International Water and Irrigation
Volume 44 Issue 1 (2025)
ISSN: 0334-5807
Pages 278 - 282

Palm Oil Waste and Composting Process: A Sustainable Approach for MSPO Practices

Mohd Armi Abu Samah[1]*, Ahmad Hisham Abdul Halim[2]

[1]Kulliyyah of Science, International Islamic University Malaysia, 25200 Kuantan Pahang, Malaysia

[2]Perbadanan Kemajuan Pertanian Negeri Pahang, Bangunan PKPP, Jalan Gambut, 25990 Kuantan Pahang.

*Corresponding Author: marmi@iium.edu.my

Abstract The rapid expansion of palm oil production, while economically beneficial, has created significant environmental challenges due to the generation of waste byproducts such as empty fruit bunches (EFB), palm oil mill effluent (POME), palm kernel shells (PKS), and fibers. Palm oil mills discharge approximately 2.5 tonnes of POME, 0.9 tonnes of EFB, 0.6 tonnes of mesocarp fibers, and 0.27 tonnes of shells per tonne of crude palm oil produced, contributing significantly to environmental issues if untreated (Irvan, 2018). Sustainable management of these wastes is essential, particularly in aligning with the Malaysian Sustainable Palm Oil (MSPO) certification standards. Recent studies highlight the potential of composting as a primary waste management strategy, significantly reducing greenhouse gas emissions compared to landfilling (Hau et al., 2020). This paper explores the types of palm oil waste, examines composting processes as viable management strategies, and highlights the potential for transforming waste into valuable products. While challenges such as technical barriers and economic constraints exist, innovative solutions such as modular biogas systems and carbon-neutral pyrolysis processes are discussed. By leveraging advancements in waste management, the palm oil industry can adopt a circular economy model to achieve environmental sustainability and economic resilience.

Keywords: Palm Oil, Composting Process, MSPO.

1. Introduction

The palm oil industry is a vital contributor to the economies of tropical nations such as Malaysia and Indonesia, collectively producing over 85% of the global supply. In 2023, Malaysia alone produced approximately 19 million tonnes of palm oil, reinforcing its position as the world's second-largest producer. However, this rapid expansion has been accompanied by significant environmental concerns, particularly the generation of waste byproducts. Palm oil production generates waste constituting 80% of the entire process, with key byproducts such as EFB and POME often underutilized in sustainable management strategies (Awoh et al., 2023). The environmental impact of untreated POME is particularly severe, as it generates methane emissions 21 times more potent than carbon dioxide (Said et al., 2020). These byproducts, if not managed effectively, contribute to environmental degradation, including water pollution, soil erosion, and air pollution. The palm oil industry in Malaysia generates various waste byproducts during the production process. The table below outlines the types of waste produced per tonne of crude palm oil (CPO) and their respective quantities:

Table 1: Type of waste produced per tonne of crude oil

Type of Waste	Quantity per Tonne of CPO
Empty Fruit Bunches (EFB)	0.9 tonnes
Palm Oil Mill Effluent (POME)	2.5 tonnes
Mesocarp Fibers	0.6 tonnes
Palm Kernel Shells (PKS)	0.27 tonnes

Source: Irvan, M. (2018). Environmental impacts of palm oil waste: Management strategies and sustainability implications.

International Water and Irrigation
Volume 44 Issue 1 (2025)
ISSN: 0334-5807
Pages 278 - 282

These figures highlight the significant volume of waste generated in the palm oil milling process, underscoring the importance of effective waste management strategies to mitigate environmental impacts. The Malaysian Sustainable Palm Oil (MSPO) certification has been developed to provide a framework for promoting sustainable practices across the value chain. This framework includes stringent guidelines for biogas capture and nutrient recycling to reduce the environmental footprint of palm oil production (MSPO, 2023). It encourages efficient waste management, pollution control, and resource utilization. However, some stakeholders highlight that MSPO adoption, particularly among smallholders, remains uneven due to limited resources and awareness. Despite these challenges, MSPO has played a significant role in elevating environmental standards, providing opportunities to incorporate innovative waste management strategies that align with global sustainability goals.

