JOURNAL OF COMPLEMENTARY MEDICINE RESEARCH
Journal of Complementary Medicine Research, ISSN: 2146-8397 Vol. 14, No. 5, 2023 (pp. 11-18)
RESEARCH ARTICLE
WWW.JOCMR.COM

Assessing Agricultural Waste Biofuel Reactor Design Needs

Adel Ranji[1], Mehrdad Fojlaley[2],Fatih Kalkan[3],Behrouz Babaei Seziroud[4], Mohammad Alijani Milash[5]

[1]Postdoctoral Fellow, Department of Food Engineering, Faculty of Engineering, University of Ardahan, 75002 Ardahan, Turkey
[2]Associate Professor, Department of Bio System Mechanic Engineering, Thechnofest Institue of Technology, 6560 Erquelinnes, Belgium
[3]Associate Professor, Department of Food Engineering, Faculty of Engineering, University of Ardahan, 75002 Ardahan, Turkey
[4]Master's degree, Department of Biotechnology, Gilan University, Rasht, 4199613776, Iran
[5]Department of Accounting, Rudsar Azad University, Rudsar, 4481714188, Iran

Abstract
Governments have invested heavily in biofuels due to the growing demand for them as fossil fuel substitutes, as well as challenges with national security, increasing farmer income, implementing new and cutting-edge technologies, and environmental and health concerns. Despite the agriculture industry having many potential facilities and producing a sizable number of crops each year, a lot of trash is regrettably abandoned or thrown in the environment without according to environmental laws. As a result, economical and technological advancements are crucial to the development of biogas and other environmentally acceptable renewable energy sources. Because producing energy in the absence of obstructions might be difficult, biogas technology has both advantages and disadvantages. In order to ensure sustainable development, it is vital to update present technology. More advancements have turned focus to biogas production techniques, which may greatly lessen potential worldwide economic problems. The goal of the current study was to assess recent technological developments as well as various aspects of biogas production, such as the use of sustainable raw materials, microbial dynamics, and enzymatic activities, as well as optimization parameters and segregation processes, to improve this technology and investigate potential inhibitors.

1. Introduction

The production of global waste has grown with rising populations, urbanization, and the effects of improved economic and industrial activities (Elsayed et al. 2020). Managing the immense waste produced has been a long-term challenge that has faced mankind over the last several decades, despite many measures taken to prevent it. For example, the entire global waste produced in 2016 amounted to 2.02 billion tons, which is expected to reach 2.59 billion tons by 2030 and 3.4 billion tons by 2050 (Tiseo, 2018).

Agricultural activities to produce foodstuffs might cause a large amount of waste into the environment, which, in any way, could cause considerable environmental problems. These wastes are produced as by-products and end products of a variety of processes and activities (Chandra et al. 2012). On the other hand, many developed and developing countries regard such waste as valuable. Valuing agricultural wastes as forms of waste conversion and recycling strategy both helps a clean environment, enhances social and economic development, preserves, and recovers resources, and provides greater access to energy security and circular economies. The present study did a social-economic and cultural-environmental evaluation of biofuel production from agricultural sector wastes and investigated the thermal, chemical, and biological conversion processes in the conversion of agricultural wastes into high-quality biofuel without risking ecological diversity or environmental standards.

Keywords: Biogas production, biogas production reactors, agricultural waste

DOI: 10.5455/jcmr.2023.14.05.2

2. Bio-economic approach

The renewed use of products as alternatives to compete with the fossil fuel industry in various sectors is recognized as a bioeconomy (Kapoor et al., 2020). An economy assisted with renewable biological resources, biological tools, and biological utilization processes helps reduce greenhouse gas emissions and produce sustainable bio-products while improving the quality of the environment and living standards (Achinas & Euverink, 2016).

Considering the reduced level of forest resources and the limited use of forests, using fast-growing non-forest plants as well as agricultural wastes is more advantageous. Agricultural wastes are economically and environmentally attractive and desirable while being easy to reach in different regions, cheap, and accessible in a shorter period of time (Kapoor et al. 2020). To successfully develop biorefining, it is necessary to provide a logical design of the entire biorefining system to achieve higher profitability and reduce environmental impacts.

