International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 16, Issue 12 (December 2020), PP. 71-77

The Effect of Microwave Power and Exposure Time to Increase Biogas of Pineapple Peel Waste

Bakti Jos[1],Siswo Sumardino[1], Safaah Nurfaizin[1]
[1]*Department of Chemical Engineering, Faculty of Engineering*
University of Diponegoro Semarang - Indonesia
Corresponding Author: safaahnurfaizin@students.undip.ac.id

ABSTRACT
Energy demand increases with human growth. Environmental damage and energy crisis are problems in the world. Dependence on fossil fuels results in depleting energy reserves and global warming. Efforts are needed to create renewable alternative energy sources, one of which is biogas. Biogas is produced from the process of degradation of organic materials and the activity of methanogenic bacteria under anaerobic conditions. Biomass which has the potential as a raw material for biogas is pineapple peel waste. To increase the efficiency of the biomass and biogas conversion produced, it can be applied a thermal delignification with microwave assistance. Microwave application is affected by power and exposure time. Therefore, this research was conducted to determine the effect of microwave power and exposure time on samples to increase biogas production and optimum microwave pretreatment conditions and to determine daily biogas production. The results of this research indicate that the power and exposure time affect the biogas yield. The power used was 300 W / 5 minutes, 450 W / 5 minutes and 600 W / 5 minutes to produce 2189 mL, 2148 mL and 2063 mL of biogas. Then, in the variation of microwave application time of 300W/7 minutes and 300W/9 minutes, the biogas yield decreased with a volume of 2044 mL and 2022 mL.The optimum conditions for increasing biogas in pineapple peel waste were obtained at a power 300 W with a radiation exposure time of 5 minutes, with a total volume 2189 mL of biogas. While, the increase power and microwave exposure time actually decreased the production of biogas in pineapple peel waste.
KEYWORDS: *Biogas, Microwave, Pineapple*

Date of Submission: 05-12-2020 Date of Acceptance: 20-12-2020

I. INTRODUCTION

Currently, human growth continues to increase very rapidly, it is certain that the energy needs that must be met are also increasing in all its forms [1]. Other that, environmental damage and energy crisis are problems in the world. One of the environmental damage is caused global warming [2]. Excessive use of fossil fuels is a deterrent to greenhouse gases [3]. The continuous use of fossil fuels results in the depletion of world energy reserves, because fossil fuels are irrenewable fuels. There are many efforts that have been made to create renewable and renewable alternative energy sources. Such as biodiesel from microalgae, bioethanoland fermentation of carbohydrates or biogas from anaerobic digestion [4].

One of the alternative energy sources that can be developed with appropriate technology and easy to apply as a substitute fossil fuel is biogas [5]. Biogas is a gas mixture resulting from the degradation process of organic materials and the activity of methanogenic bacteria under anaerobic conditions [6]. In general, biogas consists of a mixture of methane (CH4) in the range of 50-70%, carbon dioxide (CO2) about 30-50%. Other that, biogas also contains several other compounds, such as nitrogen (N2) at a concentration of 0–3%, water vapor (H2O) at a concentration of 5–10%, oxygen (O2) at a concentration of 0-1%, hydrogen sulfide (H2S).) at a concentration of 0-10,000 ppm, ammonia (NH3) at a concentration of 0-200 mg / m3 [7].

From the conditions, it has prompted a lot of research to find a potential biomass as a raw material for alternative renewable energy. The earlier research, a lot of biomass has been identified as an alternative renewable energy source [8]. Biomass source can used from: (1) forestry waste and wood processing, (2) agricultural and food processing residues, (3) municipal waste and (4) special plants (terrestrial and aquatic), (5) industrial waste. The combination of raw materials can be used to increase the nutrient and calculate how much energy can be produced from the raw material [9].One of the biomass that can produce biogas is pineapple peel waste. Because, some of the commercial products of pineapple processing include canned fruit, juice concentrate, jam, crystal fruit, and dry snacks produces about 20-40% (w / w) of waste in the form of skin and core [10].