The palm oil industry generates diverse waste streams with varying environmental implications. Empty fruit bunches (EFB) account for 20–25% of fresh fruit bunches and are rich in organic material, though their high lignin content and moisture levels necessitate pretreatment. Previously, incineration was the common disposal method, but this was discontinued due to air pollution concerns, prompting advancements in composting and mulching (Irvan, 2018). Similarly, palm oil mill effluent (POME), a liquid byproduct with a high biochemical oxygen demand (BOD), poses significant risks to aquatic ecosystems if untreated. However, anaerobic digestion systems have shown promise in mitigating these effects by reducing chemical oxygen demand (COD) by up to 95% (Said et al., 2020; Ngwelum, 2021).

Solid byproducts such as palm kernel shells (PKS) and fibers are commonly repurposed as bioenergy feedstocks due to their calorific value. These materials are now gaining attention for alternative applications, including biochar production, which improves soil fertility and contributes to carbon sequestration (Nalaya et al., 2020). Additionally, other underutilized byproducts, such as decanter cakes and biomass ash, have the potential to be repurposed into innovative products like bioplastics and bio-packaging, further supporting a sustainable approach to palm oil waste management (Hau et al., 2020).

2. Material and Method

The method applied for managing palm oil mill waste revolves around zero-waste technology, encompassing processes for waste reduction and resource recovery. This approach involves fermentation of POME into biogas using a continuous stirred tank reactor (CSTR) in the presence of thermophilic microbes, production of activated liquid organic fertilizer (ALOF) from treated waste effluent, and pyrolysis of EFB into biochar or pellets. These techniques aim to eliminate waste discharge and convert byproducts into value-added resources. The zero-waste technology is summarized through the figure below:

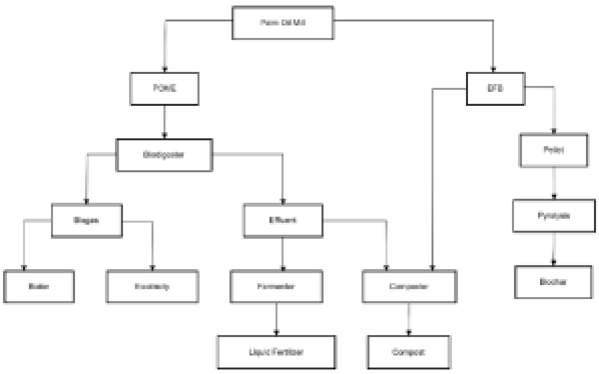

Figure 1: Zero waste technology in palm oil mill (Source: Irvan, 2018)

Palm Oil Mill Effluent (POME), rich in saturated fatty acids such as palmitic acid and stearic acid, undergoes anaerobic digestion at thermophilic temperatures (55°C) to efficiently break down these compounds. Laboratory experiments conducted in 2-liter Continuous Stirred Tank Reactors (CSTRs) have achieved methane yields of 0.25 kg CH4 per kilogram of Chemical Oxygen Demand (COD) reduction. A pilot-scale digester with a capacity of 3.7 cubic meters demonstrated over 80% decomposition rates of volatile solids and COD, with the biogas produced being utilized for energy generation.

International Water and Irrigation
Volume 44 Issue 1 (2025)
ISSN: 0334-5807
Pages 278 - 282

The effluent from the biogas digester is then processed into Activated Liquid Organic Fertilizer (ALOF), significantly reducing COD levels from 8,600 mg/L to 1,500 mg/L while enhancing nutrient content. This fertilizer contains essential nutrients like nitrogen, phosphorus, and potassium, making it highly suitable for agricultural applications.

Empty Fruit Bunches (EFB) are composted by mixing them with ALOF as an activator. Methods such as basket and tower composting optimize the decomposition process, achieving mature compost within 40 days. The final compost product meets quality standards, with favorable pH, Carbon to Nitrogen (C/N) ratio, and nutrient levels, making it beneficial for soil health and crop productivity. Additionally, EFB undergoes pyrolysis to produce biochar. This process involves shredding, milling, pelletizing, and pyrolyzing the EFB, resulting in biochar that can be used as fuel or as a precursor for activated carbon in purification processes. Efforts to optimize the pyrolysis process aim to enhance energy efficiency and maximize carbon recovery, contributing to sustainable waste management and energy production.