3. Bioenergy

Biofuel energy content comes from biological resources and organic matter that constitute living organisms. Biofuel is a kind of fuel derived from biomass resources. Various thermal, chemical, and biochemical conversion processes can transform the energy present in plants and biomasses into energy that humans can use (Blaschek et al. 2010). Biofuels, especially liquid biofuels, are divided into several generations (first, second, third, and fourth generations) based on the initial raw materials used to produce them. As each generation develops, the production of these fuels has improved and been enhanced (Pryshliak & Tokarchuk, 2020).

First-generation fuels are biofuels based on sugar, starch, oil, and animal and herbal fats and are produced from food and crop products. These fuels include biodiesel, ethanol, and biogases such as methane. In this type of generation, valuable foodstuffs should only be cultivated to produce biofuels, which could also risk the security of food chains. Also, cultivating products for biofuel production may not be economically viable (Huang et al., 2022). Second-generation biofuels are derived from non-food products or agricultural wastes, especially lignocellulosic biomass. The raw materials of this generation of fuels do not fall under foodstuffs; rather, they can be the wastes of food or crops or highly valuable nutritious products for humans. Many experiments have been conducted on algae as rich sources of fat to produce liquid biofuels. Extracting fat and making direct use of these algae could yield third-generation biofuels. Seaweeds can grow on land and in the sea, but they are not suitable for food cultivation. Seaweeds can be used to produce biofuels that can be processed into diesel, gasoline, and jet fuel. The production of third-generation fuels does not reduce the production of foodstuffs, as they need no farmlands or freshwater (Kapoor et al. 2020). The fourth-generation fuel is based on converting vegetable oils and biodiesel into gasoline. Biofuels are derived from engineered plants or biomass, which may produce higher energy yields. This type of material needs less cellulose and is also capable of growing on non-agricultural and non-water lands (Elsayed et al., 2020).

Based on their physical states, biofuels are produced in three categories: 1) liquid: bioethanol and biodiesel; 2) solid: wood or biochar; and 3) gas: biogas and biohydrogen. Biogas refers to gases produced from the fermentation and anaerobic decomposition of organic matter by anerobic bacteria, especially methanogens, fermented in a fermentation chamber. Biogas is a fuel that does not produce environmental pollution; also, the risk of biogas explosion is low, and it may also serve as a fireproof material because of the CO_2 gas in it. The increased level of CO_2 in the biogas mixture greatly reduces its heating value and flammability. Hence, using filters to isolate CO_2 could increase the heating value of biogas. This gas mixture, derived from fermenting waste organic matter under anaerobic conditions, contains 60–70% methane, 30–40% carbon dioxide, and small amounts of other gases, such as hydrogen, nitrogen, oxygen, carbon monoxide, and hydrogen sulfide. A large part of this gas is made of methane and carbon dioxide (Gao et al. 2019). This gas can be used as a direct energy carrier to supply heat and lighting in buildings or to produce electricity in gas generators. This gas is odorless, colorless, and flammable, producing a blue flame without smoke when burned, and has a heating value of 4580 to 5495 kcal per cubic meter for a degree of purity of 50 to 60% methane. The materials used to produce biogas include ranch and poultry farm wastes, and in general, livestock wastes, solid waste materials, organic wastes, and solid and food processing wastes produced by factories (Duque-Acevedo et al., 2020).

4. Biogas

Anaerobic digestion is a group of procedures in which pertinent microorganisms break down decomposable organic matter under anaerobic conditions. This process includes four stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Deng et al., 2017). The first stage includes the decomposition of matter of higher molecular weight, including cellulose, starch, proteins, and fats, and its conversion into compounds of lower molecular weight, including fatty acids, amino acids, carbon dioxide, and hydrogen. The hydrolytic group of bacteria performs the decomposition of the latter group. In the second stage, the final products of the first stage are converted into acetate and hydrogen by acetogenic bacteria. In the third stage, to produce more acetate, homoacetogenic organisms convert hydrogen and simple carbon compounds produced in the first and second stages into acetate. The fourth stage includes the conversion of acetate and other simple compounds, such as formate, carbon dioxide, and hydrogen, into methane. This stage is carried out by methanogenic organisms (Ghosh, 2016). Numerous physical and chemical factors also have an impact on the anaerobic digestion and biogas production processes, just like they do with other biochemical reactions. Various factors such as the substrate nature of nutrients to feed enzymes, moisture, volatile solids, nutrient structure, particle sizes and their degradability, digester design, inoculation, alkalinity, temperature, loading rate, hydraulic retention time, etc. could affect the process stability and the biogas production (Nopharatana et al., 2007).

