICAET 2014).

The biogas is a generally gas production in the absence of oxygen by the biological breakdown of the organic substance. The biogas mainly consists of methane and carbon dioxide with is produced by the microbial process through anaerobic digestion. The temperature, pH and organic input rate are the main factors which affect the biogas generation and those different factors are studied in this paper.

The biogas generation will be more for greater temperature range working condition i.e. thermophilic range and for neutral pH and in this paper they even concluded that through results and graphs. By providing more input can even produce more gas but with less methane content but which can be neglected because that amount is around 2% and the working cost of the system increases because of heating units and additives which can be overcome using higher wastage.

[4] Ashwini J. Kamble, [et al.]. "An Approach to Enhance Biomethanation by Thermophilic Aerobic Digestion of Combined Vegetable Waste". IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402,p- ISSN: 2319-2399. Volume 8, Issue 1 Ver. II (Jan. 2014), PP 01-07.

The volatile fatty acid is the main source of biogas generation with an increase of it can increase biomethanation. In this paper, two-phase digester system is used. The phase I digester is aerobic digester and they maintained it at 55ºC and phase II digester is anaerobic digester and it is maintained at ambient temperature. This two-phase digester system is used to study the different factors which effects on the generation of volatile fatty acid (VFA). The cow dung and vegetable wastes are used in both digesters.

From this study, the phase I digester will be helpful in increasing the initial digestion because of micro-aeration and it enhances the gas production. The aeration of the system helps in hydrolysis and the air helps for the rapid growth of the bacteria. Hence the gas production increases and volatile solids will be reduced.

[5] Aftab Anjum, [et al.]. "Economic Analysis of the Nisargruna Based Bio-Methanation Plant". Volume 3, Issue 4 (2015) 611-614, ISSN 2347 – 3258, International Journal of Advance Research and Innovation.

In this paper explained about Nisarguna biogas technology they covert most of all type of organic solid wastes into biogas. They reduced the size of the plants which helps to save space and less construction time is needed. They increased the output and reduced the digestion period. They concluded from the study that few LPG cylinders can be saved per day in an institution, restaurants, hotels where a large amount of organic solid wastes are available.

[6] Martin Gorling, [et al.]. "Bio-methane via fast pyrolysis of biomass" Applied Energy 112 (2013) 440–447

Biomethane, a renewable vehicle fuel, is today produced by anaerobic digestion and a 2nd generation production via gasification under development. This paper proposes a poly-generation plant that biomethane, biochar and heat via fast pyrolysis of biomass.

[7] Hermawan Prajitno, [et al.]. “Non-catalytic upgrading of fast pyrolysis bio-oil in supercritical ethanol and combustion behaviour of the upgraded oil” Applied Energy 172 (2016) 12–22

Supercritical ethanol based upgrading fast pyrolysis of bio-oil was developed using external catalysts and external molecular hydrogen. The unique reactivity association scEthOH including hydrogen donation, esterification, alcoholysis, cracking and alkylation effectively reduced the TAN, water/oxygen contents and at the same time increased the carbon/hydrogen content and calorific values.

[8] K. Srithar, [et al.]. “Experimental investigations on mixing of two biodiesels blended with diesel as alternative fuel for diesel engines” Journal of King Saud University – Engineering Sciences (2017) 29, 50–56

The world faces a crisis of energy demand, rising petroleum prices and depletion of fossil fuel resources. The study brings out an experiment of two biodiesels from Pongamia pinnata oil and mustard oil and is blended with diesel at various mixing ratios. The effects of dual biodiesel work in the engine at various engine loads with a constant speed of 3000rpm.The influences of blends on CO, CO_2, HC, NOx and smoke opacity were investigated by emission tests. The brake thermal efficiency of blend A was found to be higher than diesel.

