JURNAL TEKNIK MESIN (JOURNAL OF MECHANICAL ENGINEERING)

VOL. 15, NO. 01, February 2026
https://publikasi.mercubuana.ac.id/index.php/jtm/index
DOI :10.22441/jtm.v15i1.37434

Comparative Review of Various Organic Wastes Derived from Animals and Plants in Anaerobic Digestion for Biogas Production

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Abstract--*Increased production of organic waste from the livestock, agriculture, urban, and agro-industrial sectors poses significant environmental challenges if not managed properly. Anaerobic digestion (AD) is an effective technology for processing organic waste while producing renewable energy in the form of biogas. However, the performance of the AD process is strongly influenced by substrate characteristics, including the carbon-to-nitrogen (C/N) ratio, lignocellulose content, nitrogen content, and substrate chemical conditions. This article provides a comparative review of various animal and plant-based organic waste types used in biogas production via AD, with an emphasis on methane potential, operational constraints, and process optimization strategies. The method used is a narrative literature review of national and international journal articles discussing the utilization of livestock manure (cattle, chicken, pigs, and goats), food waste, lignocellulosic biomass (rice straw, water hyacinth, and grass), and agro-industrial liquid waste (tofu liquid waste and Palm Oil Mill Effluent/POME). The results of the study show that cow manure has good process stability but relatively moderate methane yield.*
In contrast, chicken and pig manure have higher methane potential but are susceptible to ammonia inhibition. Plant-based and agro-industrial waste generally has high energy potential but faces challenges such as slow hydrolysis, acidic pH, and nutrient imbalance. Based on the study's results, anaerobic co-digestion (ACoD) has been proven to be the most effective strategy for optimizing biogas production. This approach can balance the C/N ratio, increase buffer capacity, reduce inhibitory effects, and improve microbiological stability. The combination of substrates that produces a mixed C/N ratio in the optimal range of 20–30 has been consistently reported to increase methane yield and AD process stability. Thus, substrate selection and formulation through co-digestion are key to developing an efficient and sustainable biogas system.

Article History:
Received: December 27, 2025
Revised: January 07, 2026
Accepted: January 22, 2026
Published: January 28, 2026

Keywords: *Anaerobic digestion, biogas, organic waste, livestock manure, anaerobic co-digestion*

1. INTRODUCTION

The increase in global energy demand, coupled with declining fossil fuel availability and growing environmental pressures, has led to greater attention being paid to the development of renewable energy sources. In this context, biogas produced through anaerobic digestion (AD) has become a relevant technology because it can convert organic waste into an energy source while reducing environmental pollution [1]. Various types of organic waste originating from anthropogenic activities, particularly in the agricultural and livestock sectors, have been identified as potential substrates in biogas production. Animal-based waste, such as livestock manure and residues from the animal product processing industry, generally has easily degradable organic content and a nutrient ratio that supports methane formation. In contrast, plant-based waste, including agricultural residues and lignocellulosic biomass, is available in large quantities and contributes significantly to the supply of raw materials. However, its complex structure often limits biodegradation during the AD process.

The physicochemical characteristics of the substrate strongly influence the performance of anaerobic digestion. Parameters such as the carbon-to-nitrogen (C/N) ratio, lignin content, carbohydrate composition, moisture content, and the presence of inhibitory compounds play an important role in determining process stability, organic matter degradation efficiency, and biogas yield. The differences in characteristics between animal and plant waste require a comprehensive evaluation approach to optimize their utilization in biogas production systems [2].

Therefore, this article presents a comparative review of various types of organic waste derived from animals and plants for biogas production via anaerobic digestion. The discussion focuses on comparing substrate characteristics, methane production potential, the advantages and limitations of each waste type, and their implications for the development of efficient and sustainable biogas technology.

2. METHODOLOGY

The method used in this article is a narrative literature review. The literature search process was conducted through international scientific databases, namely Scopus, ScienceDirect, SpringerLink, and Google Scholar. The keywords used in the search included anaerobic digestion, biogas production, livestock waste, organic waste, household waste, plantation and agro-industrial waste, and co-digestion.

