JURNAL PERIKANAN DAN KELAUTAN
Volume 31 No. 1, February 2026: 113-120

e-issn : 2721-8902
p-issn : 0853-7607

The Potential of Various Types of Decomposers on the Effectiveness of Palm Oil Fruit Bunch (EFB) Composting and a Study of Socio-Economic Conditions in the Village of Lubuk Ogung

Potensi Berbagai Jenis Dekomposer terhadap Efektivitas Pengomposan Tandan Kosong Kelapa Sawit (TKKS) dan Kajian Kondisi Sosial Ekonomi di Desa Lubuk Ogung

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Received
22 January 2026

Accepted
26 February 2026

Abstract

Empty fruit bunches (EFB) are the main solid waste product of the palm oil industry and have great potential to be processed into high-value organic fertilizer. However, the natural decomposition process is very slow. This study aims to analyze the effectiveness of several types of decomposers (EM-4, Eco-enzyme, M-21, and MSG-3) in accelerating the TKKS composting process and to identify the socio-economic conditions and perceptions of the Lubuk Ogung Village community regarding community-based waste management. The method used was a mixed-methods design, with a completely randomized design (CRD) and three replicates for technical analysis and in-depth interviews for social aspects. The parameters observed included the C/N ratio, organic C, nitrogen, phosphorus, and potassium. The results showed that Eco-enzyme and M-21 were the most effective decomposers, producing final C/N ratios of 16.44 and 17.25, respectively, which meet the SNI 7763:2024 standard. Socially, the community showed a positive perception of TKKS composting, though they still faced obstacles in technical knowledge, market access, and program sustainability. These findings indicate that the application of decomposer technology, particularly Eco-enzyme, has the potential to strengthen waste management and promote community empowerment through circular economy practices at the village level.

Keywords: Circular Economy, Composting, Decomposer

Abstrak

ndan kosong kelapa sawit (TKKS) merupakan limbah padat utama dari industri kelapa sawit yang memiliki potensi besar untuk diolah menjadi pupuk organik bernilai tinggi, namun proses dekomposisinya secara alami berlangsung sangat lambat. Penelitian ini bertujuan menganalisis efektivitas beberapa jenis dekomposer (EM-4, Eco-enzyme, M-21, dan MSG-3) dalam mempercepat proses pengomposan TKKS serta mengidentifikasi kondisi sosial ekonomi dan persepsi masyarakat Desa Lubuk Ogung terhadap pengelolaan limbah berbasis komunitas. Metode yang digunakan adalah mixed methods, dengan rancangan acak lengkap (RAL) tiga ulangan untuk analisis teknis dan wawancara mendalam untuk aspek sosial. Parameter yang diamati meliputi rasio C/N, C-organik, nitrogen, fosfor,

dan kalium. Hasil penelitian menunjukkan bahwa Eco-enzyme dan M-21 merupakan dekomposer paling efektif, masing-masing menghasilkan rasio C/N akhir 16,44 dan 17,25 yang memenuhi standar SNI 7763:2024. Secara sosial, masyarakat menunjukkan persepsi positif terhadap pengomposan TKKS, meskipun masih terkendala pengetahuan teknis, akses pasar, dan keberlanjutan program. Temuan ini menunjukkan bahwa penerapan teknologi dekomposer, khususnya Eco-enzyme, berpotensi memperkuat pengelolaan limbah serta mendorong pemberdayaan masyarakat melalui praktik ekonomi sirkular di tingkat desa.