Pineapple waste is a very biodegradable material, containing lots of carbohydrates and protein [11]. According to Wijana et al. (1991)[12] pineapple peels contain 81.72% water, 20.87% crude fiber, 17.53% carbohydrates, 4.41% protein, 0.02% fat, 0.48% ash, 1.66% wet fiber, and 13.65% reducing sugar. Pineapple (Ananas comosus) contains high water and fiber such as 67% hemicellulose, 38-48% cellulose, 31% alpha cellulose, 17% lignin, and 26% pentose.The cellulose content in pineapple waste has the potential as a renewable energy source. Some researchers have studied pineapple as a raw material toproduce biogas[11], [13], [14],[15]. However, obstacles that the pineapple peel is difficult to crack, because the hydrolysis of lignin is a slow process [16]. Several methods have been used to improve the efficiency of the conversion of biomass and biogas produced. One of them is through a thermal delignification process with microwave assistance.

Eskicioglu et al. (2007)[17] reported a comparison of pretreatment microwave and conventional heating on waste activated sludge, pretreatment can increase solubility rate and methane production (16% after 15 days at mesophilic conditions and a temperature of 96^{o} C). Jackowiak et al. (2013)[18] conducted a study on wheat straw microwave pretreatment for biogas production. The maximum yield was achieved at a temperature of 150^{o}C with an increase in yield of 28% compared to without microwave pretreatment. Kainthola et al. (2019)[19] also stated that microwave pretreatment is one of the most effective methods, because it can directly react between thermal and non-thermal effects with raw materials and destroy the complex matrix. Microwave pretreatment at a high temperature of 175^{o}C is the maximum temperature in dissolving TWAS (Thickened Waste Activated Sludge) mixture of FOG (Fet, Oil and Grease) and increasing methane yield [20]. There are other studies regarding the effect of microwaves on other ingredients such as algae [21], suspended sludge and mobilized biomass [22], Kitchen waste [23], , municipal solid waste [24] and a comparison of the use of microwave and ultrasonic in Palm Oil Mill Effluent [25]. Pretreatment microwaves is influenced by the power and exposure time microwaves.

Therefore, this objective research to determine the effect of microwave power and exposure time microwave of pineapple peel waste to increase biogas production and optimum microwave pretreatment conditions and to determine daily biogas production from pineapple peel waste.

II. MATERIAL AND METHODS

The materials used in this research is pineapple peel waste and cow rumen, NaOH and aquades. Pineapple peel waste obtained from fruit merchant and rumen is taken from the Slaughterhouse of Semarang City, Central Java, Indonesia.

In general, the tools used in this research can be explained in the following figure:

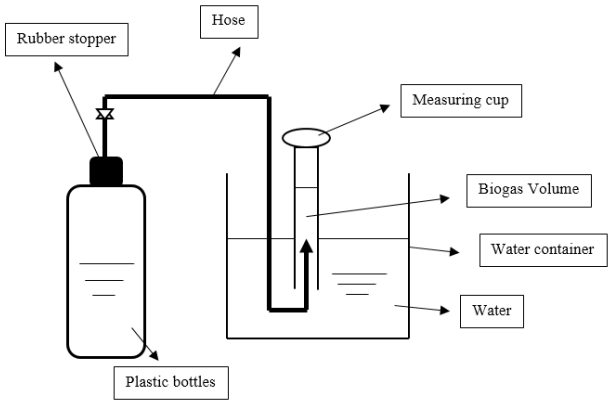

Figure 2.1 Schematic of Laboratory Scale Biogas Instruments

The experiment was carried out in a 600 mL volume digester. Several related variables during the experiment were equated, namely digester placement at room temperature, pH 6.5 - 7, total solid (TS) 10% mixture of pineapple peel and rumen waste. The independent variables of power and time were varied by the elimination method with the power used is 300W, 450 W and 600 W. While the time variables were 5 minutes, 7 minutes and 9 minutes, so that at the end of the research, 6 data would be obtained from the power and time variables. Measurement of biogas results was carried out every 2 days for 60 days.