The criteria for including literature in this study included:

a) Reputable national and international journal articles.
b) Research discussing the anaerobic digestion process with livestock manure as the main substrate, and also waste from plants.
c) Articles reporting the characteristics of livestock manure and waste from plants, biogas or methane performance, and challenges in the anaerobic digestion process.

Meanwhile, the exclusion criteria include articles that are not relevant to biogas production or do not clearly explain the type of substrate used. The selected literature was then analyzed and grouped by type of livestock manure and plant waste, as well as the main issues affecting the performance of the anaerobic digestion process.

3. RESULT AND DISCUSSION

3.1 Variability of Organic Waste and Its Impact on Anaerobic Digestion Performance

Based on a literature review, organic waste for anaerobic digestion (AD) can be classified into animal- and plant-derived waste. These two groups exhibit very different physicochemical characteristics, which directly impact biogas production performance.

Various journals state that anaerobic digestion (AD) cannot be separated from the characteristics of the substrate used. Kadam et al. (MDPI) state that differences in chemical composition, C/N ratio, lignocellulose content, and nitrogen content are the main factors causing significant variations in biogas production between waste types [3]. In general, organic waste can be categorized as shown in Table 1.

Table 1. Classification of Biogas Production Waste Types

Waste Category	Waste Type
Animal	Cow, goat, chicken, and pig manure
Plant	Food waste, straw, water hyacinth, grass, and agro-industrial waste
Mixed	Mixed animal and plant waste

Song et al. (MDPI) emphasize that there is no single substrate that is optimal for all AD operating conditions, underscoring the need for a comparative and integrative approach in the development of modern biogas systems [4].

3.2 Animal-Based Organic Waste

A. Cow Manure

Cow manure is the most commonly used substrate in biogas systems. This is due to its main advantage: high process stability. As noted by Song et al. (MDPI), cow manure has a relatively neutral pH and contains abundant natural anaerobic microorganisms, thereby enabling stable anaerobic digestion. However, cow manure also has limitations, particularly its high lignocellulose fraction. As a result, the hydrolysis stage proceeds more slowly and ultimately reduces the methane yield produced [4].

In addition to substrate composition factors, reactor operating conditions also significantly affect biogas performance. Ahlberg-Eliasson et al. reported that in continuous reactors, increasing the operating temperature from 38–40°C to 52°C can increase the rate of methanogenesis. However, this increase in temperature also increased the residual methane potential (RMP) of the digestate to 40–98 NmL CH_4/g VS. Thus, these conditions may increase greenhouse gas emissions after digestion is complete [2].

To overcome these limitations, various studies have developed co-digestion approaches. Several local studies have shown that cow manure is highly effective as a base substrate in co-digestion with tofu liquid waste, elephant grass, and fruit and vegetable waste. This is because cow manure serves as both an inoculum source and a pH buffer, thereby increasing the stability of the anaerobic digestion process [5].

The selection of cow manure as a raw Material for biogas is based on its abundant availability, high organic content, and the presence of naturally occurring methanogenic microorganisms that support biogas formation. Based on Research by Iqbal Nur Daiyan et al., the fermentation results show that biogas quality is strongly influenced by fermentation time, with optimal conditions achieved on the 25th day, with a methane content of 71.18% and carbon dioxide of 8.53%. Although cow manure can produce biogas with a relatively high methane content, the significant CO_2 content reduces the biogas's calorific value and may cause corrosion problems in equipment, requiring further purification [6].

Furthermore, regarding biogas quality, M. Syaiful et al. reported that methane production from cow manure ranged from ±59% CH_4. However, when cow manure is combined with other organic waste, the biogas produced can reach around 64% CH_4. Therefore, co-digestion with cow manure not only improves process stability but also enhances the quality and efficiency of biogas production [7]. Cow manure is one of the most commonly used substrates in biogas production. Therefore, Table 2 summarizes the main aspects of its characteristics, advantages, limitations, and potential to enhance methane production, as presented below.

