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Sustainable Neighborhood Waste Management: Hybrid Digestion Approaches for Organic Waste Processing

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ABSTRACT

Effective waste management is crucial for urban sustainability and environmental conservation. This study evaluates the efficiency and quality of compost produced through normal and thermophilic in-vessel composting and anaerobic digestion within a neighborhood waste management model. By analyzing physicochemical properties, process temperatures, carbon to nitrogen ratios, germination index, and biogas production rates, the study highlights the advantages of integrating these methods. Results indicate that thermophilic in-vessel composting accelerates the composting process, achieving rapid temperature increases and enhanced microbial activity. Anaerobic digestion complements this by producing biogas and yielding high-quality compost with low phytotoxicity. The combined approach not only optimizes compost production and quality but also contributes to renewable energy generation and reduced greenhouse gas emissions. These findings provide a framework for implementing sustainable, localized waste management systems, offering significant insights for policy and operational decisions in municipal waste management.

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1. Introduction

Effective waste management is critical for environmental sustainability and urban efficiency. Composting stands out as a particularly viable option among the various methods available for processing organic waste. Composting can be conducted through two primary methods: in-vessel and open aeration. Studies have shown that in-vessel composting not only yields higher-quality compost but also significantly reduces processing time, particularly when utilizing thermophilic conditions [1-3].

The contemporary world is grappling with an energy crisis and escalating greenhouse gas (GHG) emissions. According to the International Energy Agency [4], approximately 78% of the global energy supply comes

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from oil, coal, and natural gas, while around 62% of electricity generation is still reliant on non-renewable sources. Transitioning to renewable energy sources is crucial to mitigate these issues and reduce GHG emissions [5-6]. Municipal solid waste (MSW) management plays a vital role in this context. Optimizing economic costs and minimizing GHG emissions are essential goals in MSW management [7]. For instance, optimizing transportation routes can reduce GHG emissions by approximately 47.43% [7].

Implementing in-situ processing of the organic fraction of MSW (OFMSW), such as in-vessel composting reactors, is increasingly necessary for both economic and environmental reasons [2]. These reactors are often installed in various neighborhoods, transforming waste management from a large-scale urban model to a more localized neighborhood approach [8].

Neighborhood-based waste management systems offer several advantages. By processing waste closer to its source, transportation costs, and related emissions are significantly reduced. Additionally, localized systems can be tailored to the specific needs and capacities of individual communities, enhancing overall efficiency and engagement. This decentralized approach also promotes community responsibility and awareness regarding waste management practices.

Furthermore, the integration of anaerobic digestion with composting processes presents a promising avenue for improving waste management outcomes. Anaerobic digestion not only reduces the volume of waste but also produces biogas, a valuable source of renewable energy. This biogas can be harnessed to generate electricity or heat, further contributing to the reduction of reliance on fossil fuels and decreasing the carbon footprint of waste management operations [9].

The quality of compost produced through different methods is critical for determining the best approach to organic waste management. Thermophilic in-vessel composting, for instance, accelerates the decomposition process through higher temperatures, resulting in faster stabilization of organic matter and the elimination of pathogens. This method is particularly effective in producing high-quality compost that is rich in nutrients and free from harmful microorganisms [2].

In contrast, anaerobic digestion primarily focuses on biogas production while also generating a digestate that can be further composted. The synergy between anaerobic digestion and subsequent composting can optimize the overall process, leading to better resource recovery and improved compost quality. The integration of these processes can be particularly beneficial in neighborhood waste management models, where space and resources might be limited, but the demand for efficient and sustainable waste processing solutions is high.

This study aims to compare the quality of compost produced from normal and thermophilic in-vessel composting pilot plants with compost generated from anaerobically digested organic compounds. This comparison highlights the benefits and efficiency of different composting methods within neighborhood waste management models. By focusing on localized waste management systems, this research contributes to the broader goals of reducing energy consumption, minimizing GHG emissions, and enhancing the overall sustainability of urban environments.