[9] Vish. Kallimani, [et al.]. “Design and development of a compact high rate digester for rapid bio-methanation from a kitchen waste for Energy generation” IEEE ICSET 2010 6-9 Dec 2010, Kandy, Sri Lanka

Urbanization all over the world has created serious problems of solid waste disposal. Increased population causes increased food consumption which directly leads to increase in the solid waste resulting from the processing of food and post-consumption. The aim of the research is to develop an integrated system: Micro Power House (MPH) based on natural non-conventional energy resources such as kitchen waste, solar and water, clean energy concepts. The present study showed that by using this reactor HRT for the digestion of solid food waste can be reduced and scum formation problem could be eliminated. Yielding $0.59m^3$ CH_4/Kg VS reduced at 9 days of HRT. The output gas, when recycled at an appropriate pressure, caused the mixing of the system and at the same time, there was a least scum formation least scum, choking and carpet formation. This setup is only attended the bio-waste energy production.

[10] Renato O. Arazo, [et al.]. “Bio-oil production from dry sewage sludge by fast pyrolysis in an electrically-heated fluidized bed reactor” Sustainable Environment Research 27 (2017) 7e14

Effects of temperature, sludge particle size and vapour residence time on bio-oil properties, such as yield, high heating value(HHV) and moisture content were evaluated through experimental and statistical analyses. Characterization of the pyrolysis products (bio-oil and biogas) was also done. Optimum conditions produced a bio-oil product with an HHV that is nearly twice as much as lignocellulosic-derived bio-oil, and with properties comparable to heavy fuel oil. Contrary to generally acidic bio-oil, the sludge- derived bio-oil has almost neutral pH which could minimize the pipeline and engine corrosions.

[11] Mobolaji B. Shemfe, [et al.]. “Comparative evaluation of GHG emissions from the use of Miscanthus for bio-hydrocarbon production via fast pyrolysis and bio-oil upgrading” Applied Energy 176 (2016) 22–33

This study examines the GHG emissions associated with producing bio-hydrocarbons via fast pyrolysis of Miscanthus. The feedstock is then upgraded to bio-oil products via hydroprocessing and zeolite cracking. The system boundary considered spans from the cultivation of Miscanthus to conversion of the pyrolysis-derived bio-oil into bio-hydrocarbons up to the refinery gate. The Miscanthus cultivation subsystem considers three scenarios for soil organic carbon (SOC) sequestration rates. These were assumed as follows: (1) excluding (SOC), (2) low SOC and (3) high (SOC) for best and worst cases. Overall, Miscanthus cultivation contributed moderate to negative values to GHG emissions, from analysis of excluding SOC to high SOC scenarios.

[12] Gabriel D. Oreggioni, [et al.]. “Techno-economic analysis of bio-methane production from agriculture and food industry waste” Energy Procedia 123 (2017) 81-88

Bio-methane production via anaerobic digestion is a promising technology for the decarbonization of the energy system. Bio-gas obtained from anaerobic digestion of farm and food industry waste is largely composed of 60% CH_4 and 40% CO_2. For injection of bio-methane into the gas distribution network, it is necessary to remove CO_2 from the biogas so that a richer CH_4 stream is injected to satisfy gas network requirements. Chemical separation processes using absorbents or membranes in which CO_2 is retained and currently under investigation to reduce associated energy consumption whilst maximizing CO_2 removal.

[13] Anthony Njuguna Matheri, [et al.]. “Waste to energy bio-digester selection and design model for the organic fraction of municipal solid waste” Renewable and Sustainable Energy Reviews 82 (2018) 1113–1121

In this study, a quantification characterization of bio-digester selection and design characteristics of organic fraction of municipal solid waste (OFMSW) was investigated with aerobic digester and for biochemical methane potential (Biochemical methane solvent based (BMP) and waste to energy biodigester selection for anaerobic co-digestion.

Co-digestion of OFMSW, continuous stirring of market vegetables, animal manure and sewage sludge evolutes to the proportional of optimum temperature of 37°C and pH of 6.9 contains good methane production for up to 59%.

The quantification character of OMFC optimized to 34% at the rate of biomass conversion increased with increase in temperature and retention time until to attain equilibrium temperature, the overall design characteristics were determined by the dimension and geometry of digester parameter. Increase in scale-up indicates energy content.