4.1. Biogas production conditions and biogas production reactors

Figure 1 presents biogas production process and the residual sludge in the reactor.Types of biomass can be used as feed to produce biogas, while the bioenergy properties of each vary. The main criteria for selecting the substrate to produce biogas include the substrate's nature, accessibility, carbon-to-nitrogen ratio, production potential, and environmental effects. By "substrate nature, it means the combination of matter, proteins, fats, and relevant carbohydrates (Nopharatana et al., 2007). Also, various studies have been conducted on the biogas production potential of various organic wastes, suggesting the greater use of animal manure compared to industrial-agricultural and urban solid wastes. Thus, animal manure, industrial-agricultural waste, and urban solid waste contributed to producing biogas by as much as 36%, 31%, and 34%, respectively (Deng et al., 2017).

The carbon-to-nitrogen ratio of the feed is a major factor in determining biogas properties. Anaerobic bacteria require carbon and nitrogen to survive, as they use carbon as a source of energy and nitrogen to build their cellular walls. The ratio of these matters is key to controlling chemical interactions inside the digester, with carbon being used 31 to 35 times faster than nitrogen (Kwietniewska et al. 2014). When this ratio increases, nitrogen is more readily absorbed by methanogens to meet their protein needs, as nitrogen does not react with the carbon content, resulting in reduced biogas production. When this ratio decreases, the released nitrogen is accumulated, which subsequently causes ammonia to accumulate. This also increases alkalinity and has a toxic effect on the methanogenic population, thereby resulting in reduced gas production. In degradable wastes of high carbon content, like lignin, the carbon-to-nitrogen ratio cannot have a major effect on the degradation process. Results have suggested that when sawdust is 2–4%, it increases methane by 21% after 111 days. On the other hand, when sawdust is 6%, the total methane produced will be almost equal to the time when the fertilizer is digested alone (Paepatung et al., 2009).

Another operational aspect of biogas production is particle size. Particles should be small enough to provide an appropriate contact surface for the attack and feeding of the microorganisms. Otherwise, it causes coagulation and creates an impermeable surface due to moisture, thus preventing microorganisms from engaging in nutritional activities (Gao et al., 2019). When the substrate is less degradable, the reduced particle sizes and, subsequently, the increased specific surface area improve methane production. Few studies have examined the effects of substrate particle sizes on methane production (Nopharatana et al. 2007). The key point to note is that there is a reverse relationship between particle size and biogas production potential. Some, however, argue that there is no concrete relationship between them. It is noteworthy to note that in all cases above, the particle size should be comparable to the standard particle size, which is announced to be less than 11 mm (Rubindamayugi et al. 2006). The digestion of various biodegradable wastes has demonstrated that the methane production potential of digestion through combined digestion tests is higher than that of individual digestion. Most agricultural wastes have higher nutrients (higher nitrogen), while their lignocellulosic nature has made them resistant to microbial enzyme attacks. In the meantime, insufficient biogas is derived from the anaerobic digestion of these types of substrates. To improve the digestion of agricultural residues, they are mixed with animal manure, which has a large amount of carbon, to facilitate the production of biogas containing a suitable amount of methane and thus increase its flammability. For example, the combined digestion of paper and cow manure produces biogas with a higher quantity and quality compared to when they were separately digested. The best combination ratio of agricultural waste and animal manure is 1:1 (Ofoefule et al., 2010).