Kata kunci: Dekomposer, Ekonomi Sirkular, Pengomposan

1. Introduction

Indonesia is the country with the largest oil palm plantations in the world, covering 14.3 million hectares in 2018, with Riau Province as the main centre, covering 2.54 million hectares, and Pelalawan Regency as the largest, covering 384,790 hectares (BPS, 2024). Oil palm (*Elaeis guineensis*) plays an important role in the national economy because it has high productivity and generates greater economic value per hectare than other oil-producing crops. In addition, oil palm is used as a raw material for food, renewable energy, industrial materials, and organic fertiliser components, so demand continues to increase in both domestic and global markets (Kuvaini, 2020). However, as production needs increase, the amount of waste produced also continues to grow, especially empty palm fruit bunches (TKKS), the largest solid waste stream, accounting for around 23% of fresh fruit bunches or more than 556,000 tonnes per day nationally (Gustiar et al., 2020). In many regions, TKKS is still managed conventionally, such as by being piled up, burned, or used as mulch without further processing, thus potentially causing environmental impacts in the form of unpleasant odours, becoming a habitat for plant pests, and disrupting the balance of the local ecosystem (Salamiyah & Hizriani, 2023).

Scientifically, TKKS has great potential as a compost raw material due to its high organic content, particularly cellulose (40–60%), hemicellulose (20–30%), and lignin (15–30%) (Rosli et al., 2017). However, the high lignocellulose content slows the natural decomposition process. The success of lignocellulose biodegradation is largely determined by the activity of microorganisms that produce cellulase, hemicellulase, and ligninase enzymes. These enzymes play an important role in breaking the structural bonds of cellulose and lignin, thereby accelerating the reduction in the C/N ratio and supporting the formation of stable, mature compost (Aini et al., 2021).

In recent years, various composters have been developed with specific microbial communities to accelerate the composting of organic waste (Gunardi et al., 2023). Various studies have shown that the combination of bacteria and fungi in decomposers can accelerate lignocellulose degradation, significantly reduce the C/N ratio, increase nutrient levels of N, P, and K, and produce compost with good physical characteristics, such as a blackish-brown color and a crumbly texture (Hadri et al., 2023). The quality of compost in Indonesia is currently defined by SNI 7763:2024, which requires a C/N ratio ≤ 25, organic C ≥ 15%, pH 4–9, and a minimum macro-nutrient content of 2% (BSN, 2024).

Although the potential of TKKS is enormous and decomposer technology continues to develop, its utilization at the community level has not been optimal. In Lubuk Ogung Village, Pelalawan Regency, TKKS processing has been carried out through the Village Waste Bank using a commercial decomposer called Effective Microorganism (EM-4). However, the composting process takes more than six months, and the compost produced is still unsatisfactory, according to the waste bank manager. This condition indicates a gap between the theoretical biological capacity of decomposers and their performance in the field.

The use of TKKS as a local economic resource has not been fully integrated into community empowerment activities, even though circular-economy-based waste management has great potential to increase income, reduce dependence on chemical fertilizers, and foster the independence of farmer groups and rural communities. The mismatch between TKKS's biological potential, the community's need for quick compost, and limited management capacity underscores the need for a more comprehensive study. In line with research by Heriza et al. (2024), palm oil waste, such as TKKS, has great potential to be processed into organic fertilizer and animal feed that can improve soil fertility and local food security. The community's enthusiasm for waste-processing socialization activities shows that the use of TKKS can strengthen community capacity. However, its implementation remains limited because it has not been integrated into a sustainable management system. This condition underscores the need for a more comprehensive study to bridge the biological potential of TKKS with the community's demand for fast, high-quality organic products.

Based on this background, this study was conducted to examine the effectiveness of several types of decomposers (EM-4, eco-enzyme, M-21, MSG-3) in accelerating the TKKS composting process and producing

compost in accordance with SNI standards, as well as analyzing the socio-economic conditions and perceptions of the Lubuk Ogung Village community in supporting community-based TKKS management.

2. Material and Method

2.1. Time and Place

This research was conducted from July to December 2024 at the composting site of the Lubuk Ogung Village Waste Bank, Bandar Sei Kijang District, Pelalawan Regency, Riau Province.

2.2. Methods

This study used a mixed methods approach that combined quantitative methods through TKKS composting experiments and qualitative methods through interviews and socio-economic observations of the community. This approach was chosen to produce a comprehensive understanding of the effectiveness of decomposers and the social context of TKKS waste utilization at the community level.