[14] S.Mohan, [et al.]. "Production of Biogas by Using Food Waste" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 4, Jul-Aug 2013, pp. 390-394

The analysis shows that the yields have been determined using batch anaerobic thermoplastic digestion test for the period of 90 days. It is observed that the rate of methane production which may be due to the presence of a methylotrophic population in active sludge.

The overall experimental analysis of the production of methane and carbon dioxide was the sum of 76% methane and 24% of carbon dioxide. This indicates that the waste has better anaerobic biodegradability.

The up-flow anaerobic sludge blanket reactors (UASB) is a pretreated raw influence a high rate suspended growth in anaerobic bacteria. The food waste treatment, methanogen gradually converts the organic acid into the methane gas and carbon dioxide. Thus achieving the waste of resource utilization.

[15] Mrs Bharati Sunil Shete, [et al.]. "Anaerobic Digestion of Dairy Industry Waste Water - Biogas Evolution-A Review" International Journal of Applied Environmental Sciences ISSN 0973-6077 Volume 12, Number 6 (2017), pp. 1117-1130 © Research India Publications http://www.ripublication.com

The main objective of this paper was to investigate Bio-gas Generation and factors affecting the Bio-gas Generation such as pH, temperature, alkalinity, etc. from dairy industry wastewater to optimize the biogas liberation by biological breakdown.

The results show that biogas is one of the cheapest non-conventional energy source produced through an engineered way from dairy industry wastewater.

[16] Jatmiko Wahyudi, [et al.]. "Biogas Production in Dairy Farming in Indonesia: A Challenge for Sustainability" Contents list available at IJRED website Int. Journal of Renewable Energy Development (IJRED) Journal homepage: http://ejournal.undip.ac.id/index.php/ijred

This paper gives an overview of biogas production sustainability which consists of five sustainability dimensions such as economic, technical, social, environmental and organizational or institutional sustainability. By understanding the biogas sustainability helps to promote biogas. The feasibility of biogas will determine the success of biogas, particularly in dairy farming in the future.

[17] Nikolay Makisha. "Waste water and biogas – ecology and economy**"** Procedia Engineering 165 (2016) 1092 – 1097

This review the possible implementation of biogas technologies for dairy was the Prevention of methane discharge into the atmosphere, Improvement of the environmental situation was the source of electricity, heat and petrol production.

[18] Hamed M. El-Mashad, [et al.]. "Biogas production from co-digestion of dairy manure and food waste" Bioresource Technology 101 (2010) 4021–4028

This study determined the degradation rate and biogas and methane yields of screened and unscreened dairy manure, food waste and two mixtures of unscreened manure and food waste using an anaerobic batch digester.

[19] Lars Jürgensen, [et al.]. "A combination anaerobic digestion scheme for biogas production from dairy effluent-CSTR and ABR, and biogas upgrading" Biomass and Bioenergy xxx (2017) 1-7

This study of anaerobic digestion can be applied as a useful scheme to convert food industry wastes streams which are currently underutilized in energy generation due to issues associated with use in conventional processes.

3. CONCLUSION

1. By maintaining proper, food waste COD to ADS VS ratio gas production is increased and the lag period is decreased.
2. By providing ultrasound at proper frequency start-up time can reduce and biogas production can be doubled.
3. By operating at higher temperature and maintaining neutral pH range can increase gas production.
4. Using pre-aerobic digester bacteria growth is increased and helps in producing more volatile fatty acid.
5. By designing small digester with enhanced output can use it as economical.
6. BioMethane via fast pyrolysis of biomass: This paper proposes a poly-generation plant that biomethane, biochar and heat via fast pyrolysis of biomass.
7. Non-catalytic upgrading of fast pyrolysis bio-oil in supercritical ethanol and combustion behaviour of

the upgraded oil: This study indicates that Supercritical ethanol based on upgrading fast pyrolysis of bio-oil was developed using external catalysts and external molecular hydrogen.