III. DISCUSSION AND CONCLUSION

3.1 Effect of Microwave Power on Biogas Production

In this research, the independent variables of microwave power is 300 W (line 1), 450 W (line 2) and 600 W (line 3). Meanwhile, the fix variable in this study was a pH of 6.5 - 7, exposure time 5 minutes and total solid 10% V / Ts a mixture of pineapple peel and rumen. The results of biogas production are shown in the following graph:

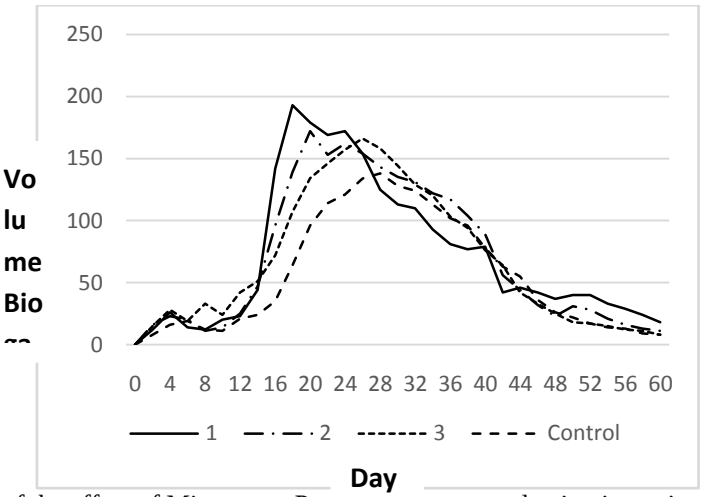

Figure 3.1 Graph of the effect of Microwave Power on Biogas production in a mixture of pineapple peels

Figure 3.1 is a graph of the effect of microwave power on biogas production from a mixture of pineapple peel waste and rumen. The graph shows that the biogas production process began to take shape on the 2nd day and on the 14th day the production of bogas increased until the 26th day. This time period is the optimum condition for produce biogas. The highest daily biogas production on the power variable was indicated at line 1 (300 W) with the amount of 96.5 mL / day on the 18th day and thereafter decreased. Whereas in the 2nd and 3rd lines the optimum conditions were achieved on the 20th and 26th days with daily gas production amounts of 86 mL / day and 83 mL / day, after which it decreased until the end of the biogas production.

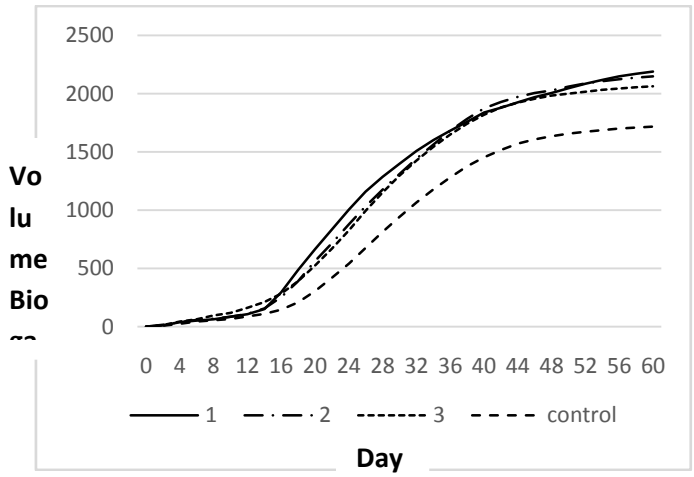

Figure 3.2 Graph of biogas production accumulation with microwave power variables on a mixture of pineapple peel and rumen for 60 days.

Figure 4.2 shows the accumulated of biogas production for 60 days. From the graph above, inform that the highest accumulated volume of biogas production with the power variable is shown at line 1 (300 W) which indicates that at 300 W the power microwave has reached the optimum condition with a total biogas produced 2189 mL. At this power, the heating result from the microwave has been able to cracking the composition of lignin so the hydrolysis process is faster and more effective. Whereas line 2 (450 W) yields 2148 mL and line 3 (600 W) produces 2063 mL. At power greater than 300 W, it actually results in a lower amount of biogas accumulation.