Raw materials cannot be injected into the biogas device the same way; rather, before loading, they should be examined in terms of concentration, bacteria absorbability, the carbon-to-nitrogen ratio, temperature, and the absence of toxic materials and inhibiting elements. Considering the recent technological advancements, lignocellulosic conversion through pretreatment before starting digestion can be utilized to maintain the industrial balance (Kwietniewska et al. 2014). Pretreatment causes the non-accumulation of lignocellulose in lignin, cellulose, and hemicellulose, as the enzymatic degradation tends to be carried out by bacteria, thereby resulting in the production of sufficient biogas. Evidence has shown that this method increases the access of lignocelluloses to hydrolytic enzymes, and improvement in the pretreatment methods could culminate in greater access to cheaper feed (Udelhoven et al. 2013). To produce biogas, their compositions and chemical structures should be examined so that there is no inhibiting factor against microorganisms. For example, antibiotics, which are capable of producing nitrogen, zinc, ammonia, fatty acids, and hydrogen sulfide, cause the digestion process to stop, as sulfates reduce the production of methane and their amounts should be less than 211 mg/L, while the amounts of ammonia should be less than 2511 mg/L (Zheng et al., 2012).

The temperature has an impact on one of the variables affecting the optimization of the biogas production process, which is reaction speed. Moreover, temperature affects the solubility of heavy metals, carbon dioxide, and consequently gas composition. Thermal variations affect microbial growth and cause a significant decrease in biogas production. In psychrophilic digestion, the retention time is over 111 days and the reaction temperature is 11–21 °C. In mesophilic digestion, the retention time ranges from 31 to 61 days, and the reaction temperature ranges from 21 to 35 °C. In thermophilic digestion, the retention time is 11–15 days, and the reaction temperature ranges from 51–61 °C (Keanoi et al. 2014). Anaerobic reactions in biogas devices are generally carried out at 11–61 °C. Bacteria active at 31–41 °C are known as mesophilic, and those active at 45–61 °C are thermophilic. Thermophilic digestion improves the release rate of methane and its production, thus requiring little retention time. This type of digestion eliminates pathogens due to higher temperature rates and operates better than mesophilic digestion in systems with higher solid content (Kwietniewska et al. 2014). In addition to its advantages, this type of digestion has disadvantages, including lower stability and greater sensitivity to the input feed. The higher temperature of this type of digestion requires more control and maintenance of the process and the digester; for this reason, this type is not suggested for temperatures higher than 45 °C. To improve the fermentation temperature and prevent its wastage, the biogas unit facilities are constructed consistent with the climatic conditions of the region. For example, Chinese devices are placed deep inside the ground to increase the temperature, while Indian units are insulated by fertilizers to prevent heat loss and increase biogas (Deng et al., 2017). Also, using solar energy and embedding hot-water pipes and heat exchangers or coils in industrial devices is one of the common methods of keeping biogas units warm. In sum, both mesophilic and thermophilic temperature ranges are suitable, provided that the proposed temperature is consistent with microbial functional features.

Surveys have demonstrated that due to the sensitivity of bacteria to methanogenic alkalinity, an alkalinity of around 6.6 to 7.2 could be appropriate for biogas production. Any volatility in alkalinity could cause problems for biogas production and fermentation. Lower alkalinity disrupts the lives of methanogenic bacteria, and if it remains unchanged for a long time, it results in the inactivity of the methanogenic bacteria and the breaking down of the digester (Fedailine et al. 2015). In this condition, the situation can be improved by adding alkaline materials or increasing the temperature. When the pH of the environment is alkaline and reaches equilibrium, the substrate can be added to the system; of course, it should be borne in mind that acidic materials are not added to the system (Udelhoven et al. 2013). As regards the concentration of solids and water, materials are required to become soluble for bacteria to absorb organic matter because water is one of the main elements for the nutrition of microorganisms, which causes the motions of the bacteria, the activity of cellular enzymes, the hydration of bio-polymers, and also the facilitation of the cell break-down. However, its optimal amount is intended because of the low amount of moisture, and consequently, the increased concentration of solids increases the adhesion and accumulation of active acids and delays the fermentation process. On the other hand, if the amount of moisture is high, it causes layering of the solution, and if the solution is not constantly stirred, it could reduce biogas production (Cesaro et al., 2012). The best solution concentration for anaerobic fermentation in biogas tanks should be 7-9% of the solids. Thus, to achieve the desired ratio, the feed must be diluted or digested before it enters the digester. If the digester input is not diluted enough, specific ammonia poisonings may arise. As a result, biogas production systems with total solids are less important, and the loading rate of 6–7% shows a significant increase in biogas production (Jeihanipour et al., 2013).