8. Experimental investigations of mixing of two biodiesels blended with diesel as alternative fuel for diesel engines: The study brings out an experiment of two biodiesels from Pongamia pinnata oil and mustard oil and is blended with diesel at various mixing ratios.
9. Design and development of a compact high rate digester for rapid bio-methanation from a kitchen waste for Energy generation: The output gas when recycled at appropriate pressure caused the mixing of the system and at the same time there was a least scum formation least scum, choking and carpet formation.
10. Bio-oil production from dry sewage sludge by fast pyrolysis in an electrically-heated fluidized bed reactor: Optimum conditions produced a bio-oil product with an HHV that is near twice as much as lignocellulose -derived bio-oil, and with properties comparable to heavy fuel oil.
11. Comparative evaluation of GHG emissions from the use of Miscanthus for bio-hydrocarbon production via fast pyrolysis and bio-oil upgrading: Sensitivity analysis revealed that the GHG emission of both routes is mostly influenced by changes in bio-hydrocarbon yield and nitrogen feed gas for the fast pyrolysis reactor.
12. Techno-economic analysis of bio-methane production from agriculture and food industry waste: Chemical separation processes using absorbents or membranes in which CO_2 is retained and currently under investigation to reduce associated energy consumption whilst maximizing CO_2 removal.
13. By co-digestion of biomass under mesophilic temperature will give optimum productivity of biomethane.
14. By treatment of flood effluent using UASB reactor, the useful bi-product, biogas has been generated with a certain rate of decrease in the amount of COD, BOD, pH acidity and alkalinity.
15. In this paper, they have concluded that efficiency of anaerobic treatment has a deep effect with several parameters such as pH, temperature, Hydraulic retention time, Organic loading rate, Sludge retention time, up-flow velocity and size distribution.
16. In this, they concluded that technology has not only potential to tackle the negative impacts of livestock waste but also to reduce poverty by supporting agriculture including livestock sectors by providing clean energy and improving human health.
17. In this, the methane discharge to the atmosphere is prevented and the biogas is used to generate electricity.
18. Using dairy manure about 90% of biogas is obtained.
19. The anaerobic digesters usually face difficulty to handle the characteristically high particles and fats contents, this problem can be solved using CSTR and ABR combination.

4. REFERENCES

[1] Shakira R. Hobbs, Amy E. Landis, Bruce E. Rittmann, Michelle N. Young, Prathap Parameswara, 2018. ‘Enhancing anaerobic digestion of food waste through biochemical methane potential assays at different substrate: inoculum ratios’. Waste Management 71 (2018) 612–617 journal homepage: www.elsevier.com/ locate/wasman

[2] J. Mallick, K. L. Narayana, S. Khuntia, D. Singh and R. Barik. ‘Biogas Generation from Leafy Biomass & Vegetable Wastes by Application of Ultrasound’.

[3] Dupade Vikrant U., Chaudhari Ajit C., Aaher Yogesh V., 2014. ‘Temperature, pH and Loading Rate Effect on Biogas Generation from Domestic Waste’. IEEE - International Conference on Advances in Engineering and Technology-(ICAET 2014)

[4] Ashwini J. Kamble, M.G.Takwale, V.S.Ghole, 2014. ‘An Approach to Enhance Biomethanation by Thermophilic Aerobic Digestion of Combined Vegetable Waste’. IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402,p- ISSN: 2319-2399. Volume 8, Issue 1 Ver. II (Jan. 2014), PP 01-07 www.iosrjournals.org

[5] Aftab Anjum, Mohit Gupta, Aadish Jain, 2015. ‘Economic Analysis of the Nisargruna Based Bio-Methanation Plant’. Volume 3, Issue 4 (2015) 611-614 ISSN 2347 – 3258 International Journal of Advance Research and Innovation

[6] Martin Gorling, Marten Larsson, Per Alvfors, 2013. ‘Bio-methane via fast pyrolysis of biomass’. Applied Energy 112 (2013) 440–447 journal homepage: www.elsevier.com/ locate/apenergy

[7] Hermawan Prajitno, Rizki Insyani, Jongkeun Park, Changkook Ryu, Jaehoon Kim, 2016. ‘Non-catalytic upgrading of fast pyrolysis bio-oil in supercritical ethanol and combustion behavior of the upgraded oil’. Applied Energy 172 (2016) 12–22 journal homepage: www.elsevier.com/ locate/apenergy