The outcomes of this research have the potential to inform policy and operational decisions in municipal waste management, providing a framework for the implementation of more sustainable and community-centric waste processing technologies. As cities continue to grow and the demand for effective waste management solutions increases, the findings of this study could play a crucial role in shaping the future of urban sustainability.

2. Material and method

Results from research conducted over the past decade have been compiled and analyzed to determine an appropriate reactor for processing the organic fraction of municipal solid waste (OFMSW) within a neighborhood waste management model.

2.1. Step 1: Bench-Scale Study

Previous research demonstrated that thermochemical pretreatment and thermophilic conditions could significantly reduce the duration of the composting process. Specifically, the average composting time for rice straw was reduced to 9 days under these conditions [3].

2.2. Step 2: Full-Scale In-Vessel Composting Pilot Plant (IVCP) Operation

Building on the findings from 2013 [3], a thermophilic in-vessel composting pilot plant was designed and constructed in 2020 (Figure 1). The IVCP comprises several components:

- In-vessel composter
- Screw mixer
- Bottom aeration system
- Leachate collection tank and recirculation system
- Hot water jacket
- Control panel

The composting process time was evaluated under both the thermophilic composting process (TCP) and the normal composting process (NCP). Approximately 500 kg of source-separated OFMSW was composted over 60 days under both TCP and NCP conditions by the pilot plant. The TCP condition was maintained using a hot water jacket around the IVCP, while the NCP was created by discontinuing the hot water flow. Parameters such as pH, electrical conductivity (EC), moisture content (MC), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), and germination index (GI) were measured based on standard methods [3].

2.3. Step 3: Full-Scale Garage Dry Anaerobic Digester (GDAD) Operation

In 2022, to investigate biogas production from urban organic waste and the effect of anaerobic digestion on accelerating the composting process, a garage dry anaerobic digester (GDAD) was constructed. This step utilized a GDAD with a capacity of approximately 3 cubic meters as a pilot plant (Figures 3 and 4). The pilot unit included:

- GDAD equipped with a hot water jacket
- Leachate collection tank and recirculation system
- Programmable logic controllers (PLC)
- Electrical heater
- Pressure valve
- Gas flowmeter
- Moisture removal column
- Gas flare

Cow manure was mixed with organic waste to optimize the carbon-nitrogen (C:N) ratio and alkalinity of the substrate [10]. Approximately 800 kg of OFMSW from the Tehran MSW processing center was used as the raw substrate. Additionally, 20 kg of cow manure mixed with 100 liters of water was added as an inoculant to the leachate collection tank. Biogas production was monitored over 30 days.

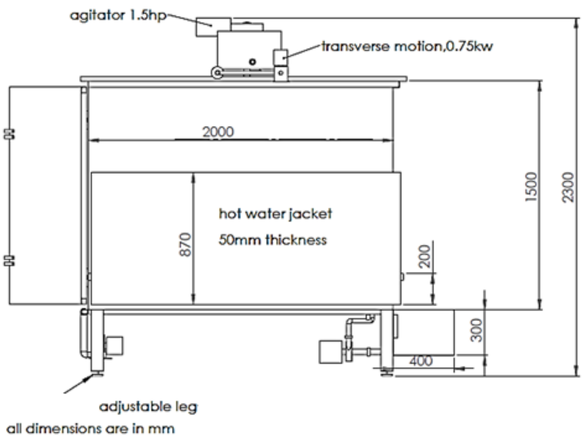

Figure 1. Dimension of In-vessel composting reactor.

Figure 2. In-vessel composting reactor pilot plant.

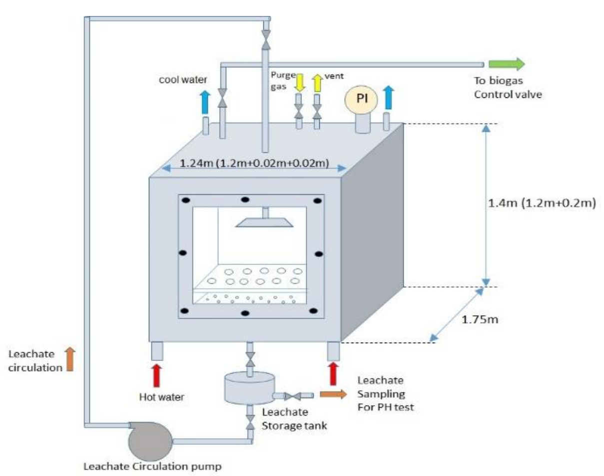

Figure 3. Garage Dry Anaerobic Digester used in this study.