2.3. Procedures

The quantitative research design used a completely randomized design (CRD) with five treatments and three replicates, resulting in 15 experimental units. The treatments consisted of:

P0 = TKKS (control), P1 = TKKS + EM-4 (100 mL),
P2 = TKKS + Eco-enzyme (100 mL), P3 = TKKS + M-21 (100 mL),
P4 = TKKS + MSG-3 Formula (5 g).

Each treatment unit used 3 kg of TKKS that had been chopped according to the RAL design. Meanwhile, for the qualitative approach, data were collected through interviews with waste bank managers, village officials, and community members involved in TKKS management and composting activities.

The research population for the social aspect included all community members involved in village waste management activities. The sampling technique used was purposive sampling, which involved selecting informants who had direct knowledge of and involvement in TKKS processing. For the TKKS sample, simple random sampling was used from the factory's TKKS pile, ensuring each part had an equal chance of being selected.

The research preparation stage included: (1) drying TKKS for 7–14 days to reduce the water content, (2) shredding TKKS using a shredding machine, (3) preparation of decomposers in the form of EM-4, eco-enzyme, and M-21 for immediate use, as well as the preparation of MSG-3 formula by mixing MSG-3 lactobio, MSG-3 supplement, agricultural lime, and water, (4) preparation of tools such as trash bags, digital scales, sprayers, thermometers, pH meters, hygrometers, and documentation tools.

During the implementation stage, 3 kg of shredded TKKS was placed in trash bags according to the treatment. The decomposer was applied using a sprayer, and the material was homogenized. The reactors were labeled and placed in a shaded area for 30 days. Turning was carried out once a week to improve aeration, reduce temperature, and optimize microbial activity. Moisture was maintained at ±50% by spraying water if the material appeared too dry. Compost samples were taken on days 10, 20, and 30 for laboratory analysis, including C/N ratio, organic C, and macronutrient content (N, P, K). The analysis results are compared with compost quality standards outlined in SNI 7763:2024.

Socio-economic data is obtained through interviews and field observations. Questions cover the community's perceptions of the benefits of TKKS compost, economic opportunities, technical barriers, and institutional support. Interviews are recorded, transcribed, and analyzed using thematic analysis techniques.

2.4. Data Analysis

Quantitative data analysis was performed using Analysis of Variance (ANOVA) to examine the effect of treatment. If significant differences were detected, Duncan's New Multiple Range Test (DNMRT) was performed at the 5% level. Data were presented in tables and graphs. Qualitative data analysis was conducted through data reduction, data presentation, and conclusion drawing to describe the socio-economic conditions based on the informants' narratives.

3. Result and Discussion

3.1. Analysis of the Effect of Decomposer Types on TKKS Composting

This study used four different types of decomposers, namely EM-4, Eco-Enzyme, M-21, and Formula MSG-3, to accelerate the decomposition process of empty palm fruit bunches (EFB) for 30 days. Laboratory tests were conducted to analyse changes in the chemical characteristics of empty palm fruit bunch compost (EFB). The results of laboratory tests on days 10, 20, and 30 showed the dynamics of changes in chemical parameters, including organic carbon (C-Organic) content, total nitrogen (N-Total), C/N ratio, and macro-nutrient content of phosphorus (P_2O_5) and potassium (K_2O). The measurement data are presented in Table 1.

Table 1. Chemical Characteristics and C/N Ratio of TKKS Compost under Various Decomposer Treatments

Treatment	Day	C-Organik (%)	N-Total (%)	C/N	P_2O_5 (%)	K_2O (%)
P0 (Control)	10	53,50	1,40	38,21	0,35	2,05
	20	52,80	1,50	35,20	0,40	2,15
	30	50,90	1,75	29,08	0,55	2,50
P1 (EM-4)	10	52,65	1,45	36,31	0,38	2,12
	20	52,61	1,53	34,38	0,58	2,44
	30	48,56	2,30	21,11	0,94	2,70
P2 (Eco-Enzyme)	10	52,37	1,70	30,81	0,46	2,64
	20	51,23	2,07	24,75	0,74	3,08
	30	48,33	2,94	16,44	1,16	3,28
P3 (M-21)	10	51,36	1,91	26,89	0,48	2,83
	20	50,82	2,68	18,96	0,98	3,42
	30	49,52	2,87	17,25	1,05	3,55
P4 (MSG-3)	10	52,73	1,56	33,80	0,36	2,29
	20	50,55	1,93	26,19	0,95	2,95
	30	49,27	2,74	17,98	1,12	3,37