We know that anaerobic decomposition of organic is one of the stages in the formation of biogas. These stages are acidogenesis and acetogenesis. At this stage, volatile fatty acids are formed which will lower the pH in the digester. The anaerobic decomposition process of biogas formation can occur at a neutral pH between 6 - 8. Although it has been stated that the biogas forming bacteria are very sensitive to pH, the pH in the digester does not have to be controlled in detail. PH control can be carried out at the beginning of the experimental process by setting the feeding raw material. So that the equilibrium reaction between acidogenesis and acetogenesis can be achieved[26]. The degree of acidity acid in the digester is influenced by the amount of

volatile fatty acids (VFA), ammonia, CO^2, and the bicarbonate alkalinity generated during fermentation. In conditions without pH control, then at a pH value below 6, the activity of methane-forming bacteria will begin to be disturbed and the bacterial activity will stop when the pH value rises to 5.5. An inappropriate pH range will inhibit bacterial growth, and when it exceeds the critical pH conditions bacterial can death. Microorganisme are sensitive to acidity, the optimum pH for bacterial is in the range of 6.8 - 7.2[27].

The role of acidogenic bacteria and methanogenic bacteria in digester is important, their existence and a,ount of bacterial be maintained. Acidogenic and methanogenic bacteria use of organic matter to produce methane and other gases in their life cycle under anaerobic conditions. These bacteria require a certain environment and are sensitive to the micro environment in the digester such as temperature, degree of acidity acid and the amount of organic material. These bacteria have several common physiological characteristics, but the morphological characteristics of these bacteria are diverse such as Methanomicrobium, Methanosarcina, Metanococcu, and Methanothrix [28].

The availability of organic material is a determining factor in producing biogas optimally so the performance of methanenogenic bacteria can work optimally. Pineapple peels known to contain high cellulose were used as feeding. Cellulose is a complex carbohydrate compound of many glucose chains a.k.a polysaccharides. The decomposition of cellulose in several organic materials is inhibited by the presence of lignin as an inhibitor of the decomposition process. Lignin is an amorphous heteropolymer consisting of three units of phenylptopane (p-coumaryl), coniferil and synapyl alcohol which are bonded differently. The function of lignin is to strengthen the structure of organic matter to withstand microbial attack and oxidation [29].

Ethaib et al. (2015)[30] stated that microwave pretreatment applied to various of different organic materials was able to produce higher sugars and remove more lignin. Microwaves are able to deciding the polymer bonds of lignocellulose. This is because the thermal effect can increase the degradation by increased temperature, internal heating and the evaporation of intracellular water which an increase in internal pressure can break the cell wall to[31]. A thermal effect occurs when an alternating microwave electric field is able to force polarized long chains of the molecular macro to break hydrogen bonds and change the molecular structure [32],[31].

The power of microwave is closely related to the energy emitted. The electrical energy emitted is accompanied by magnetic energy that moves back and forth (oscillate) to produce a harmonious impact which referredelectromagetic waves[33]. With modified microwave technology, electromagnetic waves can be adjusted at a wavelength of 1.0 cm - 1.0 m and a frequency between 0.3 - 30 GHz [17].Then, electromagnetic waves have been modified from electric, magnetic fields and intermolecular forces will produce a direct collision between polar materials or solvents will produce heat which often called conduction and rotation dipole.

It known that the power microwave is matchingwith temperature produced. In this research the effect of microwave pretreatment on pineapple peels was inform the power 300 W is optimum condition. Meanwhile, at higher power, the production of biogas decreased. It is proven in the graph above that the microwave pretreatment power 300 W produces 41 mL of biogas higher than the power 450 W which only produces 2063 mL of biogas. This condition informs that power 300 W the energy emitted by the microwave has been able to crack the bond compounds in the pineapple peel waste sample. The same result was also conveyed by several researchers who have reported that the use of higher power during microwave pretreatment causes lower results[17],[31], [34].