Figure 4. The pilot plant used in this study.

After five days, biogas production began and was sufficient to ignite the flare, with the maximum production rate observed on the 14th day (Figure 5). At the end of the 30-day period, when biogas production ended, the digested organic matter was discharged from the reactor for compost production. The reactor door was left open for two days to minimize odor emissions, after which the digested materials were piled to a height of 80 cm for further composting. Parameters such as temperature, C:N ratio, and GI were monitored over a 45-day period.

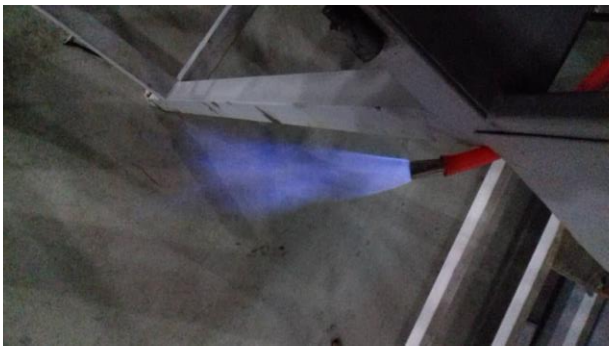

Figure 5. Biogas produced on the 14th day.

3. Results and discussion

3.1. Physiochemical properties of feedstock in step 2

The physicochemical properties of feedstock play a crucial role in determining the efficiency and effectiveness of the composting process. One of the most significant indicators is the carbon to nitrogen ratio (C:N), which is essential for evaluating the composting potential of organic materials [3]. A balanced C:N ratio ensures that the composting process proceeds efficiently, with optimal microbial activity and minimal emissions of greenhouse gases such as methane and ammonia.

As shown in Table 1, the initial C:N ratio for the OFMSW is remarkably high at 50.52. This elevated ratio indicates a carbon-rich feedstock, which can impede the composting process by slowing down the microbial activity necessary for organic matter decomposition. In contrast, cow manure has a much lower C:N ratio of 13.87, which is more conducive to composting as it provides a balanced nutrient profile that supports microbial growth and activity. Recent literature supports the importance of optimizing the C:N ratio. The ratio significantly influences the decomposition of organic waste during composting. Organisms maintain a specific C:N ratio at the tissue level, which is vital for determining the microbial decomposition pathways of organic matter. Carbon provides energy and serves as the fundamental building block of life, while nitrogen is essential for the formation of proteins, nucleic acids, and other cellular components. Therefore, a balanced supply of carbon-rich and nitrogenous materials is necessary for effective composting. The ideal C:N ratio for efficient composting ranges from 25–35:1. Excess carbon can slow down the decomposition process, whereas too much nitrogen can cause unpleasant odors. Regular turning of compost piles helps maintain the C:N ratio by releasing excess nitrogen in the form of ammonia [11].

Table 1.
Physiochemical properties of feedstocks in step2.

No	Parameters	OFMSW	Cow manure
1	MC (%)	82	63
2	TOC (%)	48	43
3	TKN (%)	0.95	3.1
4	C:N	50.52	13.87
5	pH	6.92	7.14
6	EC (μS/cm)	2542	1252

By mixing OFMSW with cow manure, the overall properties of the feedstock become more suitable for the composting process. This adjustment not only enhances the C:N ratio but also improves other critical parameters. For instance, the moisture content (MC) of OFMSW is 82%, which is higher than the 63% found in cow manure. A high moisture content can lead to anaerobic conditions, negatively impacting the composting process. By blending these materials, the moisture content can be balanced to create an optimal environment for aerobic decomposition. A study by Tang et al. [12] corroborates these findings, indicating that maintaining moisture content between 50-60% is crucial for effective aerobic composting. Excessive moisture can create anaerobic pockets, slowing down the composting process and potentially leading to the production of malodorous compounds.