Based on the chemical characteristics and C/N ratio presented in Table 1, all treatments showed consistent chemical changes throughout the composting process. The organic carbon content decreased in all treatments from day 10 to day 30, indicating that the decomposition of organic matter in TKKS occurred actively. The greatest decrease in organic carbon was observed in P2 (Eco-Enzyme) and P3 (M-21), decreasing from 52.37% to 48.33% and from 51.36% to 49.52%, respectively. This pattern suggests that these two decomposers were more effective in degrading lignocellulosic components of TKKS.

The high effectiveness of Eco-Enzyme observed in this study is consistent with the findings of Paendong et al. (2023), who reported that Eco-Enzyme contains active enzymes such as cellulase, catalase, and pectinase, which play a role in accelerating the breakdown of cellulose and lignin. This enzymatic activity is further supported by Mar'ah & Alicia (2021), who stated that fermentation-based liquid bioactivators respond more rapidly to organic substrates than other decomposers. This explains why treatment P2 showed the most consistent decreases in both organic carbon content and the C/N ratio throughout the composting period.

In addition to the decrease in organic carbon, total nitrogen content increased in all treatments during the composting process. The most substantial increases were observed in P2 (from 1.70% to 2.94%) and P3 (from 1.91% to 2.87%). This increase in nitrogen content indicates that Eco-Enzyme and M-21 created favorable microenvironmental conditions that supported nitrogen transformation and microbial activity. According to Mulya et al. (2025); Harahap et al. (2022), an increase in nitrogen content accelerates the reduction in the C/N ratio, a key indicator of compost maturity. The C/N ratio in P2 reached 16.44, confirming that Eco-Enzyme and M-21 were highly effective in accelerating decomposition.

Furthermore, treatment P3 (M-21) showed the highest potassium (K_2O) content (3.55%) at the end of the composting period, indicating strong potassium solubilization activity. The effectiveness of M-21 is attributed to its microbial composition, including Actinomycetes, Pseudomonas, and Streptomyces. These microbial groups play an important role in lignin and cellulose degradation by producing ligninase and cellulase enzymes, thereby accelerating the breakdown of complex organic compounds in TKKS.

Treatment P1 (EM-4) showed moderate effectiveness compared to other decomposers. This was reflected in a slight decrease in organic carbon and a lower increase in nitrogen content. This condition suggests that the microbial consortium in EM-4 requires a longer adaptation period when applied to high-fiber substrates such as TKKS. Hastuti et al. (2021) reported that EM-4 performs more optimally on softer organic materials, such as kitchen and garden waste, where decomposition occurs more rapidly due to the substrates' simpler structures. Therefore, the high lignin and cellulose content of TKKS likely limited the early effectiveness of EM-4 in this study. Treatment P4 (MSG-3) demonstrated relatively good performance, particularly in reducing the C/N ratio and increasing P_2O_5 content, although its effectiveness remained lower than that of Eco-Enzyme and M-21. MSG-3 contains decomposing microbes, such as Bacillus sp. and Enterobacter sp., which produce hydrolytic enzymes, including cellulase. However, MSG-3 is not specifically formulated as a cellulolytic consortium, which may explain its lower effectiveness on high-fiber substrates like TKKS. This finding is consistent with Aini et al. (2021), who emphasized that TKKS decomposition strongly depends on the presence of a cellulolytic microbial consortium.

