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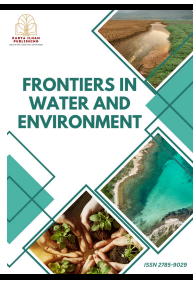

From Waste to Resource: A Review of Food Waste Generation and Industrial Applications in Malaysian Urban Centers

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ABSTRACT

The proliferation of food waste in Malaysia's urban areas has escalated due to swift urbanisation, a rising population, and evolving consumption patterns, posing significant environmental and economic issues. This research examines the trends in food waste generation in Malaysia and evaluates the possibility for transforming this waste into useful resources via industrial uses. The research examines the origins and quantities of food waste through the analysis of previous studies, alongside emerging methods such as anaerobic digestion, incineration, and composting. It highlights prospects for industrial application, including bioenergy production and organic fertiliser manufacturing, while recognising challenges such as inadequate infrastructure, legislative deficiencies, and little public awareness. The results suggest that implementing circular economy concepts in urban waste management may enhance sustainability and economic advantages, positioning Malaysian cities as leaders in food waste valorisation.

1. Introduction

Food waste happens over the whole food supply chain, affecting every phase from harvesting to disposal. Analysing the food supply chain elucidates the impact of food waste on production, distribution, and consumption [1]. The chain commences at the agricultural tier, where waste comprises cornstalks, manure, inferior fruits, or damaged crops.

Food processing and manufacturing generate waste due to transit damage, insufficient storage, processing faults, contamination, or defective packaging. Retail establishments and markets contribute to food waste, sometimes termed food loss, due to inadequate handling or insufficient refrigeration facilities. At the domestic level, food waste arises from over purchasing, inadequate storage methods, over-preparation, or misunderstanding of "best before" and "use by" labelling [3]. Food loss and food waste yield adverse environmental, social, and economic effects.

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On the environmental front, they contribute to greenhouse gas emissions from landfills and the processes of producing, processing, and transporting food, while also squandering resources like soil, water, and energy and causing ecological disruption through intensive farming. Food loss and waste present ethical dilemmas about global food security. Economically, they result in financial detriments for both producers and consumers.

Despite the increasing volume of research on global food waste management, there is a significant deficiency of thorough studies examining the incorporation of modern industrial applications in urban settings in Malaysia. The research frequently neglects the interaction among local cultural traditions, regional policy differences, and the scalability of technologies like as anaerobic digestion and composting in Malaysian cities. This research seeks to evaluate the possibilities for converting food waste into industrial resources, taking into account Malaysia's distinct socio-economic and environmental concerns.

2. Food Waste Generation

Malaysia, a rapidly developing Southeast Asian nation, confronts the dual challenges of urbanisation and managing waste. Recent World Bank statistics reveals that 75% of Malaysia's population currently resides in urban areas, a significant increase from merely 27% fifty years prior.

Table 1
Waste Generation in Malaysia [4]

Year	Population	Waste Generation (Tonnage) Per Day	Waste Generation (Tonnage) Per Year
2015	31,705,650	37,100.29	13,541.606.33
2016	31,950,000	37,381.50	13,613,195.24
2017	32,045,700	37,498.15	13,686,824.39
2018	32,385,000	37,890.45	13,830,014.25
2019	32,581,400	38,120.24	13,913,886.87
2020	32,584,000	38,123.28	13.914.997.20
2021	32,655,400	38,206.82	13,945,488.57

Table 1 illustrates that Malaysia's daily waste production increased by 83.54 tonnes from 2020 to 2021, highlighting a significant escalation in the waste management challenge within one year. This substantial rise underscores the urgent necessity for improved waste reduction methods and more efficient solutions to manage the escalating daily waste volume. The nation is grappling with a rising issue, revealing that current methods are insufficient to address the problem's scale.

Table 2
Waste composition in Malaysia

Type of waste	Percentage (%)
Food	45
Plastics	24
Paper	7
Metal	6
Others	18

Food waste patterns in Malaysia are profoundly influenced by cultural traditions and regional disparities. In urban centres like Kuala Lumpur, the presence of night markets and street food culture significantly contributes to food waste due to over-preparation and unsold perishables. In contrast, rural areas like Kelantan generate larger volumes of agricultural waste, including rice husks and

vegetable scraps, due to traditional farming practices. Cultural activities, such as preparing elaborate dinners for occasions like Hari Raya or Chinese New Year, often lead to household food waste, exacerbated by a lack of awareness regarding portion control and preservation techniques. Table 2 demonstrates that food waste represents the principal component of total waste generated in Malaysia, including a substantial 45%. This significant number underscores the imperative to tackle and reduce food waste problems.