The total organic carbon (TOC) content is 48% for OFMSW and 43% for cow manure. While both materials are rich in organic carbon, the presence of cow manure helps to moderate the overall carbon levels, making the substrate more favorable for composting microorganisms. The total Kjeldahl nitrogen (TKN) content also shows a significant difference, with OFMSW having 0.95% and cow manure having 3.1%. This difference further highlights the importance of blending these feedstocks to achieve a balanced nutrient profile that supports effective composting. This result aligns with findings by Yatoo et al. [13], who highlighted the necessity of a balanced TOC and TKN for microbial growth and efficient composting. They noted that integrating nutrient-rich materials like cow manure can significantly enhance compost quality by providing essential nutrients for microbial communities.

The pH values of the feedstocks are relatively close, with OFMSW at 6.92 and cow manure at 7.14, indicating that both materials are within the optimal range for composting. However, the electrical conductivity (EC) values differ significantly, with OFMSW having an EC of 2542 µS/cm and cow manure at 1252 µS/cm. High EC levels can indicate the presence of soluble salts, which can inhibit microbial activity if not properly managed. Mixing the two feedstocks can help to dilute these salts, reducing potential inhibitory effects and promoting a healthier composting process.

It can be concluded that the adjustment of the C:N ratio and other physiochemical properties through the combination of OFMSW and cow manure is essential for optimizing the composting process. This blend ensures a balanced nutrient supply, appropriate moisture content, and a conducive pH environment, all of which are critical for efficient microbial activity and effective composting. Such strategic management of feedstock properties is fundamental to improving compost quality and process efficiency, ultimately contributing to more sustainable waste management practices.

3.2. Comparison of changes in compost production index

This section compares key parameters across two distinct periods, including the process temperature, C:N ratio, and GI. The comparison aims to identify any significant changes or trends in these parameters over time, providing valuable insights into the dynamics of the process.

3.2.1. Temperature

Temperature is a critical parameter in the composting process as it influences the rate of microbial activity and the overall efficiency of organic matter decomposition. The temperature variations observed in the NCP, IVCP, and GDAD provide valuable insights into the effectiveness of each method. As depicted in Figure 6, the temperature in the IVCP increases more rapidly compared to NCP and GDAD. This rapid temperature rise in the IVCP indicates a more accelerated composting process. The thermophilic conditions maintained within the IVCP, coupled with effective agitation and adequate moisture content, create an optimal environment for thermophilic microorganisms. These microorganisms thrive at higher temperatures, leading to faster decomposition of organic wastes and a more efficient composting process.

The NCP, on the other hand, exhibits a slower temperature increase. This slower rise can be attributed to the lack of controlled conditions that are present in the IVCP. In open composting processes, such as NCP, temperature regulation is more challenging, leading to less consistent microbial activity and prolonged composting times.

GDAD, which operates under anaerobic conditions, shows a different temperature profile compared to both NCP and IVCP. The anaerobic digestion process does not rely on high temperatures to the same extent as aerobic composting. Instead, it focuses on biogas production through microbial activity in the absence of oxygen. The temperature in GDAD tends to stabilize at a moderate level, sufficient to support the anaerobic microbes responsible for breaking down organic matter. While GDAD may not achieve the high temperatures seen in IVCP, it effectively converts organic waste into biogas and digestate. The higher process rate in the IVCP can be attributed to the thermophilic conditions, which significantly enhance the microbial degradation of organic materials. The effective agitation and moisture control further support this accelerated decomposition. As a result, the IVCP can achieve complete composting more quickly than NCP and GDAD.

