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Utilization of *Pseudomonas fluorescens* Bacteria in Weed Control and Phosphate Supply in Oil Palm (*Elais Guineensis Jacq.*) Plantations

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ABSTRACT

With growing environmental concerns, sustainable management practices in oil palm plantations are becoming increasingly essential. This review examines the potential of Pseudomonas fluorescens as a biological agent for both weed control and phosphate solubilization in oil palm (*Elaeis guineensis*) cultivation. A systematic literature search was conducted across Google Scholar, Scopus, and ScienceDirect databases, focusing on studies published between 2007 and 2023. Studies that investigated the role of *P. fluorescens* in enhancing plant growth through weed suppression or improving phosphate uptake were selected. The findings reveal that *P. fluorescens* can significantly benefit plant health by minimizing weed competition and enhancing the availability of phosphorus in the soil. However, challenges such as the variability in environmental conditions, strain specificity, and scalability of application persist. The review highlights the importance of further field trials and experimental research to refine the practical use of *P. fluorescens* in achieving more sustainable oil palm production.

Keywords: Palm oil, *Pseudomonas fluorescens*, sustainable agriculture, weed control

INTRODUCTION

On facing agricultural demands that keep on increasing, palm oil plantations remain the most crucial in terms of Indonesia's horticulture and state revenue. With the increasing pressure to take into serious matters of environmental concerns, the integration of biological solutions like *Pseudomonas fluorescens* could be the next frontier in oil palm cultivation. In the matter of palm oil as horticulture commodity, Indonesia hold its status as the largest manufacturer of palm oil, with 1.7 billion liters (bL) of biodiesel exported (with records that crude palm oil (CPO) as the main feedstock for biodiesel production in Indonesia) (Khatiwada *et al.* 2018). Aside from its usage on biodiesel main ingredients, CPO are also widely used for food and other industrial non-food uses. Palm oil has its own advantages as vegetable oil that

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make it superior when compared with other edible oils. To benchmark with other important horticultural commodities in Indonesia, such as rubber, oil palm cultivation offers higher returns with respect to both land use and labor demands (Krishna *et al.* 2017). Soaps, detergents, and grease are a few examples of non-food industrial uses of palm oil, which make it inseparable from our daily lives. As a result, there is a strong tendency for the palm oil industry to have a stronghold contributing to the Indonesian economy, not only on the scale of country income but also on enhancing household welfare and improving local infrastructure (Euler *et al.* 2016).

According to Anjani *et al.* (2022), Indonesia is the world's largest producer and exporter of palm oil with production greater than 18 million tons per year. The palm oil industry contributes significantly to the national economy by generating a state revenue of up to IDR 239.4 trillion, also to note that it opens up employment opportunities. Based on BPS RI (2020), the area of oil palm plantations in Indonesia has almost reached 15–16 million hectares. Palm oil is the leading vegetable oil used for food in Indonesia, consumed at double the rate of soybean oil. Since 2011, domestic consumption of palm oil for food has risen by 20%, reaching the number of 5.5 million tonnes in 2014. This demand is projected to keep growing alongside the population increase and gross domestic product (GDP) in Indonesia (Khatiwada *et al.* 2018).

With palm oil being a vital commodity in many aspects, maintaining high yields becomes increasingly critical, especially due to the persistent problem of weeds in oil palm plantations. Controlling weed growth in oil palm fields is a crucial factor in maintaining the productivity and also the sustainability of oil palm plantations. One of the major problems during the early stage of oil palm plantation is weed invasion, where competitive and invasive weeds such as *Imperata cylindrica, Mikania cordata, Cyperus rodontus,* and *Lantana camara,* compete for resources (nutrients, moisture, and light) that is necessary for the growth of oil palm (Thongjua and Thongjua 2016). A study conducted by Prasetyo & Zaman (2016) showed that in Jambi Province, losses in palm oil plantation due to weeds such as *Mikania micrantha* (locally known as *sembung rambat*) reached IDR 38,110,550 with an infestation area up to 757.5 ha, losses due to *Imperata cylindrica* (locally known as *alang-alang*) reached IDR 59,971,500 with an infestation area of 1086 ha, and losses due to *Paspalum conjugatum* (locally known as *rumput kerbau*) reached IDR 43,416,599 with an infestation area of 1149.9 ha. The damage caused by weeds is often not immediately visible. Several factors contribute to these losses, including stunted plant growth, which leads to longer production times, a decrease in both the quantity and quality of harvests, disruptions in work productivity, the potential for weeds to serve as breeding grounds for pests and diseases, and the high costs associated with weed control (Dahlianah 2019).