[8] K. Srithar, K. Arun Balasubramanian, V. Pavendan, B. Ashok Kumar, 2018. ‘Experimental investigations on mixing of two biodiesels blended with diesel as alternative fuel for diesel engines’. Journal of King Saud University – Engineering Sciences (2017) 29, 50–56 www.ksu.edu.sa, www.sciencedirect.com

[9] Vish. Kallimani, Anurag. Guduri, Mahesh. Reddy, Jyoti.Kallimani, 2010. ‘Design and development of a compact high rate digester for rapid bio-methanation from a kitchen waste for Energy generation’. IEEE ICSET 2010 6-9 Dec 2010, Kandy, Sri Lanka

[10] Renato O. Arazo, Divine Angela D. Genuino, Mark Daniel G. de Luna, Sergio C. Capareda,2017. ‘Bio-oil production from dry sewage sludge by fast pyrolysis in an electrically-heated fluidized bed reactor’. Sustainable Environment Research 27 (2017) 7e14 journal homepage: www.journals.elsevier.com/sustainableenvironment-research/

[11] Mobolaji B. Shemfe, Carly Whittaker, Sai Gu, Beatriz Fidalgo, 2016. ‘Comparative evaluation of GHG emissions from the use of Miscanthus for bio-hydrocarbon production via fast pyrolysis and bio-oil upgrading’. Applied Energy 176 (2016) 22–33 journal homepage: www.elsevier.com/ locate/apenergy

[12] Gabriel D. Oreggionia, Mauro Luberti, Matthew Reilly, Marie E.Kirby, Trisha Toop, Michael Theodorou, Savvas A. Tassou, 2017. ‘Techno-economic analysis of bio-methane production from agriculture and food industry waste’. Energy Procedia 123 (2017) 81-88

[13] Anthony Njuguna Matheri, Charles Mbohwa, Freeman Ntuli, Mohamed Belaid, Tumisang Seodigeng, Jane Catherine Ngila, Cecilia Kinuthia Njenga, 2018. ‘Waste to energy bio-digester selection and design model for the organic fraction of municipal solid waste’. Renewable and Sustainable Energy Reviews 82 (2018) 1113–1121 journal homepage: www.elsevier.com/locate/rser

[14] S.Mohan, K.Jagadeesan, 2013. ‘Production of Biogas by Using Food Waste’. International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 4, Jul-Agu 2013, pp. 390-394

[15] Mrs. Bharati Sunil Shete, Dr. N.P. Shinkar, 2017. ‘Anaerobic Digestion of Dairy Industry Waste Water - Biogas Evolution-A

Review'. International Journal of Applied Environmental Sciences ISSN 0973-6077 Volume 12, Number 6 (2017), pp. 1117-1130 © Research India Publications http://www.ripublication.com

[16] Jatmiko Wahyudi, Tb. Benito Achmad Kurnani, Joy Clancy, 2018. 'Biogas Production in Dairy Farming in Indonesia: A Challenge for Sustainability' Contents list available at IJRED website Int. Journal of Renewable Energy Development (IJRED) Journal homepage: http://ejournal.undip.ac.id/index.php/ijred

[17] Nikolay Makisha, 2016. 'Waste water and biogas – ecology and economy'. Procedia Engineering 165 (2016) 1092 – 1097

[18] Hamed M. El-Mashad, Ruihong Zhang, 2010. 'Biogas production from co-digestion of dairy manure and food waste'. Bioresource Technology 101 (2010) 4021–4028 journal homepage: www.elsevier.com/locate/biortech

[19] Lars Jürgensen, Ehiaze Augustine Ehimen, Jens Born, Jens Bo Holm-Nielsen, 2017. 'A combination anaerobic digestion scheme for biogas production from dairy effluent-CSTR and ABR, and biogas upgrading'. Biomass and Bioenergy xxx (2017) 1-7 journal homepage: http://www.elsevier.com/locate/biombioe