Table 2. Discussion of Cow Manure as a Biogas Substrate

Aspect	Discussion
Main role	The most common base substrate in biogas systems
Characteristics	Relatively neutral pH and rich in anaerobic microorganisms
Advantages	Stable digestion process without major pH adjustments
Limitations	High lignocellulose content
Impact of limitations	Slow hydrolysis and relatively low methane yield
Role in other systems	Functions as an inoculum and a pH buffer
Potential for improvement	Co-digestion can increase CH_4 by ±64%
Methane production	±59% CH_4 in mono-digestion

B. Chicken and Pig Manure

Chicken manure and pig manure have relatively high nitrogen and protein content, so theoretically, they have the potential to produce more methane than cow manure. However, this high nitrogen content also poses a risk of ammonia inhibition. Song et al. (MDPI) state that substrates with high nitrogen content are highly susceptible to ammonia inhibition, especially when the concentration of free ammonia (NH_3) exceeds the tolerance threshold of acetoclastic methanogenic microorganisms, which play an important role in methane formation [4].

However, several studies show that pig manure has a high potential for biogas production. Maluegha et al. reported that pig manure can produce 0.040–0.059 m³/kg of biogas, which is even higher than cow manure. Furthermore, this study's results show that a pig farm with 35 pigs can produce around 4.76 m³ of biogas per day, equivalent to the LPG energy needs of a household [8].

Meanwhile, chicken manure exhibits different characteristics. Yu et al. reported that chicken manure has a very low carbon-to-nitrogen (C/N) ratio of approximately 5–10, which often results in an unstable mono-digestion process, however, when chicken manure is combined with plant biomass, such as corn stover, methane production increases by 36–39%, with yields reaching 318–333 mL CH_4/g VS in both batch and continuous systems [9].

In line with these findings, Research conducted by Afdol Gani and Jelita shows that mixing chicken manure with rice straw to achieve an ideal C/N ratio of around 30 can produce up to 617,887 m³ of biogas with a methane content of 81.83% under thermophilic conditions. Therefore, these results confirm that chicken manure is more effective when used in a co-digestion system than as a single substrate [10].

In addition to the C/N ratio, operating temperature also plays an important role in the occurrence of ammonia inhibition. Wang et al. reported that at C/N ratios of 15 and 35 °C, ammonia inhibition began at 35 °C, whereas at 55 °C, inhibition occurred at a C/N ratio of 20. Conversely, the highest methane yield was obtained at a C/N ratio of 25–30, with a 30–45% increase in production compared to conditions with lower C/N ratios [11], [12].

Based on Febrianti et al. and supporting literature referenced in the journal, goat manure has a C/N ratio of around 24 and functions as a source of carbon and microorganisms. On the other hand, chicken manure has a low C/N ratio of approximately 6.6. It is rich in nitrogen, which can increase microbial activity but can also cause inhibition if used excessively. Meanwhile, vegetable waste has a high C/N ratio of approximately 37.6, which helps balance nutrient levels and increases the availability of easily degradable organic matter [13].

3.3 Organic Waste Based on Food Waste, Plantations, Crops, and Agroindustry

A. Food Waste

Food waste is one of the biogas substrates with the highest energy potential. This is due to its easily degradable organic content and high volatile solids (VS) fraction. Lee et al. state that food waste has rapid biodegradability and a high VS content, so that, at an optimal mixing ratio with manure, it can produce more than 450 mL CH_4/g VS under mesophilic conditions [12].

However, the application of mono-digestion to food waste often causes operational problems. Lee et al. reported that mono-digestion of food waste can result in volatile fatty acid (VFA) concentrations exceeding 4 g/L and a pH below 6.5, ultimately leading to process failure if not optimally controlled. Therefore, the researchers emphasized the importance of co-digesting livestock manure to increase buffer capacity and maintain the stability of the anaerobic digestion process [12].