Another factor affecting biogas production is the complete stirring of materials inside a tank, which helps with the uniformity of the materials, temperature, concentration, and other environmental factors. Other advantages include minimizing the formation of a hard surface layer, preventing gas emissions, preventing heavy materials from being deposited on the reactor’s bottom, floating light materials on the reactor’s surface, and providing more and equal access to microorganism nutrition across all upper, middle, and lower levels of the digester. Also, an increase in the rate of microorganism reproduction, their stimulation, a greater amount of gas production, and the increased efficiency of the anaerobic digester may follow (Khalil et al. 2019). Stirring and mixture are performed by the daily addition of materials to create a motion in the mass of the materials and to subject the undecomposed materials to the adjacency of anaerobic bacteria. This process can be carried out manually, mechanically, and finally hydraulically using a pump under gas pressure. At a larger scale and in treatment facilities, in addition to using mechanical stirrers, part of the gas obtained can be re-injected under pressure into the lower part of the tank. The stirring practice should be performed daily, as all tank volumes should be stirred two or three times a day for several minutes each. When the temperature is high, the mixing practice can be performed before pouring the materials into the digester, thus avoiding the daily stirring of the mixture. However, this method yields lower device efficiency. Surveys have indicated that the gas produced in the digester causes the materials to move; however, this amount is not usually enough to mix the materials inside the digester (Duque-Acevedo et al., 2020).

Since the digestion process inside the biogas production device is anaerobic, air must not enter the system to create the best fermentation conditions. If some air enters the system during the process, it will put the system into a long acid phase and cause the process to stop (Cesaro et al., 2012). The retention time of the materials inside the digester depends on the type of materials, the rate of input material decomposition, the level of gas produced, fermentation temperature, and other environmental factors. Gas production experiences an ascending trend with an increase in retention time. If the input materials do not remain inside the digester for as long as needed, the digestion and fermentation processes will not be completed, and consequently, no gas will be produced.

Single-stage digesters were conventionally used to produce biogas in the past, but they suffered from some limitations, including more instability due to the presence of various factors. Two-stage continuous biogas systems that ensure the continuous production of biogas and slurry can be used for commercial and industrial purposes. The two-stage digestion system separates hydrolysis-acidification and methanogenic stages for anaerobic digestion to yield more process stability and increase biogas production (Janke et al. 2015). More studies have demonstrated that separating acidification and hydrolysis in anerobic digestion can reduce retention time and increase biogas and methane production. Biogas devices are generally made of two inlet and outlet ponds, a fermentation (digester) tank, and a gas tank. In this regard, such conditions as climate, culture, economy, and technologies have led to the creation of various forms and models. In all these devices, water and raw materials are mixed in the inlet pond, where they are directed to the fermentation tank. After fermentation and gas production, they (water and raw materials) are directed to the outlet channel and the outlet pond, with raw materials added (Lalov et al., 2001).

Concerning the global greenhouse phenomenon, it is estimated that annually around 74 million tons of methane are produced from livestock dung and agricultural wastes, while 40 million tons of this gas are produced from urban wastes and scattered in the air, thus polluting the environment. To reverse this critical trend, more efficient methods must be utilized. An airtight chamber called a biogas reactor is used to accelerate the anaerobic breakdown of biodegradable wastes such as black water, sludge, or organic waste. Additionally, this gadget makes it easier to collect biogas made during reactor fermentation. The gas is composed of liquid and ascends above the chamber, thus causing the liquid to get mixed. The digested material is rich in organic and nutritious matter, has almost no odor, and has its pathogens somehow inactivated (Khalil et al. 2019). Biogas reactors can take the form of prefabricated tanks or domes made of bricks. Depending on the space, soil properties, available resources, and volume of waste produced, they are placed over or under the ground. They can also be constructed in the form of fixed or floating dome digesters. In fixed domes, the reactor volume is fixed. The produced gas creates pressure, and the liquid goes up and expands inside the tank. When the gas is recovered, the liquid returns to the reactor. The pressure can be used to transfer the gas inside the pipes. In a floating-domed reactor, the dome goes up and down with the production and extraction of gas. In other words, it can expand like a balloon. To reduce distribution drops, the reactor should be placed in the closest place to be consumed (Khalil et al. 2019). The reactor’s hydraulic retention time should be in a warm climate for at least 15 days and in a moderate climate for 25 days. For inputs with high pathogen loads, the hydraulic retention time should be 60 days. Biogas reactors are utilized within the mesophilic range of 30–38 °C. A thermophilic temperature of 50–57 °C is needed for pathogen degradation; however, this is only possible by heating the reactor (Janke et al. 2015).