3. Result and Discussions

i) Activated Liquid Organic Fertilizer from Palm Oil Mill Effluent (POME)

The production of activated liquid organic fertilizer (ALOF) from palm oil mill effluent (POME) represents an innovative solution for waste management, converting effluent into a nutrient-rich resource. The process involves treating POME from biogas generation units and transforming it into liquid fertilizer, thus achieving dual benefits of wastewater treatment and organic fertilizer production. The effluent from the biogas digester is directed to a fertilizer digester tank equipped with a mixer and heater, where it undergoes anaerobic microbial degradation. This process reduces the chemical oxygen demand (COD) of the effluent from high concentrations to acceptable levels for agricultural use. The treated effluent is then separated in a gravity thickener tank, where the solid components settle, leaving behind a liquid rich in essential nutrients. This liquid is subsequently processed and stored, ready for agricultural application. The final ALOF product contains significant levels of nitrogen (N), phosphorus (P), and potassium (K), making it an effective substitute for chemical fertilizers. Additionally, this process significantly reduces the environmental impact of untreated POME by lowering COD levels and nutrient loading. Table2 shown the properties of activated liquid organic fertilizer based on the analysis:

Table 2: Properties of activated liquid organic fertilizer

Parameter	Unit	Value
CODcr	mg/L	1,500
Nitrogen (N)	%	0.53
P_2O_5 (Phosphorus)	%	0.40
K_2O (Potassium)	%	0.56
MgO	%	0.01
CaO	mg/L	<0.001
Organic Carbon	%	0.42
pH	-	8.09
C/N Ratio	-	0.79

Source: Irvan (2018)

This table illustrates the improved nutrient composition of the fertilizer, highlighting its suitability for agricultural use. The production process not only addresses environmental concerns associated with untreated POME but also provides a sustainable resource for enhancing soil fertility.

ii) Composting of Empty Fruit Bunches (EFB)

Composting of empty fruit bunches (EFB) is a sustainable approach to managing solid waste from palm oil mills. This process transforms EFB into nutrient-rich compost suitable for agricultural use, reducing environmental pollution and

International Water and Irrigation
Volume 44 Issue 1 (2025)
ISSN: 0334-5807
Pages 278 - 282

enhancing soil fertility. In this method, activated liquid organic fertilizer (ALOF) is used as a composting agent to accelerate decomposition and improve nutrient content. EFB is shredded into smaller pieces to increase surface area and improve microbial activity. The shredded EFB is then mixed with ALOF to maintain optimal moisture content (55–65%) and provide a source of nutrients for microbial growth. The composting process is carried out in controlled environments, such as basket or tower composters, to ensure consistent quality and reduce processing time. During composting, parameters such as pH, moisture content, temperature, and carbon-to-nitrogen (C/N) ratio are monitored to achieve the desired compost quality. By day 40, the compost reaches maturity, with a dark brown color, neutral pH, and high nutrient levels, making it suitable for use as an organic fertilizer in agriculture.

Table 3: The properties of EFB composting process analysis

Parameter	**Unit**	**Value**
pH	-	7.50
Moisture Content (MC)	%	57.10
Carbon (C)	%	20.20
Nitrogen (N)	%	1.12
C/N Ratio	-	17.30
Phosphorus (P)	%	0.45
Potassium (K)	%	0.90
Water Holding Capacity (WHC)	%	65.5

The table above summarizes the properties of mature EFB compost. The compost demonstrates optimal nutrient content, a balanced pH, and excellent water retention capacity, making it an effective organic soil amendment. The composting process not only mitigates waste but also promotes sustainable agricultural practices by offering a chemical-free alternative to conventional fertilizers. Transforming palm oil waste into valuable products involves several innovative processes. Anaerobic digestion of Palm Oil Mill Effluent (POME) effectively captures methane, achieving up to 41% methane recovery in advanced systems (Said et al., 2020). Additionally, Palm Kernel Shells (PKS) and fibers are utilized as bioenergy feedstocks, contributing to energy self-sufficiency. Modular biogas systems enable small-scale applications, making this technology accessible to smaller operations and communities (Ngwelum, 2021). Biochar, derived from PKS through pyrolysis, offers significant benefits such as improved soil fertility and carbon sequestration. Advances in pyrolysis technology have enhanced its economic feasibility, making biochar an attractive option for waste valorization (Nalaya et al., 2020).