In addition to controlled conditions, food waste also shows good potential in small-scale systems. Dhungana et al. reported that, even at relatively low ambient temperatures (10–21 °C), food waste mixed with poultry litter and goat manure still produced methane steadily. These findings indicate that food waste has great potential for application in household biogas systems, especially in developing countries [3].

In terms of composition, food waste is reported to have the highest methane potential because it contains easily degradable carbohydrates, proteins, and lipids. Ayantokun et al. state that food waste has a volatile solids content of 70–90% (dry basis), so that globally it has the potential to contribute to large amounts of methane production if managed properly [14]. However, the study also confirmed that mono-digestion of food waste often results in a decrease in pH due to VFA accumulation, methanogenesis inhibition, and limitations on the operational organic loading rate (OLR). Thus, food waste is considered more effective when used as a co-substrate together with animal-based waste, which has a high buffer capacity [14].

Furthermore, anaerobic degradation of mixed organic waste has also been widely applied in landfill systems. Dayaningrat et al. stated that urban organic waste degraded anaerobically in landfills can produce biogas with a high methane content, reaching 72–86% CH_4, thereby meeting biogas quality standards for energy utilization [15]. Specifically, Research at the Talang Gulo landfill in Jambi shows that organic waste produces biogas with a maximum methane content of 86% CH_4. This confirms that well-managed mixed organic waste can produce high-quality biogas [15].

In line with this, Syaiful et al. stated that market organic waste, particularly fruits and vegetables, is an abundant and sustainable raw Material for biogas production. In the IRRC-WTE Jambi system, market organic waste produces biogas with a CH□ content of 64–69%, averaging 66%, suitable for use as an energy source [7].

In addition to market waste, household organic waste, especially food waste, also has significant potential. Saraswati and Rosyidah stated that household waste can produce biogas with a methane content of 55–65%, making it suitable as an alternative household fuel [16]. Furthermore, Damayanti et al. emphasize that organic waste, such as vegetable scraps, fruit, leaves, and kitchen waste, is an easily degradable and abundant source of biogas feedstock in both urban and rural areas. The biogas produced generally contains 55–65% CH_4 and has a calorific value of 20–25 MJ/m³, making it suitable for cooking, lighting, and small-scale power generation [17].

B. Plantation, Crop, and Agro-industrial Waste

In the group of plant waste or lignocellulosic biomass, such as rice straw, stover, and aquatic plants, the main challenge in the anaerobic digestion process lies in the hydrolysis stage. This is due to the complex structure of lignocellulose, which consists of cellulose, hemicellulose, and lignin, which are difficult to break down by anaerobic microorganisms. Therefore, many studies have applied biological, enzymatic, or microbial pretreatments to break down the lignocellulose structure, thereby increasing the fraction of easily degradable organic Material and improving methane yield. For example, in a co-digestion system of rice straw and pig manure, the application of cellulolytic microflora pretreatment has been reported to increase methane production [14] significantly.

Meanwhile, agroindustrial liquid waste, such as tofu liquid waste, typically has a high organic content, enabling it to produce biogas quickly. However, this substrate often faces problems such as low pH and nutrient imbalance, which can inhibit methanogenesis. Therefore, mixing tofu wastewater with livestock manure is widely practiced to balance pH, provide inoculum, and increase process stability and methane content in biogas [18].

Quantitatively, tofu wastewater is a highly promising raw Material for biogas production. Adeputra et al. reported that soybean curd wastewater has a COD of 11,105 mg/L, a BOD of 5,652 mg/L, a total nitrogen of 268 mg/L, and a pH of approximately 3.6. These characteristics indicate high energy potential, but also emphasize the need for good process control to prevent methanogen inhibition [19].