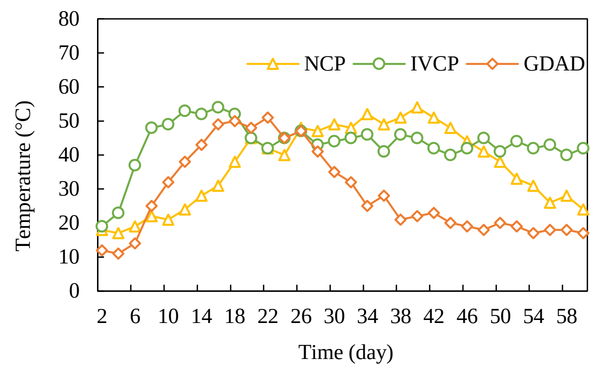

Figure 6. Variations in the temperature of NCP, IVCP and GDAD.

The temperature variations observed in the different composting methods highlight the superior efficiency of the IVCP in processing organic waste. The controlled thermophilic conditions in the IVCP lead to a faster and more effective composting process, producing high-quality compost in a shorter time frame. In contrast, the NCP and GDAD, while effective in their own right, do not achieve the same level of temperature control and process efficiency as the IVCP. These findings highlight the importance of temperature management in composting and the benefits of in-vessel systems for rapid and efficient organic waste processing.

3.2.2. C:N ratio

The C:N ratio is a key indicator in composting, reflecting the balance of carbon-rich and nitrogen-rich materials. While it is not an absolute measure of compost maturity, it is highly correlated with the rate of composting and the quality of the final product [3]. The changes in C:N ratio during composting can provide valuable insights into the effectiveness of different composting processes. As shown in Figure 7, the C:N ratio for the IVCP decreases more rapidly compared to the GDAD and the NCP. This rapid decline in the C:N ratio for IVCP indicates a faster decomposition of organic materials facilitated by the controlled thermophilic conditions and effective agitation within the reactor. These conditions enhance microbial activity, accelerating the breakdown of carbon-rich compounds and converting them into more stable forms.

In contrast, the GDAD shows a slower decrease in the C:N ratio initially, but it eventually reaches the lowest level after 26 days. This slower initial reduction can be attributed to the anaerobic conditions in GDAD, where the breakdown of organic matter is driven by different microbial communities compared to aerobic composting. However, once the anaerobic microbes become fully active, the process accelerates, resulting in a significant reduction in the C:N ratio.

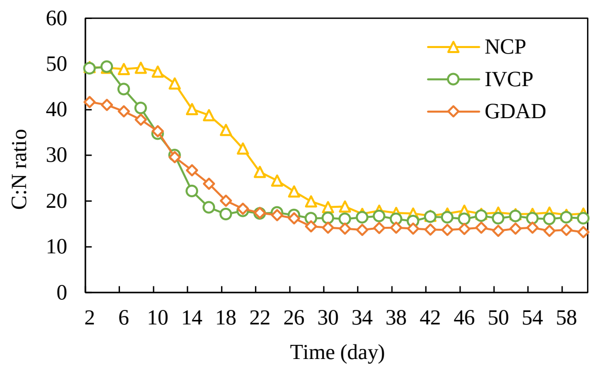

Figure 7. C:N ratio variation in NCP, IVCP, and GDAD.

The lower C:N ratio at the end of the GDAD process suggests a more complete degradation of organic matter, potentially leading to higher-quality compost. This is supported by the observation that the quality of compost produced from GDAD is better than that from IVCP, despite the faster process rate in IVCP. The higher quality of GDAD compost may be due to the comprehensive breakdown of complex organic compounds under anaerobic conditions, producing a more stable and nutrient-rich product.

In the case of NCP, the C:N ratio decreases at a slower rate compared to both IVCP and GDAD. This can be attributed to the less controlled environmental conditions in NCP, which result in less efficient microbial activity and slower decomposition of organic matter. The lower efficiency of NCP indicates the advantages of controlled composting environments, such as those provided by IVCP and GDAD, in achieving faster and more effective composting.

While the C:N ratio alone cannot fully determine compost maturity, its variation during the composting process provides critical insights into the efficiency and quality of different composting methods. The rapid reduction in IVCP highlights its efficiency, while the low final C:N ratio in GDAD points to its potential for producing high-quality compost. These findings suggest that a combination of these methods could optimize both the speed and quality of compost production, contributing to more sustainable and effective waste management practices.