Kainthola et al. (2019)[19] stated that thermal pretreatment at 160^oC can increase lignin solubility. Increasing temperature and reducing exposure time can accelerate thermal hydrolysis, reduce discoloration and reduce odors during fermentation. High thermal values are able to reduce surface tension and the effect of the Marangoni effect (thermocapilarry convection) which further reduces the viscosity of the mixture so that substrate solubility increases[35]. While the increase temperature (> 200^oC) sCOD and decreased VFA (Volatile Fetty Acide) concentration will inhibit the life of microorganisms, the decrease is possible due to the effect of substrate pyrolysis. The destruction of the lignin structure will provide structural support of the biomass which results in increased cellulolytic enzyme accessibility (decreased oxidative stress). So the reasons for increasing biogas production are due to the acceleration of substrate hydrolysis, increased fragility of sample cells, inter-cell disruption and efficiency of dissolved compounds [19].

3.2 Effect of Microwave Heating Time on Biogas Production

Microwave exposure time in the microwave is one of the variables that greatly affects the degradation process of pineapple peel waste. Therefore, the variation of exposure time microwave was carried out to determine the effect on biogas production. The independent variables used were 5 minutes, 7 minutes and 9 minutes with fixed variables in the form of 300 W power, a ratio of 10% V / Ts of a mixture of pineapple peel and rumen, pH 6.5 - 7 and fermentation temperature at room temperature for 60 days. The research results are shown in the following table:

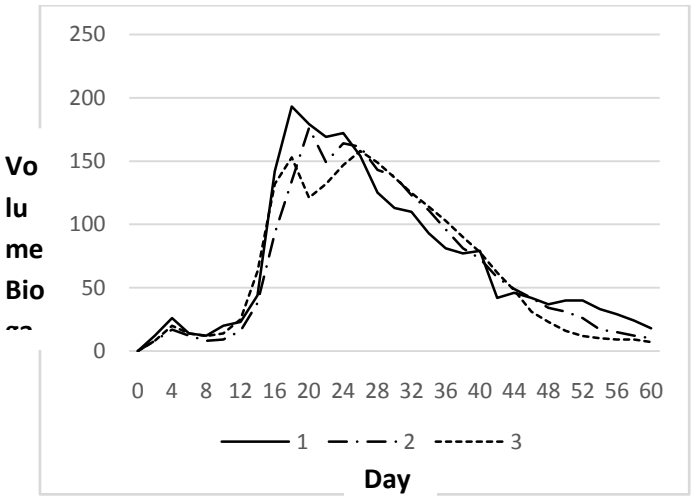

Figure 3.3 Graph of the effect of Microwave Heating Time on biogas production in a mixture of pineapple skin and rumen

The graph above shows the results of biogas production by varying the exposure time microeave of the mixed sample between pineapple peel waste and rumen. The second day after fermentation in the digester has shown the formation of biogas. Biogas production increased on 14th dayuntil 20th day, which shows that during that time the cell degradation has been optimum. The optimum conditions for biogas production are in the range of 18th day to 26thdays, while the highest daily biogas production is shown by line 1 (5 minutes) with a total biogas 96.5 mL/day followed by line 2 (7 minutes) and line 3 (9 minutes) with a total biogas of 88 mL/day and 79 mL/day. Furthermore, it decreased until the end of production.

The optimal exposure time microwave is shown by the highest accumulated amount of biogas volume for 60 days. The highest total biogas accumulation data can be seen in the following graph:

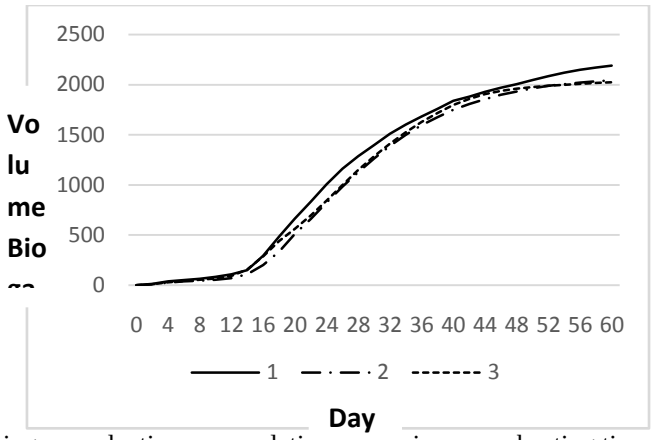

Figure 3.4 Graph of biogas production accumulation with microwave heating time variable on a mixture of pineapple skin and rumen for 60 days.