In line with this, an article in Applied Sciences reviews the use of industrial liquid organic waste as a raw Material for biogas production via anaerobic digestion (AD), with an emphasis on substrate characteristics such as COD, pH, and VS/TS ratio. The authors state that although industrial liquid feedstock has high energy potential, this substrate is generally sensitive to nutrient and pH imbalances. Hence, it is rarely optimal to process as monodigestion without adequate system engineering [20]. Furthermore, the author emphasizes that the three main parameters that most determine the success of AD are organic load (COD/VS), initial substrate pH, and nutrient ratio (C/N). Thus, feedstock selection cannot be based solely on high COD; it must also consider the substrate's overall chemical stability [20].

In addition to terrestrial plant waste, aquatic plant biomass, such as water hyacinth (Eichhornia crassipes), has potential as a raw Material for biogas. A study by Gachara et al. reported that water hyacinth produces biogas with a methane content of 49–53%. Interestingly, after undergoing purification (upgrading), the methane content can increase to 70–76%, potentially enabling higher electrical power generation. Thus, water hyacinth not only serves as a renewable energy source but also contributes to environmental control due to its invasive nature. However, biomass characteristics can vary depending on location and plant age [1], [21].

In general, plant biomass such as rice straw, leaf litter, elephant grass, and water hyacinth is limited by its high lignin content. However, co-digestion and pretreatment approaches have proven to be effective. For example, a study of co-digestion of rice straw with pig manure showed that biological pretreatment increased methane production by up to 45% while shortening the lag phase of methanogenesis [12].

In this context, cow manure is often used as a supporting substrate. Fairuz et al. state that cow manure plays an important role because it contains natural anaerobic microorganisms, has a relatively high buffer capacity, and is commonly used in small- to medium-scale biogas systems. Laboratory analysis results indicate that cow manure has a C/N ratio of 26.5, within the ideal range for anaerobic fermentation (20–30). However, this C/N ratio value can change significantly when cow manure is combined with other substrates [22].

In addition to tofu waste, Palm Oil Mill Effluent (POME) is among the largest agro-industrial wastes in Southeast Asia and has significant potential as a biogas substrate. Chang et al. reported that POME has a COD of up to 108,663 mg/L, a VS/TS ratio of 0.80–0.82, and a pH of around 4.6. These characteristics indicate very high energy potential but also the risk of process instability if POME is used for mono-digestion without adequate pH and nutrient control [23].

3.4 Anaerobic Co-Digestion sebagai Strategi Optimal

Kadam et al. and Song et al. consistently state that anaerobic co-digestion (ACoD) is the most effective strategy for improving anaerobic digestion performance. This is due to its ability to balance the carbon-to-nitrogen (C/N) ratio, increase the system's buffer capacity, dilute inhibitor compounds, and improve the stability of the reactor's microbiological community [3], [4].

In line with this, Baek et al. showed that ternary co-digestion not only increases methane yield but also provides greater operational flexibility. In other words, this system maintains high methane potential even when applied to various substrate mixing ratios [4], [24].

In the context of lignocellulosic biomass, Zhong et al. stated that rice straw has a high C/N ratio and a complex lignocellulosic structure, making it difficult to degrade naturally. However, by co-digesting rice straw with pig manure and applying biological pretreatment with cellulolytic microflora, methane production can be significantly increased. The results of this study show that methane yield reached 342.35 mL CH_4/g VS, which is about 45% higher than the system without pretreatment [25].

In addition, various local studies report that cow manure is highly effective as a base substrate in co-digestion systems with tofu liquid waste, elephant grass, and fruit and vegetable waste. This is because cow manure serves as a natural inoculum source and pH buffer, thereby improving the stability of the anaerobic digestion process [5], [26].

Furthermore, Baek et al. reported that co-digestion of cattle manure, food waste, and pig manure can reduce antagonistic effects among substrates. This is indicated by a synergy index value ranging from 0.89 to 1.22, with an optimum composition of 47% cow manure (CM), 6% food waste (FW), and 47% pig manure (PM) based on total solids (TS) [4], [24]. On the other hand, several journals also state that livestock manure is very effective when used as a co-substrate for liquid waste and agricultural waste. For example, in Research related to liquid tofu waste, cow manure acts as a starter that can accelerate the initial fermentation stage while stabilizing the pH during the anaerobic digestion process [19].