3.2.3. Germination index (GI)

The Germination Index is a valuable tool for assessing compost maturity and phytotoxicity due to its shorter measurement time and lower cost [14]. This index serves as a reliable indicator, reflecting the presence and reduction of phytotoxic substances produced during the initial stages of the composting process. As compost matures, the concentration of these toxic substances decreases, resulting in higher GI values, indicative of a non-toxic, mature compost [14]. Kong et al. [14] emphasized that a GI above 80% indicates mature and non-phytotoxic compost.

Figure 8 illustrates the variation in GI values across the NCP, IVCP, and GDAD. The GI values for GDAD increase at a faster rate compared to NCP and IVCP, highlighting the effectiveness of the anaerobic digestion process in reducing phytotoxicity and enhancing compost maturity. By the 18th day, the GI value for GDAD surpasses 90%, signifying that the compost has reached full maturity. In contrast, the GI values for IVCP and NCP achieve similar maturity levels at later stages, specifically on the 24th and 36th days, respectively. The rapid increase in GI for GDAD can be attributed to the anaerobic conditions, which effectively facilitate the breakdown of organic matter and the stabilization of compost. The anaerobic digestion process promotes the degradation of complex organic compounds and the reduction of phytotoxic substances, resulting in a compost product that is safe for plant growth in a shorter period.

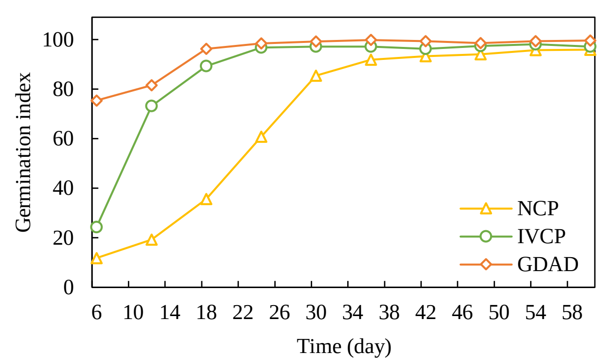

Figure 8. GI variation in NCP, IVCP, and GDAD.

In the case of IVCP, the controlled thermophilic conditions and mechanical agitation contribute to a steady increase in GI values. Although the maturation process in IVCP is slightly slower than GDAD, the in-vessel system ensures a consistent and efficient composting environment.

This controlled setting helps maintain optimal temperatures and moisture levels, which are critical for microbial activity and the decomposition of organic matter. By the 24th day, the GI values in IVCP indicate mature compost suitable for agricultural and horticultural applications.

The NCP exhibits the slowest increase in GI values, reaching maturity on the 36th day. The slower progression in NCP can be attributed to the less controlled environmental conditions resulting in variable temperatures and moisture levels. These fluctuations can hinder microbial activity and slow down the decomposition process, thereby delaying the reduction of phytotoxic substances and the maturation of compost.

Overall, the GI data highlights the efficiency and effectiveness of different composting methods. rapid increase of high GI values in GDAD indicates its potential for producing mature compost quickly, making it a valuable option for waste management strategies prioritizing speed and efficiency. IVCP, while slightly slower, offers the benefits of a controlled environment, ensuring consistent and high-quality compost production. NCP, although effective, requires a longer time frame to achieve similar results. These findings emphasize the importance of selecting appropriate composting methods based on specific requirements and constraints. The rapid maturation in GDAD and the controlled efficiency in IVCP present compelling options for enhancing compost production processes, ultimately contributing to more sustainable and effective waste management practices.

3.3. Biogas generation rate

The production of biogas is a vital component of the anaerobic digestion process, particularly in the context of municipal solid waste (MSW) management. Biogas, primarily composed of methane, can be harnessed as a renewable energy source, thereby reducing reliance on fossil fuels and contributing to sustainable energy solutions. As noted by Avinash and Mishra [9] incorporating leachate or sludge from wastewater treatment can significantly enhance the biogas production rate in an anaerobic digestion process. Specifically, increasing the moisture content to greater than 75% of field capacity (FC) can boost biogas production by approximately 30%. This increase is due to the improved microbial activity facilitated by the higher moisture content, which creates an optimal environment for the anaerobic bacteria responsible for biogas generation.