This graph shows the accumulated biogas production in a mixture of pineapple peel and rumen for 60 days. Line 1 (5 minutes) shows the highest amount of biogas production with a total biogas 2189 mL. Then, on line 2 (7 minutes) and line 3 (9 minutes) occur difference the total amount of biogas, namely 2044 mL and 2022 mL. The time above 5 minutes actually reduces the yield of biogas production which an indicator thatthe time has been excess energy emitted by the microwave, causing damage the structure of the compounds in the sample.

Solvents heated with the aid of microwaves can boil at temperatures above the equilibrium boiling point and at certain atmospheric pressure. This makes it possible to accelerate the homogeneity reaction in the high temperature Arrhenius equation[36]. Microwave heating is selective because polar substances absorb and convert microwaves into heat. Microwave can heat up selectively due to the presence of non-polar substances because non-polar substances do not absorb microwave energy. This situation can be shown clearly in heterogeneous and selectivity systems where heating is not achieved by conventional means [37].In a homogeneous mixture when a polar substance in a non-polar substance, Microwave energy will be absorbed

selectively which will increase reactivity[38]. This condition is very important in intramolecular reactions because reactants can act at an effective temperature without transmitting heat to the media.

Kainthola et al., (2019)[19] reported that during the microwave pretreatment process, lignin undergoes destruction efficiently. This condition can be identified by comparing the efficiency between samples with thermal pretreatment and without thermal treatment with the difference exposure time. The optimum exposure time is reported to be 4 minutes at 190^{o}C, while at higher temperatures the efficiency decreases. In this study, 5 minutes of exposure time and 300 W of power produced the most biogas, which is possible in that condition the heat produced able to damage the structure compounds in the sample. While the effect on physical properties of pineapple peel waste samples, previous studies that have been inform the same results without any differences, where the character of the samples that are pretreated and without pretreatment. The tool that is often used for physical analysis is Scan Electro Microscopic (SEM), the results show that the samples without pretreatment have a smooth and flat surface, while the pretreated samples have a shape like unloaded fibers. This structural change can be attributed to removal of the lignin layer from the gaps in the microfibrils structure. The presence of a microfibril cellulose gap is an important feature that results in faster hydrolysis.

Meanwhile, during the longer exposure time, the biogas yield decreased. The metter is evaporation or decomposition of the cellulose contained in the sample. So the reduced amount of material oeganic will results in less conversion to biogas. Similar to the research results of Sumardiono et al. (2015)[33]stated that the optimum power microwave and exposure time variations were obtained at 400 W / 7 minutes, while the longer exposure time variations of 400 W / 9 minutes resulted in a lower biogas volume.

IV. CONCLUSIONS & RECOMMENDATIONS

The results of this research indicate that the power and exposure time affect the biogas yield. The power used was 300 W / 5 minutes, 450 W / 5 minutes and 600 W / 5 minutes to produce 2189 mL, 2148 mL and 2063 mL of biogas. Then, in the variation of microwave application time of 300W/7 minutes and 300W/9 minutes, the biogas yield decreased with a volume of 2044 mL and 2022 mL.

It can be concluded that the optimum conditions for increasing biogas in pineapple peel waste were obtained at a power 300 W with a radiation exposure time of 3 minutes, with a total volume 2189 mL of biogas. While, the increase power and microwave exposure time actually decreased the production of biogas in pineapple peel waste.

REFERENCES

[1]. Nunes L. Matias J.C.D.O., Catalao J.P.D.S. 2017. Torrefaction of Biomass for Energy Application. eBook ISBN. 9780128096970 (2017)

[2]. Li Y.P., Huang G.H., Li M.W. 2014. An integrated optimization modeling approach for planning emission trading and clean-energy development under uncertainty, *Renewable Energy* 62 (2014) 31-46.