In response to this growing concern, there is a heightened focus on shifting from the conventional linear "take-make-dispose" model to a circular economy framework, in which food waste is transformed into valuable industrial products [5]. Technologies such as anaerobic digestion, composting, and biorefinery provide significant potential for transforming organic waste into bioenergy, fertilisers, and bioproducts. However, despite their potential, the implementation of these technologies in Malaysia is impeded by inadequate infrastructure, inconsistent regulations, and little public engagement, which obstructs progress in sustainable waste management.

3. Current Method of Food Waste Disposal in Malaysia

The management of food waste in Malaysia is inadequate, primarily due to insufficient financial backing. Malaysia, as a growing nation, faces considerable obstacles like outdated technology, limited land availability, and inadequate labor, resulting in facilities that are ill-equipped to handle increasing food waste volumes [7]. As a result, most food waste is either disposed of in landfills or incinerated [8]. While landfills provide a cost-effective disposal method, they pose significant environmental risks, especially as many locations in Malaysia operate as open dumps that contribute to global warming [9].

Incineration is a more effective solution for reducing odours, pests, and land utilisation; yet, it necessitates greater expenses and energy, rendering it less feasible for extensive implementation [10]. Incineration technique entails the regulated combustion of organic materials to produce heat, which can be utilised as a bioenergy source and transformed into power via steam turbines [19]. This procedure additionally generates wastes including flue gas and ash. Flue gas, comprising trace amounts of nitrogen, sulphur dioxide, and carbon dioxide, can be advantageous when appropriately harnessed. Nitrogen derived from flue gas can be utilised in fertilisers to enhance crop yield, carbon dioxide can be repurposed for fire extinguishers, and sulphur from sulphur dioxide can be employed in dental applications. The incineration process has several distinct phases: the initial combustion of waste materials, the recovery of energy generated during this process, the release of stack gases into the atmosphere, and the implementation of a comprehensive cleaning system to mitigate environmental impact.

4. Potential Industrial Applications of Food Waste and Their Challenges

4.1 Anaerobic Digestion

Various technologies has the capability to convert food waste into valuable industrial resources. Anaerobic digestion, a technique that converts organic material into biogas, is especially appropriate for Malaysia's moisture-laden waste. This approach is receiving acknowledgement for its ecological and financial advantages. It produces methane, a sustainable biofuel that can substitute fossil fuels, hence diminishing greenhouse gas emissions [11]. This technique decreases waste volume, hence reducing dependence on landfills for disposal and mitigating environmental damage [12-14]. The waste, termed digestate, is nutrient-dense and can be employed as an organic fertiliser to promote sustainable agriculture [15]. Anaerobic digestion is more energy-efficient than oxygen-dependent

processes. Furthermore, it offers a dependable waste management solution, regularly transforming high-organic waste into a stable energy source [16]. Despite the numerous advantages of anaerobic digestion, its extensive implementation in Malaysia is obstructed by various hurdles, as seen in Table 3.

Table 3
Challenges in implementing anaerobic digestion [24]

Challenge	Description
High Costs of Building Biogas Plants	Building biogas plants with electricity generation equipment is costly compared to current waste treatment methods.
Uncertain Supply of Raw Materials	Local banks and investors are concerned about the long-term availability of waste to feed biogas plants. Many industries are reducing waste by improving processes, and the waste they produce is often used for other profitable products, like turning chicken or dairy manure into organic fertilisers for quick returns.
Lack of Regulations on Biogas Emissions	Many industries with wastewater don't capture methane gas from waste treatment because there are no strict laws requiring it in Malaysia.
Limited Awareness Among Policymakers	There's a lack of skilled and knowledgeable people in renewable energy among decision-makers, leading to low awareness of its benefits and opportunities.
Market and Pricing Issues	The electricity market structure discourages biogas plant developers due to low financial returns.
Lack of Local Technology and Grid Access	Most biogas technology, like anaerobic digesters, is imported from countries like Germany, making it expensive for local developers.
Shortage of Skilled Workers	There aren't enough trained local workers to manage, operate, and maintain biogas plants, slowing their development.