Regarding phosphorus content (P_2O_5), the highest increase was observed in P2 (Eco-Enzyme), followed by P4 and P3. The strong performance of Eco-Enzyme in increasing phosphorus availability aligns with Kartika (2021), who reported that bioactivators derived from nutrient-rich organic materials can enhance the release of phosphorus

and potassium during composting. Meanwhile, the relatively high K_2O content in P3 further confirms the effectiveness of M-21 in mineral solubilization processes. Statistical analysis showed that the type of decomposer had a significant effect on the reduction of the C/N ratio ($F = 14.103$; Sig. = $0.001 < 0.05$). The observation time factor also had a significant effect ($F = 35.608$; Sig. = $0.000 < 0.05$), indicating that both decomposer type and composting duration significantly influenced the decomposition process of TKKS organic material.

The Duncan's multiple range test further clarified the differences among treatments. P3 (M-21) had the lowest average C/N ratio (21.03) and was classified in the most effective subset, followed by P2 (Eco-Enzyme) with an average C/N ratio of 24.00. Treatment P4 (MSG-3) was categorized as having moderate effectiveness, while P1 (EM-4) showed lower effectiveness. These results are consistent with those of Septinar et al. (2024), who reported that fermentation-based enzymes can accelerate lignocellulose hydrolysis, resulting in a faster reduction in the C/N ratio.

According to SNI 7763:2024, compost is considered mature when the C/N ratio is less than 25. All decomposer treatments (P1–P4) met this criterion within 30 days, whereas the control treatment did not. This confirms that the application of bioactivators plays an important role in accelerating the decomposition of complex TKKS compounds. Overall, the results indicate that Eco-Enzyme and M-21 were the most effective decomposers in accelerating TKKS compost maturation and improving compost quality. These findings provide scientific evidence that the selection of decomposer type significantly influences composting efficiency and final compost quality.

3.2. Socio- Economic Aspects in TKKS Waste Management

Rural communities in Lubuk Ogung Village have traditionally relied on chemical fertilizers, despite the abundant availability of oil palm waste in the form of empty fruit bunches (EFB), as most plantations in the area are smallholder-owned. Based on interviews with farmers, the majority perceive using EFB waste as organic fertilizer to be complicated and time-consuming. In addition, farmers experience difficulties in understanding the composting process of EFB waste, leading them to prefer burning the waste or leaving it to accumulate around plantation areas. From a social perspective, interview results also indicate that many farmers still perceive inorganic fertilizers as superior to organic fertilizers. However, several community groups that have received prior socialization regarding the benefits of EFB compost and composting techniques have begun to show interest in adopting composting systems as a more environmentally friendly and sustainable alternative.

To quantitatively assess community perceptions and levels of understanding regarding EFB compost utilization, several social indicators were evaluated using a scoring approach. The results of the perception and understanding assessment are presented in Table 2.

Table 2. Community Perception and Understanding of EFB Compost Utilization

Measured Aspect	Average Score (1–3)	Quantitative Interpretation
Understanding of EFB Compost Benefits	2.2 (Moderate)	Community understanding varies, showing polarization between informed and uninformed groups.
Perception of EFB Compost Use	2.3 (Moderate)	Neutral-to-positive attitudes, though still accompanied by hesitation
Dependency on Chemical Fertilizers	1.5 (High)	The majority of farmers remain highly dependent on chemical fertilizers
Perceived Difficulty of the Composting Process	1.5 (Difficult)	Composting is generally perceived as a challenging activity

The data presented in Table 2 clearly reinforce the qualitative findings. The low score for dependency on chemical fertilizers (1.5) confirms that reliance on chemical inputs remains dominant among farmers. Meanwhile, the moderate scores for understanding (2.2) and perception (2.3) indicate that the knowledge base needed to drive behavioral change remains weak. According to Indrianingsih (2011), continuous education and training can significantly improve farmers' awareness of the benefits of compost derived from oil palm empty fruit bunches. Intensive training programs implemented in several regions have enabled farmers to better understand the advantages of organic fertilizers, particularly in terms of improving soil fertility and reducing production costs. Furthermore, experiences from other regions suggest that targeted, consistent socialization efforts can gradually encourage farmers to shift toward organic fertilizers derived from oil palm waste.