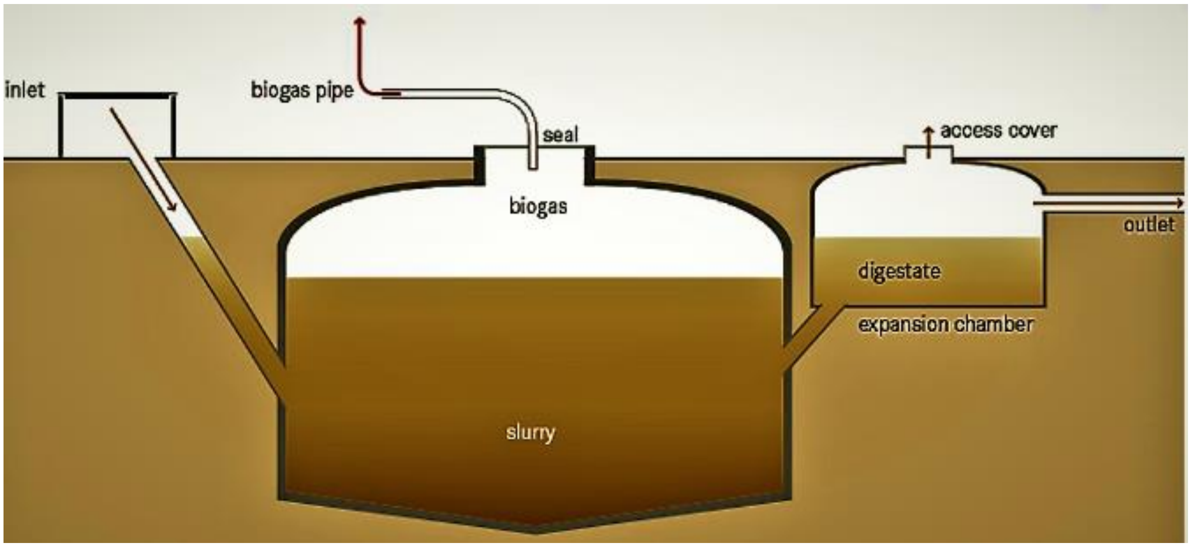

Figure 1 Biogas production process and the residual sludge in the reactor

Because of the digester's continuous production, measures should be taken for its storage, use, and transfer. Digested materials are somewhat disinfected, though they may still expose an infection. Depending on the final use, the next treatment may appear to be necessary. If managed improperly, flammable gas risks can endanger human health. If the design and construction of a reactor are proper, repair and maintenance will be minimized (Jeihanipour et al., 2013). To operate a reactor, the inoculation of anaerobic bacteria, e.g., by adding cow dung or the septic sludge of the tank, should be used. Before the feeding process, organic wastes used as nutrients should be crushed, mixed, or digested. Gas equipment should be carefully cleaned because this could prevent leakage or corrosion. Sand and gravel settled on the bottom must be removed. Depending on the design of the entrances, the reactor must be discharged every 5–10 years. Reactors can be used most often where there is continuous feeding. Mostly, biogas reactors are used as suitable alternatives to septic tanks because the reactors enjoy an equivalent treatment level and also involve biogas advantages. Biogas reactors are not suitable in colder climates because the conversion rate of organic matter inside the biogas is very low, more hydraulic retention time will be needed, and the volume will be high (Cesaro et al., 2012).