A case study in Johor, Malaysia, illustrated the viability of anaerobic digestion at a small-scale palm oil mill, where food and agricultural waste were transformed into biogas, producing 1.2 MW of power daily [24]. Nonetheless, expanding this approach to urban areas presents difficulties due to irregular waste supply and substantial initial expenses, underscoring the necessity for customised infrastructure development.

4.2 Composting

Composting is an effective method for addressing the issue of food waste management. This biological process transforms organic waste into a nutrient-dense product rich in humic compounds, enhancing soil quality, mitigating erosion, and fostering plant development [18]. Unlike other municipal solid waste (MSW) treatment techniques such as anaerobic digestion, incineration, and pyrolysis, composting employs less complex technology and incurs reduced operational expenses. Once devoid of heavy metals and pathogens, properly grown compost may serve as a soil conditioner or organic fertiliser. Moreover, the presence of advantageous bacteria in compost can assist in mitigating some plant diseases.

Notwithstanding its benefits, the implementation of composting as a strategy for managing food waste poses numerous problems. A significant impediment is the insufficient segregation of waste at the source, leading to contamination with inorganic elements and undermining compost quality. Public knowledge and engagement are essential, as inadequate disposal procedures and a lack of incentives may dissuade homes and companies from embracing composting, as illustrated in Table 4.

Table 4
Challenges in implementing composting method

Section	Description	References
Case Study Findings	A prior study found that while 64% of respondents were familiar with composting, only 14% had started the practice, and none had sustained it consistently. Most respondents were willing to begin composting and share knowledge with others only if provided with all necessary facilities. Key barriers for those unwilling to compost included a lack of facilities and insufficient information on proper composting methods	[22]
	A case study in Kampar, Perak, revealed that 72.19% of respondents lacked knowledge of best practices for solid waste management. Only 34% practiced composting at home, while 72.60% discarded their food waste directly into waste bins without efforts to reduce daily solid waste generation. Additionally, just 23.3% disposed of their food waste through alternative means, such as using it as pet food or burying it. Furthermore, many respondents viewed composting as unhygienic, believing it attracts flies and vermin, highlighting a lack of awareness and understanding of organic composting.	[23]
	Another case study indicated that only 24.9% of respondents from three major districts in Kedah were willing to compost food waste at home, further emphasizing the low awareness of proper food waste management practices.	[6]

Empirical research in Malaysia emphasises the possibilities and limitations associated with composting. A pilot study in Penang, including 200 households, revealed that with proper guidance and the supply of composting bins, 68% of participants sustained composting practices for six months, leading to a 30% decrease in food waste sent to landfills [25]. A study in Kampar, Perak, revealed that 72.19% of participants were uninformed of suggested practices, with only 34% participating in home composting [23]. In Kedah, just 24.9% of respondents indicated a readiness to compost, attributing their reluctance to perceived inconvenience and inadequate facilities as the main reasons [6]. These findings underscore the imperative for specialised education and infrastructure to bridge the gap between awareness and action.

Cultural misunderstandings, such as the notion that composting is unhygienic or arduous, particularly among urban Malay and Chinese communities, hinder its adoption, highlighting the need for culturally sensitive awareness campaigns.

Engaging stakeholders is crucial for resolving composting challenges. Municipal authorities may partner with NGOs to distribute free composting kits and conduct workshops, as seen by a successful trial in Johor Bahru, which led to a 40% increase in community engagement following these initiatives [26]. Educational institutions and religious groups should serve as hubs for composting education, inspiring youth and community leaders to promote sustainable practices. Incentives, such as discounts in waste collection fees for households that compost, could increase involvement.