Putri et al. (2023) reported that using oil palm waste for compost production not only improves soil fertility but also reduces expenditures on chemical fertilizers, which often represent a significant economic burden for smallholder farmers. In addition, EFB composting can mitigate the accumulation of solid waste in surrounding communities. Nevertheless, the adoption rate of this practice remains relatively low, indicating the need for further education and technical assistance to ensure that farmers fully understand both the benefits and proper techniques of EFB composting.

3.3. Factors Influencing Community Acceptance

Community acceptance of organic fertilizer–based systems remain limited, primarily due to limited knowledge and technical skills related to composting. The failure of previous composting programs was not incidental, but rather the result of weaknesses in information dissemination, technical assistance, and institutional capacity. Quantitative scores for factors influencing community acceptance are presented in Table 4.

Table 4. Scores of Factors Influencing Community Acceptance

Aspect	Average Score (1–3)	Interpretation
Frequency and Quality of Socialization	1.5	Very limited and unsustained
Availability of Technical Support	1.7	Limited access to expert assistance
Readiness of BUMDes	1.5	Institutionally unprepared

Low socialization scores (1.5) indicate fragmented, discontinuous information delivery, resulting in weak community understanding. Limited technical assistance (1.7) reduces confidence in composting practices and the perceived reliability of compost quality. Institutional unpreparedness of BUMDes (1.5) further constrains program sustainability, as insufficient managerial and technical capacity hindered long-term operation following external interventions. Interviews revealed that although BUMDes had previously generated short-term profits, high operational costs and long composting periods discouraged continuation, shaping negative perceptions of EFB composting as costly and inefficient. Farmers remain reluctant to adopt composting due to insufficient information, lack of technical validation, and continued dependence on chemical fertilizers, which are perceived as more practical and faster-acting. Psychological resistance and risk aversion further reinforce reliance on conventional inputs. Previous studies emphasize that continuous extension services, technical assistance, and institutional strengthening are critical to improving acceptance and adoption of EFB composting at the community level (Indrianingsih, 2011; Destiani et al., 2021; Sitorus et al., 2024).

3.4. Constraints in the Implementation of Oil Palm Empty Fruit Bunch (EFB) Composting

Despite its considerable potential to improve soil fertility, the implementation of oil palm empty fruit bunch (EFB) composting in Desa Lubuk Ogung still faces several major constraints. Interviews with BUMDes managers, farmer groups, and waste bank operators identified three primary barriers. First, high operational costs remain a significant challenge. Although basic infrastructure, such as processing sites and shredding machines, is available, labor costs and limited financial resources hinder large-scale production. The lack of economic incentives further reduces community participation in sustained composting activities.

Second, the long decomposition period discourages adoption. Without appropriate methods and optimal use of bioactivators, EFB composting requires a relatively long processing time. Farmers generally prefer practices that deliver faster results, making composting less attractive than conventional fertilization methods. Third, limited technical expertise and inadequate training constrain implementation. Insufficient access to skilled personnel and ongoing guidance creates uncertainty about compost quality and effectiveness. As a result, communities remain hesitant to adopt composting practices with economic value. Previous studies indicate that government support, community involvement, and private-sector partnerships play a critical role in accelerating compost adoption through training and technical assistance (Salamiyah & Hizriani, 2023).

3.5. Role of Community and Government Support and Sustainability Potential of EFB Waste Management

Local communities, including farmer groups and waste bank managers, play an important role in introducing composting practices. However, their efforts require reinforcement through clearer village-level policies and institutional support. Cooperative-based partnership models have proven effective in improving income, reducing transaction costs, and enhancing marketing efficiency. Farmers with access to government and private-sector support show higher success rates in adopting sustainable agricultural practices (Putra et al., 2020). Strategic efforts to support composting implementation include continuous training and socialization, optimization of BUMDes management and partnerships, development of sustainable business models with clear benefit-sharing schemes, and product diversification, such as liquid organic fertilizer or biochar to increase economic value (Saputra et al., 2017).