Conclusion

Fossil fuels could never provide enough energy to meet human needs for survival and development due to escalating energy demands and diminishing fossil fuel resources. On the other hand, as important contributors to the greenhouse effect and environmental pollution, the rise in waste, animal dung, and agricultural wastes around the world is seen as a limiting factor in human life. For this, precise and effective planning should be in place to control and manage resources appropriately and replace fossil fuels with renewable energies, particularly biogas technologies, which are widely used in energy production, pollution reduction, fertilizer quality improvement, and weed seed eradication. Installations of biogas lessen the need for fossil fuels while also being profitable. This gas is produced through a natural process at no cost; nonetheless, there are expenses associated with managing, maximizing, and using this gas. The fertilizer produced by biogas systems contains significantly more and better-quality nitrogen than fertilizers made from ordinary botanical ingredients. Economically speaking, chemical fertilizers can be replaced with digester tank effluent. Direct combustion of this gas is substantially more expensive than producing electrical energy from biogas fuels. The construction of biogas power plants can aid in the collection and control of environmental pollutants and agricultural wastes, preserving society's public health while also meeting some of the electrical and thermal energy needs.

References

1. Achinas, S., & Euverink, G. J. W. (2016). Theoretical analysis of biogas potential prediction from agricultural waste. *Resource-Efficient Technologies*, 2(3), 143-147
2. Blaschek, H. P., Ezeji, T. C., & Scheffran, J. (2010). *Biofuels from agricultural wastes and byproducts*. John Wiley & Sons.
3. Cesaro, A., Naddeo, V., Amodio, V., & Belgiorno, V. (2012). Enhanced biogas production from anaerobic codigestion of solid waste by sonolysis. *Ultrasonics sonochemistry*, *19*(3), 596-600