In the current study, biogas production was monitored over a specified period to evaluate the effectiveness of the GDAD in converting organic waste into biogas. The results indicate that biogas production commenced on the fifth day and peaked on the 14th day. This peak production highlights the efficiency of the GDAD system in rapidly initiating and maintaining the anaerobic digestion process.

The addition of leachate or sludge likely played a crucial role in this enhanced biogas generation. The higher moisture content provided by these additives ensures that the anaerobic bacteria have sufficient water for their metabolic processes, essential for breaking down organic matter and producing methane. Additionally, the presence of leachate or sludge may introduce additional nutrients and microbial consortia that further aid in the digestion process. The sustained biogas production observed over the 30-day period demonstrates the stability and effectiveness of the GDAD system. The gradual decline in biogas generation towards the end of the period is typical of anaerobic digestion processes as the readily digestible organic matter is depleted. At this stage, the residual digested material can be further processed into compost, contributing to a circular waste management approach.

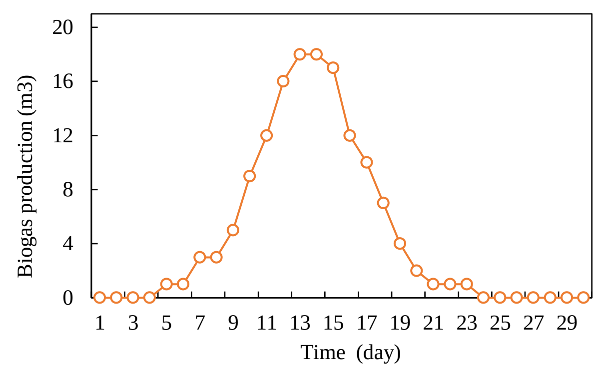

Figure 9. Biogas production in Garage Dry Anaerobic Digester.

The practical implications of these findings are significant. By optimizing the moisture content and incorporating wastewater sludge, it is possible to enhance biogas production rates, thereby improving the overall efficiency of anaerobic digestion systems. This approach not only maximizes energy recovery from organic waste but also supports waste reduction and resource recycling objectives. In conclusion, the addition of leachate or wastewater sludge to anaerobic digestion processes markedly improves biogas production. The results from the GDAD system underscore the potential of such enhancements in municipal solid waste management, providing a pathway towards more sustainable and efficient waste-to-energy solutions.

The reported results in the current study align well with recent literature on composting and anaerobic digestion. The integration of thermophilic in-vessel composting and anaerobic digestion presents a promising approach for efficient waste management, combining rapid composting processes with renewable energy production. Future research and practical implementations should focus on optimizing these processes to enhance sustainability and resource recovery in urban waste management systems.

4. Conclusion

This study underscores the potential of integrating thermophilic in-vessel composting and anaerobic digestion in neighborhood waste management models to achieve superior efficiency and sustainability. Thermophilic in-vessel composting, with its controlled high-temperature environment, significantly enhances the decomposition rate and compost quality by promoting optimal microbial activity. In contrast, anaerobic digestion not only reduces waste volume and produces renewable biogas but also generates a nutrient-rich digestate that can be further composted to yield high-quality compost.

The findings demonstrate that a balanced C:N ratio, achieved by combining OFMSW with cow manure, is critical for efficient composting. Additionally, the rapid attainment of high GI values in anaerobic digestion highlights its efficacy in swiftly producing mature, non-phytotoxic compost. The synergy between these processes offers a robust solution for localized waste management, addressing the dual goals of waste reduction and renewable energy production.