[3]. Nevzorova T., Kutcherov V. 2019. Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review. *Energy Strategy Reviews* 26 (2019) 100414

[4]. Murele O.C., Zulkafli N.I., Kopanos G., Hart P., Hanak D.P. 2019. Integrating biomass into energy supply chain networks. *Journal of Cleaner Production* (2019),

[5]. Yasmina N., Grundmanna P. 2019. Adoption and diffusion of renewable energy – The case of biogas as alternative fuel for cooking in Pakistan. *Renewable and Sustainable Energy Reviews* 101 (2019) 255–264

[6]. Dragičević V., Miletić M., Pavković B. 2015. Investigation on possibilities for biogas production from organic waste on the Croatian island of Krk. *Tech Gaz* 2015;22:755–62.

[7]. Angelidaki I., Treu L., Tsapekos P., Luo G., Campanaro S., Wenzel H., Kougias P.G. 2018. Biogas Upgrading and Utilization: Current and perspectives. *Bitechnology Advances* 36 : 452-466.

[8]. Singh J., Gu S. 2015. Commercialization potensial of microalgaefor biofuel production. *Renewable and sustainable Energy Reviews* 14:2596-610

[9]. Koppelmaki K., Parviainen T., Virkkunen E., WinQuist E., Schulte P.O.R., Helenius J., 2019. Ecological intensification by integrating biogas production into nutrient cycling: modeling tge case of Agroecological Symbiosis. *Agric. Syst.* 170, 39-48

[10]. Sanguanchaipaiwong V., Leksawasdi N. 2018. Butanol production by *Clostridium beijerinckii* from pineapple waste juice. *Energy Procedia* 153 (2018) 231–236

[11]. Namsree P., Suvajittanont W., Puttanlek., Uttapap., Rungsardthong V. 2012. Anaerobic digestion of pineapple pulp and peel in a plug-flow reactor. *Journal of Enviromental* 110 : 40-47.

[12]. Wijana, S., Kumalaningsih, A. Setyowati, U. Efendi dan N. Hidayat, 1991, Optimalisasi Penambahan Tepung Kulit Nanas dan Proses Fermentasi pada Pakan Ternak terhadap Peningkatan Kualitas Nutrisi, ARMP (Deptan), Universitas Brawijaya, Malang.

[13]. Hariyadi, Tri Retno D. L., Siswanto. 2012. *Utilization of Sugarcane Bagasse and Pineapple Waste for Biogas Production.* Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan Vol. 2 No. 2 (Desember 2012): 56-64

[14]. *Chulalaksananukul S., Sinbuathong N., and Chulalaksananukul W. 2012.* Bioconversion of Pineapple Solid Waste under Anaerobic Condition through Biogas Production. *Res. J.* 2012; 17(5):734-742

[15]. Sarangi P.K., Nanda S., Das R. 2018. Bioconversion Of Pineapple Residues For Recovery Of Value-Added Compounds. *International Journal of Research In Science & Engineering* e-ISSN: 2394-8299

[16]. Kozo I., Hisajima S., Carryl R.J. 1996. Utilization of agriculture wastes for biogas production in Indonesia. Traditional technology for environmentan convertion and sustainable development in asia pacific region. 9th ed: 134-38

[17]. Eskicioglu C., Nicolas T., Kevin J.K., Ronald L.D., Hamoda M. 2007. Athermal microwave effect for enhancing disgestibility of waste activated sludge. *Water research* 41:2457-66.

[18]. Jackowiak D., Bassard D.A., Pauss A., Ribeiro T. 2011. Optimisation of a microwave pretreatment of wheat straw for methane production. *Bioresource technology* 102: 6750.