4. Chandra, R., Takeuchi, H., & Hasegawa, T. (2012). Methane production from lignocellulosic agricultural crop wastes: A review in context to second generation of biofuel production. *Renewable and Sustainable Energy Reviews*, *16*(3), 1462-1476.
5. Deng, L., Liu, Y., Zheng, D., Wang, L., Pu, X., Song, L., ... & Long, Y. (2017). Application and development of biogas technology for the treatment of waste in China. *Renewable and Sustainable Energy Reviews*, *70*, 845-851
6. Duque-Acevedo, M., Belmonte-Ureña, L. J., Yakovleva, N., & Camacho-Ferre, F. (2020). Analysis of the circular economic production models and their approach in agriculture and agricultural waste biomass management. *International Journal of Environmental Research and Public Health*, *17*(24), 9549
7. Elsayed, M., Ran, Y., Ai, P., Azab, M., Mansour, A., Jin, K., ... & Abomohra, A. E. F. (2020). Innovative integrated approach of biofuel production from agricultural wastes by anaerobic digestion and black soldier fly larvae. *Journal of Cleaner Production*, *263*, 121495
8. Fedailaine, M., Moussi, K., Khitous, M., Abada, S., Saber, M., & Tirichine, N. (2015). Modeling of the anaerobic digestion of organic waste for biogas production. *Procedia Computer Science*, *52*, 730-737
9. Gao, M., Wang, D., Wang, H., Wang, X., & Feng, Y. (2019). Biogas potential, utilization and countermeasures in agricultural provinces: A case study of biogas development in Henan Province, China. *Renewable and Sustainable Energy Reviews*, *99*, 191-200
10. Ghosh, S. K. (2016). Biomass & bio-waste supply chain sustainability for bio-energy and bio-fuel production. *Procedia Environmental Sciences*, *31*, 31-39
11. Huang, X., Wang, S., Shi, Z., Fang, L., & Yin, C. (2022). Challenges and strategies for biogas production in the circular agricultural waste utilization model: A case study in rural China. *Energy*, *241*, 122889.
12. Janke, L., Leite, A., Nikolausz, M., Schmidt, T., Liebetrau, J., Nelles, M., & Stinner, W. (2015). Biogas production from sugarcane waste: assessment on kinetic challenges for process designing. *International journal of molecular sciences*, *16*(9), 20685-20703
13. Jeihanipour, A., Aslanzadeh, S., Rajendran, K., Balasubramanian, G., & Taherzadeh, M. J. (2013). High-rate biogas production from waste textiles using a two-stage process. *Renewable Energy*, *52*, 128-135
14. Kapoor, R., Ghosh, P., Kumar, M., Sengupta, S., Gupta, A., Kumar, S. S., ... & Pant, D. (2020). Valorization of agricultural waste for biogas based circular economy in India: A research outlook. *Bioresource Technology*, *304*, 123036
15. Karellas, S., Boukis, I., & Kontopoulos, G. (2010). Development of an investment decision tool for biogas production from agricultural waste. *Renewable and Sustainable Energy Reviews*, *14*(4), 1273-1283
16. Keanoi, N., Hussaro, K., & Teekasap, S. (2014). Effect of with/without agitation of agricultural waste on biogas production from anaerobic co-digestion-a small scale. *American Journal of Environmental Sciences*, *10*(1), 74-85
17. Khalil, M., Berawi, M. A., Heryanto, R., & Rizalie, A. (2019). Waste to energy technology: The potential of sustainable biogas production from animal waste in Indonesia. *Renewable and Sustainable Energy Reviews*, *105*, 323-331
18. Kwietniewska, E., & Tys, J. (2014). Process characteristics, inhibition factors and methane yields of anaerobic digestion process, with particular focus on microalgal biomass fermentation. *Renewable and sustainable energy reviews*, *34*, 491-500
19. Lalov, I. G., Krysteva, M. A., & Phelouzat, J. L. (2001). Improvement of biogas production from vinasse via covalently immobilized methanogens. *Bioresource Technology*, *79*(1), 83-85
20. Liu, C. F., Yuan, X. Z., Zeng, G. M., Li, W. W., & Li, J. (2008). Prediction of methane yield at optimum pH for anaerobic digestion of organic fraction of municipal solid waste. *Bioresource technology*, *99*(4), 882-888
21. Muradin, M., & Foltynowicz, Z. (2014). Potential for producing biogas from agricultural waste in rural plants in Poland. *Sustainability*, *6*(8), 5065-5074
22. Nopharatana, A., Pullammanappallil, P. C., & Clarke, W. P. (2007). Kinetics and dynamic modelling of batch anaerobic digestion of municipal solid waste in a stirred reactor. *Waste management*, *27*(5), 595-603
23. Ofoefule, A. U., Nwankwo, J. I., & Ibeto, C. N. (2010). Biogas Production from Paper Waste and its blend with Cow dung.
24. Osman, G. A., El-Tinay, A. H., & Mohamed, E. F. (2006). Biogas production from agricultural wastes. *Journal of Food Technology*, *4*(1), 37-39

25. Paepatung, N., Nopharatana, A., & Songkasiri, W. (2009). Bio-methane potential of biological solid materials and agricultural wastes. *Asian Journal on Energy and Environment*, *10*(1), 19-27

26. Pryshliak, N., & Tokarchuk, D. (2020). Socio-economic and environmental benefits of biofuel production development from agricultural waste in Ukraine. *Environmental & Socio-economic Studies*, *8*(1), 18-27

27. Rubindamayugi, M. S., Mshandete, A. M., Björnsson, L., Kivaisi, A. K., & Mattiasson, B. (2006). Effect of Particle Size on Biogas Yield from Sisal Fibre Waste.

28. Tiseo, I. (2018). Global Municipal Solid Waste Generation Projection 2016–2050.

29. Udelhoven, T., Delfosse, P., Bossung, C., Ronellenfitsch, F., Mayer, F., Schlerf, M., ... & Hoffmann, L. (2013). Retrieving the bioenergy potential from maize crops using hyperspectral remote sensing. *Remote Sensing*, *5*(1), 254-273

30. Yevich, R., & Logan, J. A. (2003). An assessment of biofuel use and burning of agricultural waste in the developing world. *Global biogeochemical cycles*, *17*(4).

31. Zheng, Y. H., Wei, J. G., Li, J., Feng, S. F., Li, Z. F., Jiang, G. M., ... & Ning, T. Y. (2012). Anaerobic fermentation technology increases biomass energy use efficiency in crop residue utilization and biogas production. *Renewable and Sustainable Energy Reviews*, *16*(7), 4588-4596