The results of this study align with contemporary research, reinforcing the importance of controlled composting environments and the benefits of integrating composting with anaerobic digestion. This integrated approach supports the broader objectives of urban sustainability by reducing energy consumption, minimizing greenhouse gas emissions, and enhancing resource recovery. Future research should focus on optimizing these processes further to enhance their applicability and efficiency in diverse urban settings, contributing to the global efforts towards sustainable waste management and renewable energy utilization.

References

[1] Devendra, R., et al. "Quality control and assessment of compost obtained from open and In-Vessel composting methods." Materials Today: Proceedings (2023). https://doi.org/10.1016/J.MATPR.2023.06.350

[2] Yang, Mingchao, et al. "Operational performance of organic fraction of municipal solid waste discarded from communities, using an in-vessel hyperthermophilic composting technology." Journal of Cleaner Production 427 (2023): 139059. https://doi.org/10.1016/J.JCLEPRO.2023.139059

[3] Hosseini, Seyed Mohammad, and Hamidi Abdul Aziz. "Evaluation of thermochemical pretreatment and continuous thermophilic condition in rice straw composting process enhancement." Bioresource technology 133 (2013): 240-247. https://doi.org/10.1016/J.BIORTECH.2013.01.098

[4] International Energy Agency. (2020). World Energy Statistics 2020. International Energy Agency. Retrieved from [IEA Website] (https://www.iea.org/reports/world-energy-statistics-2020)

[5] Mohsin, Muhammad, et al. "Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies." Journal of environmental management 284 (2021): 111999. https://doi.org/10.1016/j.jenvman.2021.111999

[6] Sanz-Cobena, Alberto, et al. "Strategies for greenhouse gas emissions mitigation in Mediterranean agriculture: A review." Agriculture, ecosystems & environment 238 (2017): 5-24. https://doi.org/10.1016/j.agee.2016.09.038

[7] Pamukçu, Hale, Pelin Soyertaş Yapıcıoğlu, and Mehmet İrfan Yeşilnacar. "Investigating the mitigation of greenhouse gas emissions from municipal solid waste management using ant colony algorithm, Monte Carlo simulation and LCA approach in terms of EU Green Deal." Waste Management Bulletin 1.2 (2023): 6-14. https://doi.org/10.1016/j.wmb.2023.05.001

[8] Pasang, Haskarlianus, Graham A. Moore, and Guntur Sitorus. "Neighbourhood-based waste management: a solution for solid waste problems in Jakarta, Indonesia." Waste management 27.12 (2007): 1924-1938. https://doi.org/10.1016/j.wasman.2006.09.010

[9] Avinash, Lagudu S., and Anumita Mishra. "Enhancing biogas production in anaerobic digestion of MSW with addition of bio-solids and various moisture sources." Fuel 354 (2023): 129414. https://doi.org/10.1016/J.FUEL.2023.129414

[10] DeCola, Amy C., et al. "Microbiome assembly and stability during start-up of a full-scale, two-phase anaerobic digester fed cow manure and mixed organic feedstocks." Bioresource Technology 394 (2024): 130247. https://doi.org/10.1016/J.BIORTECH.2023.130247

[11] Ahmed, Temoor, et al. "Fertilization of Microbial Composts: A Technology for Improving Stress Resilience in Plants." Plants 12.20 (2023): 3550. https://doi.org/10.3390/plants12203550

[12] Tang, Ruolan, et al. "Effect of moisture content, aeration rate, and C/N on maturity and gaseous emissions during kitchen waste rapid composting." Journal of Environmental Management 326 (2023): 116662. https://doi.org/10.1016/j.jenvman.2022.116662

[13] Yatoo, Ali Mohd, et al. "Production of nutrient-enriched vermicompost from aquatic macrophytes supplemented with kitchen waste: Assessment of nutrient changes, phytotoxicity, and earthworm biodynamics." Agronomy 12.6 (2022): 1303. https://doi.org/10.3390/agronomy12061303

[14] Kong, Yilin, et al. "Determining the extraction conditions and phytotoxicity threshold for compost maturity evaluation using the seed germination index method." Waste Management 171 (2023): 502-511. https://doi.org/10.1016/J.WASMAN.2023.09.040