Therefore, to meet the high demand for palm oil, whether in its raw form or as CPO, effective weed management is essential. In its implementation to suppress weeds, plantations generally use chemical herbicides because they are relatively cheap. However, the use of chemical herbicides has disadvantages and side effects if used continuously and in the long term. Long-term herbicide application can also kill species of bacteria, fungi, and protozoa that combat disease-causing microorganisms, disrupting the balance between harmful pathogens and beneficial organisms (Latha and Gopal 2010). Apart from weeds, oil palm plantations also encounter problems in the form of macronutrient deficiencies in the soil, especially phosphorus, where phosphorus deficiency can lead to the inhibition of palm oil growth. Phosphorus in soil is a non-mobile nutrient, which can be defined as its tendency to bind mostly to soil particles and partly present as organic phosphorus, with only a little available in a form that can be taken up directly by plants (Ibrahim *et al.* 2022). In addition, to increase and meet the basic phosphorus needs for palm oil, chemical phosphorus (P) fertilizers are usually used to meet needs (Supriatna *et al.* 2023), where this is highly hypocritical on the principles of sustainable agriculture, due to its negative impact. Excessive use of P fertilizers increases the risk of nutrients percolating into deeper soil layers, leading to the loss of essential minerals, which can reduce soil fertility (Dubos *et al.* 2016).

Given these challenges, an effective and rapid solution must be developed that is environmentally friendly and cost-effective. The use of biocontrol plant-growth-promoting rhizobacteria (PGPR) has been demonstrated to be environmentally friendly, and proven to enhance plant growth and control diseases and weed infestation (Zainab *et al.* 2021). One of the most prominent potentials is the use of P. fluorescens, a gram-negative-bacteria, to compete with common weeds in palm oil plantations while increasing the supply of phosphorus for palm oil growth. *P. fluorescens* can enhance plant growth through increase of antioxidant enzymes, and converting P into available forms for palm oil (usually known as orthophosphates) (Linu *et al.* 2019). While the application of PGPR as biocontrol has proven to be both eco-friendly and cost-effective in enhancing plant growth, its specific role in weed control and phosphate solubilization in palm oil plantations remains under-explored. Addressing this gap can provide valuable insights for sustainable agriculture practices. Thus, the objectives of this review study are: 1) To identify the potential of *P. fluorescens* as a weed control agent at palm oil plantations; 2) To elucidate the interaction between *P. fluorescens* and common weeds at palm oil plantation; 3) To identify the potential of *P. fluorescens* on increasing the availability of phosphate in the soil of palm oil plantations; lastly, 4) To determine effective application strategies to optimize the role of *P. fluorescens* in weed control and increasing soil phosphate in palm oil plantations.

MATERIALS AND METHODS

This study employed a qualitative methodology through a systematic literature review to investigate the role of *Pseudomonas fluorescens* in weed control and phosphate availability in oil palm plantations. We performed the literature search across three major databases: Google Scholar, ScienceDirect, and Scopus. The search was limited to articles published from 2010 onward, with the following keywords: “*Pseudomonas fluorescens*”, “biocontrol of weed”, “palm oil”, and “phosphate solubilization”. Articles were included if they specifically discussed *P. fluorescens* as a biofertilizer or biopesticide or its use as a biofertilizer in palm oil cultivation. Studies were excluded if they didn’t focus on weed control or phosphate supply, or if they were not related to agricultural settings. The initial screening process was conducted by a team of four reviewers, who independently reviewed the abstracts to determine their relevance. Articles that passed this initial screening underwent full-text review. While this review does not include a formal quality assessment of the studies, it focuses on presenting the main trends and current findings from the literature on the use of *P. fluorescens* as weed control and phosphate supply on palm oil plantations.

RESULTS AND DISCUSSION

Scientific studies have proven the effectiveness of *Pseudomonas fluorescens* in controlling weed populations, including in oil palm plantations. Research conducted by Kim *et al.* (2017) found that the application of

P. fluorescens significantly reduced the growth of weeds such as *Imperata cylindrica* and *Mikania micranth*a in agricultural soils. In addition, research by Verma *et al.* (2020) concluded that *Pseudomonas fluorescens* can inhibit the growth of weeds such as *Echinochloa colona* and *Cyperus rotundus* by increasing the competitiveness of the main crop against weeds. In oil palm plantations, commonly encountered weed types include *Imperata cylindrica* (locally known as alang-alang), weeds, and *Cyperus rotundus*. Thus, the application of *P. fluorescens* has the potential to be an effective tool in weed management in oil palm plantations, helping to improve the productivity and quality of oil palm crops by reducing competition from noxious weeds.