Interview results indicate that if key constraints, such as limited socialization, a lack of technical expertise, and high operational costs, are addressed, EFB composting has strong potential for sustainable development. Farmers who have received training expressed willingness to adopt composting practices, provided that technical support and economic incentives are available. Partnership schemes between farmers, government institutions, and private companies are considered essential to expand adoption and enhance the economic and social benefits of EFB waste management (Ala et al., 2015).

4. Conclusions

This study evaluated the effectiveness of several decomposers in the composting process of oil palm empty fruit bunches (EFB). It analyzed the community's associated socio-economic conditions in Desa Lubuk Ogung. The results indicate that all composting treatments met the Indonesian National Standard (SNI) at the end of the composting period, except for the control. Eco-enzyme and M-21 treatments successfully reduced the C/N ratio to meet SNI requirements within 20 days, with eco-enzyme achieving the optimal C/N ratio after 30 days. No significant differences were observed among treatments in terms of compost weight reduction. From a socio-economic perspective, the community remains highly dependent on chemical fertilizers, while knowledge and acceptance of organic fertilizers are still limited. Although EFB composting shows considerable potential for development, its implementation is constrained by limited technical knowledge, long processing time, and the lack of sustainable program support.

5. References

[BPS] Badan Pusat Statistik Provinsi Riau. (2024). *Provinsi Riau dalam Angka 2024*. Badan Pusat Statistik Provinsi Riau.

[BSN] Badan Standar Nasional. (2024). *Standar Nasional Indonesia 3 - Pupuk organik padat* (Patent 7763:2024).

Aini, D.N., Hanifa, H., Mulfa, D.S., & Linda, T M. (2021). Pengaruh Bioaktivator selulolitik untuk mempercepat pengomposan tandan kosong kelapa sawit (*Elaeis guineensis* Jacq). *Biota* : *Jurnal Ilmiah Ilmu-Ilmu Hayati*, 6(1): 1–7.

Ala, K., Juraemi, J., & & Suhadi, I. (2015). Efektivitas kemitraan inti plasma perkebunan kelapa sawit (studi kasus pada petani plasma PT Gunta Samba Kecamatan Kongbeng). *Jurnal Pertanian Terpadu*, 3(1): 76–88.

Destiani, D., Kusmiyati, K., & Saridewi, R.T. (2021). Persepsi Petani terhadap penerapan teknologi konservasi lahan pada budidaya padi di Kecamatan Nagrak Kabupaten Sukabumi. *Jurnal Penyuluhan Pertanian*, 16(1): 37–50.

Gunardi, H., Himawan, A., & Hastuti, P.B. (2023). Pengaruh beberapa jenis dekomposer dan lama waktu pengomposan terhadap kualitas kompos tandan kosong. *Agroforetech*, 1(3): 1478-1484.

Gustiar, F., Wibisono, I., & Munandar, M. (2020). Kompos tandan kosong kelapa sawit dengan penambahan kotoran sapi dan berbagai bioaktivator. *Jurnal Riset Agribisnis dan Peternakan*, *5*(2): 14-24.

Hadri, M.J., Hastuti, B.P., & Rochmiyati, S.M. (2023). Pengomposan hasil samping perkebunan sawit dengan berbagai macam dekomposer. *Agroforetech*, 1(4): 2177–2185.

Harahap, S.H., Hasnudi, H., & Ginting, N. (2022). Effect of fermentation duration and dosage of eco enzyme use on nutrient content of kepok banana stem (*Musa Paradisiaca* L.). *Jurnal Peternakan Integratif*, 9(3): 58-64.

Hastuti, S., Martini, T., Pranoto, P., Purnawan, C., Masykur, A., & Wibowo, A.H. (2021). Pembuatan kompos sampah dapur dan taman dengan bantuan aktivator EM4. *Proceedings of Chemistry Conferences*, 6: 18–21.