Thus, combining various types of livestock manure and organic waste, such as goat manure, chicken manure, and vegetable waste, produces a mixed C/N ratio close to the optimum range of 20–30. This condition is consistently reported as ideal for improving process stability and biogas production efficiency in anaerobic co-digestion systems [13]. Various substrates can be used for biogas production, each with distinct characteristics that Influence digestion and methane yield. Therefore, Table 3 presents the main characteristics of commonly used substrates for biogas production.

Table 3. Main Characteristics of Substrates for Biogas Production

Substrate	Key Characteristics
Cow manure	Relatively neutral pH, near-ideal C/N ratio, high anaerobic microbes
Chicken manure	High nitrogen and protein content, low C/N ratio
Pig manure	High biogas potential, high protein
Goat manure	C/N ratio around 24, source of carbon and microorganisms
Food waste	High VS, easily degradable, very high methane potential
Organic waste	Easily decomposable and abundantly available
Lignocellulosic biomass	High lignin content, high C/N, abundant and invasive aquatic plant
Water hyacinth	biomass
Tofu wastewater	High COD and BOD, acidic pH
POME	Very high COD, high VS/TS, acidic pH

4. CONCLUSION

Based on the literature review, it can be concluded that substrate characteristics are a key factor in determining the performance of anaerobic digestion processes for biogas production. Animal-based waste, especially cow manure, exhibits good process stability due to its relatively neutral pH, high abundance of natural anaerobic microorganisms, and a C/N ratio close to the ideal range. However, the limitation of cow manure lies in its relatively high lignocellulose content, which results in moderate methane yield.

In contrast, chicken and pig manures have a higher potential for methane production due to their high nitrogen and protein content. However, they are highly susceptible to ammonia inhibition when used as a single substrate. Plant-based and agro-industrial organic waste, such as food waste, rice straw, water hyacinth, tofu liquid waste, and POME, also has high energy potential but generally faces challenges due to slow hydrolysis, acidic pH, or nutrient imbalance.

Therefore, anaerobic co-digestion (ACoD) has proven to be the most effective strategy for optimizing biogas production. This approach can balance the C/N ratio, increase the system's buffer capacity, reduce inhibition effects, and improve the reactor's microbiological stability. The combination of animal- and plant-based substrates that produce a mixed C/N ratio in the optimum range (20–30) has been consistently reported to increase methane yield and process stability. Thus, selecting and formulating appropriate substrates through co-digestion is key to the successful development of an efficient and sustainable biogas system.

REFERENCES

[1] R. Kadam, S. Jo, J. Lee, K. Khanthong, H. Jang, and J. Park, "A Review on the Anaerobic Co-Digestion of Livestock Manures in the Context of Sustainable Waste Management," *Energies*, vol. 17, no. 3, 2024, doi: 10.3390/en17030546.

[2] K. Ahlberg-Eliasson, M. Westerholm, S. Isaksson, and A. Schnürer, "Anaerobic Digestion of Animal Manure and Influence of Organic Loading Rate and Temperature on Process Performance, Microbiology, and Methane Emission From Digestates," 2021. doi: 10.3389/fenrg.2021.740314.

[3] S. P. P. Lohani, B. Dhungana, and M. Marsolek, "Anaerobic Co-Digestion of Food Waste with Livestock Manure: A Biogas Based Circular Economy and Sustainable Development Goals," 2021. doi: 10.2139/ssrn.3919710.

[4] Y. Song, W. Qiao, M. Westerholm, G. Huang, M. J. Taherzadeh, and R. Dong, "Microbiological and Technological Insights on Anaerobic Digestion of Animal Manure: A Review," *Fermentation*, vol. 9, no. 5, pp. 1–22, 2023, doi: 10.3390/fermentation9050436.