[19]. Kainthola, J., Kalamdhad, A.S., Goud, V.V., 2019. Optimization of methane production during anaerobic co-digestion of rice straw and hydrilla verticillata using response surface methodology. Fuel 235, 92–99.
[20]. Alqaralleh R.M., Kennedy K., Delatolla R. 2019. Microwave vs. alkaline-microwave pretreatment for enhancing Thickened Waste Activated Sludge and fat, oil, and grease solubilization, degradation and biogas production. *Journal of Environmental Management* 233 (2019) 378–392
[21]. Zaidi A.A., RuiZhe F., Malik A., Sohaib Z., Khan., Bhutta A.J., Shi Y., Mushtaq K. 2019. Conjoint effect of microwave irradiation and metal nanoparticles on biogas augmentation from anaerobic digestion of green algae. *international journal of hydrogen energy* 44 (2019) 14661e14670
[22]. Zieliński, M., Dębowski, M., Rusanowska, P. 2017. Influence of microwave heating on biogas production from *Sida hermaphrodita* silage, *Bioresource Technology* (2017), j.biortech.2017.08.165
[23]. Marin J., Kevin J.K., Eskicioglu C. 2010. Effect of irradiation on anaerobic degradability of model kitchen waste. *Waste management* 30: 1772-79.
[24]. Mehdizaden S.Y., Eskicioglu C., Bobowski J. 2013. Conductive heating and microwave hydrolysis under indentical heating profile for aadvenced anaerobic digestion of municipal sludge. *Water research* 47: 5040-51.
[25]. Saefuddin, fadzili S.A. 2013. Effectof microwave and ultrasonic pretreatment on biogas production from anaerobis digestion of palm oil mill effluent. *Amerivan J. of engineering and alloied science* 2(1): 139-46.
[26]. Budiyono, Widiasa I.N., Johari S., Sunarso. 2010. The kinetic of biogas rate from cattle manure in batch mode. *International journal of Chemical and Biological Engineering* 3(1):39-44
[27]. Savoo, S., Mudhoo, A., 2018. Biomethanation macrodynamics of vegetable residues pretreated by low-frequency microwave irradiation. Bioresour. Technol. 248,280–286.
[28]. Haryati T. 2006. Biogas: Limbah peternakan yang menjadi sumber energy alternative. Jurnal Wartazoa Vol. 16 No. 3
[29]. Hendriks A., Zeeman G. 2008. Pretreatments to Enhance Digestibility of Lignocellulosic Biomass. Bioresource Technology 100(1):10-8
[30]. Ethaib S., Omar R., Kamal S.M., Biak D.R. 2015. Microwave-Assisted Pretreatment Of Lignocellulosic Biomass: A Review. Somche 2014 & Rsce 2014 Conference, January (2015) 97 – 109
[31]. Sólyom K., Mato R.B., Pérez-Elvira S.I., Cocero M.J. 2011. The influence of the energy absorbed from microwave pretreatment on biogasproduction from secondary wastewater sludge. Bioresource Technology 102 (2011) 10849–10854
[32]. Hong, S.M., Park, J.K., Lee, Y.O., 2004. Mechanisms of microwave irradiation involved in the destruction of fecal coliforms from biosolids. Water Res. 38, 1615–1625.
[33]. Sumardiono S.,, Budiyono, Mardiani D.T. 2015. The effect of microwave power and heating time pretreatment on biogas production from fresh and dried water hyacinth (Eichhornia crassipes). ICCME. 1699, 050018 (2015)
[34]. Toreci, I., Kennedy, K.J., Droste, R.L., 2009. Evaluation of continuous mesophilic anaerobic sludge digestion after high temperature microwave pretreatment. Water Res. 43, 1273–1284.
[35]. Barber, W.P.F., 2016. Thermal hydrolysis for sewage treatment : a critical review. Water Res. 104, 53–71.
[36]. Chemat F., Esveld E. 2001. Microwave Super-Heated Boiling of Organic Liquids: Origin, Effect and Application. Chem. Eng. Technol. 24 (2001) 7
[37]. Dı´az-Ortiz A., Prieto P., and de la Hoz A. 2018. A Critical Overview on the Effect of Microwave Irradiation in Organic Synthesis. Chem. Rec. 2018, 18, 1–14
[38]. Kaiser N.-F. K., Bremberg U., Larhed M., Moberg C., Hallberg A., Angew. Chem. Int. Ed. 2000, 39, 3595–3598; Angew. Chem. 2000, 112, 3741–3744.