Heriza, S., Putri, E.M., Agus, R.A., Diaz, A.A., & Afdia, S.R. (2024). community empowerment through processing palm waste into organic fertilizer and animal feed. *Buletin Dharmas Andalas*, 1(2): 46–51.

Indrianingsih, K.S. (2011). Pengaruh penyuluhan terhadap keputusan petani dalam adopsi inovasi teknologi usahatani terpadu. *Jurnal Agro Ekonomi*, 29(1): 1–24.

Kartika, W. (2021). Limbah buah pisang sebagai bioaktivator alternatif pada pengomposan sampah organik. *Politeknologi*, 20(3): 239–249.

Kuvaini, A. (2020). Inovasi Pembuatan pupuk organik berbahan baku tandan kosong kelapa sawit dengan bantuan cacing tanah (*Lumbricus rubellus*). *Jurnal Citra Widya Edukasi*, 12(1): 1–8.

Mar'ah, S., & Farma, A.S. (2021). *Making and utilizing organic waste into bio eco-enzyme as an indicator of organic plant fertilizer.* Prosiding Semnas Bio 2021(1): 689–699.

Mulya, M.H., Kurniawan, E., Jalaluddin, J., Ibrahim, I., & Kamar, I. (2025). Perbandingan bioaktivator pada fermentasi pupuk organik cair dari kulit kopi dan air tahu. *Chemical Engineering Journal Storage (CEJS)*, 5(1): 68–79.

Paendong, A., Horopu, A.L., Momongan, C.R., Durandt, N., Frilli-Rey, J., & Manginsela, P.E. (2023). Eco style: Utilization of eco-enzyme as a local organic fertilizer that will benefit *Stevia rebaudiana* farming production and income. *Agri-Sosio Ekonomi Unsrat*, 19(1): 549–556.

Putra, C.P., Sadono, D., & Susanto, D. (2020). Perceptions of smallholder farmers on oil palm plantation cooperative in Kongbeng, East Kutai. *Jurnal Penyuluhan*, 16(1): 134–146.

Putri, A.M., Afriwana, D.S., Pulungan, H.S., & Hasibuan, A. (2023). Analisis pemanfaatan limbah tandan kosong kelapa sawit sebagai pupuk bagi masyarakat Simandiangin Kab. Labuhanbatu Selatan. *Journal of Health and Medical Research*, 3(3): 408–412.

Rosli, N.S., Harun, S., Jahim, J.M., & Othaman, R. (2017). Pencirian kimia dan fizikal bagi tandan kosong buah kelapa sawit. *Malaysian Journal of Analytical Sciences*, 21(1), 188–196.

Salamiyah, S., & Hizriani, N. (2023). Penyuluhan pembuatan pupuk organik limbah tandan kosong kelapa sawit (TKKS) di sekolah. *Jalujur*: *Jurnal Pengabdian Masyarakat*, 2(2): 69–78.

Saputra, I.M.G.D., Anggreni, I.G.A.A.L., & Dharma, I.P. (2017). Pola kemitraan usaha tani kelapa sawit Kelompok Tani Telaga Biru dengan PT. Sawindo Kencana melalui koperasi di Kabupaten Bangka Barat Provinsi Bangka Belitung. *E-Jurnal Agribisnis dan Agrowisata,* 6(2): 249–258.

Septinar, H., Anggraini, P., Suryani, E., & Puspasari, R. (2024). Pemanfaatan limbah organik menjadi eco enzyme dan kandungan unsur hara makro untuk meningkatkan kualitas lingkungan. *Environmental Science Journal (ESJo)*, 2(2): 20–26.

Sitorus, A.U.D., Perangin-angin, M.I., & Wahyudi, D. (2024). *Persepsi pekebun dalam pemanfaatan limbah tandan kosong kelapa sawit (TKKS) sebagai pupuk organik.* Prosiding Seminar Nasional Pembangunan dan Pendidikan Vokasi Pertanian, 5(1), 1470–1484.