5. Conclusion

Transforming food waste from a management challenge into a profitable resource presents significant opportunities for Malaysia's urban regions. This research underscores that, despite the rise in food waste attributable to urbanisation and evolving consumer behaviours, much scope for industrial innovation remains. Technologies such as anaerobic digestion, incineration, and composting offer strategies to reduce dependence on landfills, mitigate environmental harm, and generate economic benefits through bioenergy and fertiliser production. However, realising these opportunities requires overcoming substantial challenges, including inadequate infrastructure and policy shortcomings. Malaysia ought to implement national regulations mandating the segregation of food waste at its origin and offer incentives, such as tax reductions or subsidies, to encourage

enterprises to adopt sustainable practices. Investing in regional biogas and composting facilities, particularly in urban areas like Kuala Lumpur and Penang, through public-private partnerships may alleviate significant initial costs. Moreover, the execution of culturally tailored efforts, such as the "Zero Waste Malaysia" campaign, may educate households on composting and waste reduction, fostering community engagement across diverse linguistic and cultural groups. Collaboration among academics, industry, and local governments is essential for testing innovative solutions like biorefineries and sharing best practices. By embracing circular economy principles and fostering stakeholder collaboration, Malaysia may position its urban centres as leaders in sustainable waste management. Future research should emphasise cost-benefit analyses of these technologies and the development of scalable methods for community-driven waste valorisation, ensuring that food waste becomes an integral component of urban resource recovery rather than persisting as a recurring problem.

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References

[1] Omolayo, Yetunde, Beth J. Feingold, Roni A. Neff, and Xiaobo Xue Romeiko. "Life cycle assessment of food loss and waste in the food supply chain." *Resources, Conservation and Recycling* 164 (2021): 105119. https://doi.org/10.1016/j.resconrec.2020.105119

[2] Balaji, M., and K. Arshinder. "Modeling the causes of food wastage in Indian perishable food supply chain." *Resources, Conservation and Recycling* 114 (2016): 153-167. https://doi.org/10.1016/j.resconrec.2016.07.016

[3] Papargyropoulou, Effie, Rodrigo Lozano, Julia K. Steinberger, Nigel Wright, and Zaini bin Ujang. "The food waste hierarchy as a framework for the management of food surplus and food waste." *Journal of cleaner production* 76 (2014): 106-115. https://doi.org/10.1016/j.resconrec.2016.07.016

[4] The Star. "Take Action on Waste Management." (2022)

[5] Do MSc, Nhu Quynh. *An investigation into practices and determinants of the circular economy in the food by-product management using multiple case research design*. University of Hull, 2022.

[6] Thi, Ngoc Bao Dung, Gopalakrishnan Kumar, and Chiu-Yue Lin. "An overview of food waste management in developing countries: Current status and future perspective." *Journal of environmental management* 157 (2015): 220-229. https://doi.org/10.1016/j.jenvman.2015.04.022

[7] Badgie, Dawda, Mohd Armi Abu Samah, Latifah Abd Manaf, and Azizi B. Muda. "Assessment of Municipal Solid Waste Composition in Malaysia: Management, Practice, and Challenges." *Polish journal of environmental studies* 21, no. 3 (2012).

[8] Lim, W. J., N. L. Chin, A. Y. Yusof, A. Yahya, and T. P. Tee. "Food waste handling in Malaysia and comparison with other Asian countries." *International Food Research Journal* 23 (2016): S1.

[9] Cudjoe, Dan, and Patience Mensah Acquah. "Environmental impact analysis of municipal solid waste incineration in African countries." *Chemosphere* 265 (2021): 129186. https://doi.org/10.1016/j.chemosphere.2020.129186

[10] Ong, Khai Lun, Guneet Kaur, Nattha Pensupa, Kristiadi Uisan, and Carol Sze Ki Lin. "Trends in food waste valorization for the production of chemicals, materials and fuels: Case study South and Southeast Asia." *Bioresource technology* 248 (2018): 100-112. https://doi.org/10.1016/j.biortech.2017.06.076

[11] Li, Yue, Yinguang Chen, and Jiang Wu. "Enhancement of methane production in anaerobic digestion process: A review." *Applied energy* 240 (2019): 120-137. https://doi.org/10.1016/j.apenergy.2019.01.243

[12] Papa, Gabriella, Mirko Cucina, Khadija Echchouki, Patrizia De Nisi, and Fabrizio Adani. "Anaerobic digestion of organic waste allows recovering energy and enhancing the subsequent bioplastic degradation in soil." *Resources, Conservation and Recycling* 188 (2023): 106694. https://doi.org/10.1016/j.resconrec.2022.106694