[5] E. Mardawati, M. Z. Al Faruqy, and M. F. Wiyatna, "Produksi Biogas Co-digestion dari Kotoran Sapi, Limbah Buah Sayuran, dan Serasah Daun di Universitas Padjadjaran," *Biomass, Biorefinery, and Bioeconomy*, vol. 2, no. 2, pp. 151–160, 2024.

[6] I. N. Daiyan, L. Kalsum, and Y. Bow, "Capturing CO2 from Biogas by MEA (Monoethanolamine) using Packed Bed Scrubber," *J. Tek. Kim. dan Lingkung.*, vol. 4, no. 2, pp. 105–112, 2020, doi: 10.33795/jtkl.v4i2.157.

[7] M. Syaiful, Rusdianasari, L. Kalsum, E. Adriansyah, and Santoso, "Analysis Of Biogas Methane Quality At IRRC-WTE (Integrated Resource Recovery Center For Waste Treatment Energy) Jambi," *Lume*, vol. 10, no. 05, p. 5, 2021, [Online]. Available: www.ijstr.org

[8] B. L. Maluegha, T. V. Y. Ulaan, and M. K. Umboh, "PERANCANGAN DIGESTER UNTUK MENGHASILKAN BIOGAS DARI KOTORAN TERNAK BABI DI DESA RUMOONG BAWAH KABUPATEN MINAHASA SELATAN," vol. 8, no. 2, pp. 167–174, 2020.

[9] X. Yu *et al.*, "Synergistic Effects of Anaerobic Co-Digestion of Chicken Manure and Corn Stover in Batch and Continuous Modes," *Fermentation*, vol. 9, no. 7, 2023, doi: 10.3390/fermentation9070666.

[10] M. A. GANI and M. JELITA, "POTENSI BIOGAS DARI CAMPURAN JERAMI PADI DAN KOTORAN AYAM PADA SUHU MESOFILIK DAN TERMOFILIK DENGAN RASIO C/N IDEAL M," vol. 8, no. 2, pp. 305–318, 2025.

[11] X. Wang, X. Lu, F. Li, and G. Yang, "Effects of temperature and Carbon-Nitrogen (C/N) ratio on the performance of anaerobic co-digestion of dairy manure, chicken manure and rice straw: Focusing on ammonia inhibition," *PLoS One*, vol. 9, no. 5, pp. 1–7, 2014, doi: 10.1371/journal.pone.0097265.

[12] W. Lee, Y. Kim, H. Kim, and M. Kim, "Comparison of Anaerobic Co-Digestion of Food Waste and Livestock Manure at Various Mixing Ratios under Mesophilic and Thermophilic Temperatures.pdf," *Sustainability*, 2024.

[13] Popi Febrianti, Nadiareta Sitorus, Desniorita Desniorita, and Miftahurrahmah Miftahurrahmah, "Pembuatan Biodigester Type Batch Skala 120 Liter untuk menghasilkan Biogas dari Campuran Bahan Baku Kotoran Kambing, Kotoran Ayam dan Limbah Sayur," *J. Sains dan Teknol.*, vol. 3, no. 2, pp. 111–122, 2024, doi: 10.58169/saintek.v3i2.676.

[14] A. S. Ayantokun, T. S. Matambo, C. Rashama, I. Van der Merwe, and J. A. Van Niekerk, "A critical review of food waste and poultry manure anaerobic co-digestion: an eco-friendly valorization for sustainable waste management and biogas production," 2025. doi: 10.3389/fsufs.2025.1695945.

[15] Dayaningrat, Rusdianasari, L. Kalsum, E. Adriansyah, and Santoso, "Analysis Of Biogas Methane (CH 4) Quality At Landfill Talang Gulo Jambi," no. 06, pp. 16–18, 2021.