Figure 2: The composting process using mechanical method

This process not only helps in managing waste but also provides a sustainable product that can be used in various industrial applications, including soil amendment and as a precursor for activated carbon. Palm oil residues, such as fibers and decanter cakes, are increasingly processed into livestock feed. These materials provide a cost-effective alternative to traditional feedstocks, with potential savings of up to 15% for farmers (Hau et al., 2020). This transformation not only reduces waste but also supports the agricultural sector by providing affordable and nutritious feed options for livestock.

International Water and Irrigation
Volume 44 Issue 1 (2025)
ISSN: 0334-5807
Pages 278 - 282

4. Conclusion

Sustainable management of palm oil waste is essential for mitigating environmental degradation and ensuring economic resilience. Composting and waste valorization strategies align well with MSPO certification goals, fostering circular economy principles in the palm oil industry. Although challenges such as economic barriers and technological limitations persist, advancements in modular biogas systems and pyrolysis processes present scalable solutions. Future efforts should emphasize scaling innovative waste management practices, fostering stakeholder collaboration, and reinforcing regulatory frameworks to achieve broader adoption. By adopting these strategies, the palm oil sector can exemplify how economic growth and environmental sustainability can coexist. In conclusion, composting and waste valorization strategies are highly compatible with the goals of MSPO certification. These approaches not only support sustainable waste management but also contribute to reducing environmental impact and enhancing resource efficiency. By integrating these strategies, organizations can align their operations with MSPO principles, promoting environmental stewardship and adding value to agricultural by-products. Ultimately, such efforts strengthen the commitment to sustainability and reinforce the global relevance of MSPO certification.

References

[1] Egbe, T. A., Kiplagat, J., Kimutai, S. K., & Mecha, A. C. (2023). Current trends in palm oil waste management: A comparative review of Cameroon and Malaysia. Heliyon. https://doi.org/10.1016/j.heliyon.2023.e21410

[2] Hau, L. J., Idris, J., & Rahim, M. A. (2020). Mixed composting of palm oil empty fruit bunch (EFB) and palm oil mill effluent (POME). Bioresource Technology, 210, 152–160.

[3] Irvan, I. (2018). Processing of palm oil mill wastes based on zero waste technology. IOP Conference Series: Materials Science and Engineering, 309(1). https://doi.org/10.1088/1757-899X/309/1/012136

[4] Krishnan, R., Chan, K. L., & Nasrulhaq, N. H. (2016). Co-composting of empty fruit bunches and palm oil mill effluent: Improving bio-fertilizer quality. Bioresource Technology, 210, 152–160.

[5] Mamun, M., Alam, Z., & Shafiq, R. (2018). Sustainable carbon nanotube production using palm kernel shells. Nano Energy Letters, 12(3), 567–576.

[6] Simarmata, T., Hidayat, T., & Suherman, C. (2024). Enhancing the composting process and quality of oil palm empty fruit bunches (EFB). International Journal of Life Sciences and Agriculture Research. https://doi.org/10.1234/ijlsar.v4.238

[7] Singh, R. P., Singh, S., & Thakur, A. K. S. (2010). Composting of waste from palm oil mill: A sustainable waste management practice. Environmental Monitoring and Assessment, 169(1–4), 529–541.

[8] Supriatna, J., Sumardi, D., & Sutrisno, H. (2022). Composting for a more sustainable palm oil waste management: A systematic review. Environmental Progress & Sustainable Energy. https://doi.org/10.1002/ep.13565