[13] Náthia-Neves, G., Mauro Berni, Giuliano Dragone, S. I. Mussatto, and T. Forster-Carneiro. "Anaerobic digestion process: technological aspects and recent developments." *International journal of environmental science and technology* 15 (2018): 2033-2046. https://doi.org/10.1007/s13762-018-1682-2

[14] Chew, Kah Rong, Hui Yi Leong, Kuan Shiong Khoo, Dai-Viet N. Vo, Hirra Anjum, Chih-Kai Chang, and Pau Loke Show. "Effects of anaerobic digestion of food waste on biogas production and environmental impacts: a review." *Environmental Chemistry Letters* 19, no. 4 (2021): 2921-2939. https://doi.org/10.1007/s10311-021-01220-z

[15] Lamolinara, Barbara, Amaury Pérez-Martínez, Estela Guardado-Yordi, Christian Guillén Fiallos, Karel Diéguez-Santana, and Gerardo J. Ruiz-Mercado. "Anaerobic digestate management, environmental impacts, and techno-economic challenges." *Waste Management* 140 (2022): 14-30. https://doi.org/10.1016/j.wasman.2021.12.035

[16] Zamri, M. F. M. A., Saiful Hasmady, Afifi Akhiar, Fazril Ideris, A. H. Shamsuddin, M. Mofijur, IM Rizwanul Fattah, and T. M. I. Mahlia. "A comprehensive review on anaerobic digestion of organic fraction of municipal solid waste." *Renewable and Sustainable Energy Reviews* 137 (2021): 110637. https://doi.org/10.1016/j.rser.2020.110637

[17] Manea, Elena Elisabeta, Costel Bumbac, Laurentiu Razvan Dinu, Marius Bumbac, and Cristina Mihaela Nicolescu. "Composting as a sustainable solution for organic solid waste management: Current practices and potential improvements." *Sustainability* 16, no. 15 (2024): 6329. https://doi.org/10.3390/su16156329

[18] Wang, Xuan, Ammaiyappan Selvam, and Jonathan WC Wong. "Influence of lime on struvite formation and nitrogen conservation during food waste composting." *Bioresource technology* 217 (2016): 227-232. https://doi.org/10.1016/j.biortech.2016.02.117

[19] Cudjoe, Dan, and Hong Wang. "Plasma gasification versus incineration of plastic waste: Energy, economic and environmental analysis." *Fuel Processing Technology* 237 (2022): 107470. https://doi.org/10.1016/j.fuproc.2022.107470

[20] Nidoni, Pooja G. "Incineration process for solid waste management and effective utilization of by products." *International Research Journal of Engineering and Technology* 4, no. 12 (2017): 378-382.

[21] Zainu, Zaipul Anwar, and Ahmad Rahman Songip. "Policies, challenges and strategies for municipal waste management in Malaysia." *Journal of Science, Technology and Innovation Policy* 3, no. 1 (2017): 10-14. https://doi.org/10.11113/jostip.v3n1.18

[22] Hassan, R. O. K. I. A. H., FADZILAH ADIBAH ABDUL Majid, and A. A. Rahman. "The potential of implementing food waste composting at source using biosense scheme." *J. of Research in Applied Natural and Social Sciences* 3, no. 4 (2015): 55-66.

[23] Bashir, M. J. K., G. H. Tao, S. S. Abu Amr, and K. W. Tan. "Public concerns and behaviors towards solid waste minimization using composting in Kampar district, Malaysia." (2018): 316-323. https://doi.org/10.30955/gnj.002592

[24] Kumaran, Palanisamy, David Hephzibah, Ranganathan Sivasankari, Normanbay Saifuddin, and Abd Halim Shamsuddin. "A review on industrial scale anaerobic digestion systems deployment in Malaysia: Opportunities and challenges." *Renewable and sustainable energy reviews* 56 (2016): 929-940. https://doi.org/10.1016/j.rser.2015.11.069

[25] Lim, S. Y., and J. K. Wong. "Community-Based Composting Initiatives in Penang: A Case Study." *Journal of Sustainable Waste Management* 12, no. 3 (2023): 45–56.

[26] Tan, K. H., and S. M. Lee. "Stakeholder-Driven Composting in Johor Bahru: A Pilot Study." *Malaysian Journal of Environmental Studies* 15, no.1 (2024): 78–89.