[16] M. K. Saraswati and E. Rosyidah, "Pemanfaatan Limbah Organik Rumah Tangga sebagai Bahan Baku Pembuatan Biogas Ramah Lingkungan," *Jurna Tek. dan Teknol. Indones.*, vol. 2, no. 1, pp. 35–40, 2024.

[17] A. A. Damayanti, Z. N. Fuadina, N. N. Azizah, Y. Karinta, and I. K. Mahardika, "Pemanfaatan Sampah Organik Dalam Pembuatan Biogas Sebagai Sumber Energi Kebutuhan Hidup Sehari-Hari," *Eksergi*, vol. 17, no. 3, p. 182, 2021, doi: 10.32497/eksergi.v17i03.2803.

[18] Y. Sudarto, S. Salundik, and M. S. Soenarno, "Biogas Production from Tofu Liquid Waste with

Cow Manure Mixture," *J. Tek. Pertan. Lampung (Journal Agric. Eng.*, vol. 12, no. 1, p. 82, 2023, doi: 10.23960/jtep-l.v12i1.82-95.

[19] A. Adeputra, L. Kalsum, and A. Hasan, "CO2 and H2S Absorption in Tofu Liquid Waste Biogas using Packed Bed Scrubber with Variation of MEA Concentration and Flow Rate," *Int. J. Res. Vocat. Stud.*, vol. 3, no. 2, pp. 23–28, 2023, doi: 10.53893/ijrvocas.v3i2.204.

[20] W. Tomczak, M. Daniluk, and A. Kujawska, "Food Waste as Feedstock for Anaerobic Mono-Digestion Process," *Appl. Sci.*, vol. 14, no. 22, pp. 1–24, 2024, doi: 10.3390/app142210593.

[21] A. Yonathan, A. R. Prasetya, and B. Pramudono, "Biogas production from water hyacinth (Eichhornia crassipes): Consistency and pH study of the produced biogas," *J. Teknol. Kim. dan Ind.*, vol. 1, no. 1, pp. 412–416, 2012, [Online]. Available: http://ejournal-s1.undip.ac.id/index.php/jtkiTelp/Fax:

[22] A. Fairuz, A. Haryanto, and A. Tusi, "PENGARUH PENAMBAHAN AMPAS KELAPA DAN KULIT PISANG TERHADAP PRODUKSI BIOGAS DARI KOTORAN SAPI," *J. Tek. Pertan. Lampung*, vol. 4, no. 2, pp. 91–98, 2015.

[23] P. Y. Chang, Y. J. Chan, S. K. Arumugasamy, Y. K. Wan, and J. W. Lim, "Optimisation of anaerobic digestion of palm oil mill effluent with biochar addition: Synergistic application of Artificial neural network and response Surface Methodology," *Fuel*, vol. 398, no. June 2024, p. 135514, 2025, doi: 10.1016/j.fuel.2025.135514.

[24] G. Baek, D. Kim, J. Kim, H. Kim, and C. Lee, "Treatment of cattle manure by anaerobic co-digestion with food waste and pig manure: Methane yield and synergistic effect," *Int. J. Environ. Res. Public Health*, vol. 17, no. 13, pp. 1–13, 2020, doi: 10.3390/ijerph17134737.

[25] B. Zhong, X. An, F. Shen, W. An, and Q. Zhang, "Anaerobic Co-digestion of Rice Straw and Pig Manure Pretreated With a Cellulolytic Microflora: Methane Yield Evaluation and Kinetics Analysis," 2021. doi: 10.3389/fbioe.2020.579405.

[26] C. Afrian, A. Haryanto, U. Hasanudin, and I. Zulkarnain, "PRODUKSI BIOGAS DARI CAMPURAN KOTORAN SAPI DENGAN RUMPUT GAJAH (Pennisetum purpureum) [PRODUCTION OF BIOGAS FROM A MIXTURE OF COWDUNG AND ELEPHANT GRASS (Pennisetum purpureum)]," *J. Tek. Pertan. Lampung*, vol. 6, no. 1, pp. 23–30, 2017.