Research conducted in the field has shown significant differences between weed populations in plots treated with *P. fluorescens* and control plots (without *P. fluorescens*). For example, research conducted by Smith *et al.* (2019) in oil palm plantations found that *P. fluorescens* application consistently resulted in a significant reduction in weed numbers and density compared to control plots. The results included significant reductions in weeds commonly encountered in oil palm plantations, such as *Imperata cylindrica* (commonly known as alang-alang), weeds, and *Cyperus rotundus*. In addition, the study also noted that the difference in weed populations between the plots treated with *P. fluorescens* and the control plots remained significant over the long observation period, indicating a sustained effect of the treatment (Smith *et al.* 2019). These findings provide strong evidence of the effectiveness of *Pseudomonas fluorescens* as a potential biological control agent in reducing weed populations in oil palm plantations, with positive implications for weed management and overall farmland productivity.

P. fluorescens has promising potential as a biological alternative in weed control when compared to the use of chemical herbicides. The use of chemical herbicides is often effective in controlling weeds, but can cause several problems, including weed resistance to chemicals and negative impacts on the environment and human health (Rani *et al.* 2019). In contrast, the use of P*. fluorescens* as a biological control agent offers a more environmentally frindly and sustainable approach. This bacterium works by inhibiting weed growth through several mechanisms, such as nutrient competition, production of antibacterial compounds, and stimulating plant defense systems. In addition, the use of *P. fluorescens* does not leave harmful chemical residues in soil and water, and does not cause weed resistance (Mehmood *et al.* 2023). Thus, the use of *P. fluorescens* as a biological alternative in weed control can help reduce reliance on chemical herbicides and promote a more sustainable approach in weed management in the agricultural sector. The interaction between *P. fluorescens* and oil palm (*Elais guineensis*) serves as a crucial mechanism driving the growth and development of plants. *P. fluorescens* forms a mutualistic relationship with the oil palm by colonizing the rhizosphere and adhering to the root surfaces, forming a biofilm. Such colonization significantly enhances nutrient availability for the plant by facilitating the solubilization and mineralization of essential nutrients like phosphorus and iron. This process will promote robust root growth and strengthen the overall vigor of the plant. Additionally, *P. fluorescens* produces plant growth promoting hormons, such as auxins and cytokinins. This hormons will stimulate root elongation and branching, further optimizing nutrient uptake and fostering improved plant growth.

Beyond direct growth enhancement, *P. fluorescens* also exerts an indirect influence on oil palm health by bolstering the plant's defense mechanisms against pathogens. The bacterium accomplishes this through the production of antimicrobial compounds, such as antibiotics and lytic enzymes which inhibit the proliferation of phytopathogens in the rhizosphere. This suppression of harmful microbes effectively reduces the incidence of diseases such as Fusarium and basal stem rot in oil palm plantations. Moreover, *P. fluorescens* triggers systemic resistance in the oil palm, fortifying the plant's immune system and enabling it to mount a more effective defensive response against pathogen attacks. The symbiotic interaction between *P. fluorescens* and oil palm underscores the importance of this bacterium as a bioinoculant for promoting plant growth and health in agricultural systems. By improving nutrient availability, fostering root development and strengthening the plant's defense mechanisms, *P. fluorescens* offers substantial benefits for sustainable oil palm cultivation, significantly contributing to increased productivity and resilience against environmental stress and pathogenic threats.

Utilizing microorganisms like *P. fluorescens* for weed management give a promising approach in agriculture. This bacterium offers several mechanisms to suppress weeds, primarily through the production of allelochemicals and competition for resources. The allelochemicals that are released will inhibit the germination and growth of weed seeds, which will effectively reduce weed populations in agricultural fields. Additionally, the bacterium competes with weeds for essential nutrients and space in the rhizosphere further limiting weed establishment and growth. Therefore, by harnessing the natural antagonistic properties of *P. fluorescens*, farmers can lessen their reliance on synthetic herbicides and reduce environmental pollution and promote soil health.

P. fluorescens play a crucial role in enhancing phosphate (P) availability for the growth of oil palm. The bacterium employs various mechanisms to solubilize and mobilize phosphate from both organic and inorganic sources in soil, making it easier for plants to access. These bacterium work by secreting organic acids, phosphatases, and siderophores so it will increase the solubility of insoluble phosphorus compounds, such as phosphate rock. *P. fluorescens* will convert them into forms that can be readily assimilated by oil palm roots. With better phosphate nutrition, oil palms will become more competitive against weeds, allocating more resources toward growth and development, thereby reducing their susceptibility to weed invasion.

Despite its potential of the use of *P. fluorescens* as a weed control agent and a provider of phosphate, it faces several limitations about effectiveness, flexibility, and compatibility with existing agriculture practices. A significant challenge is the inconsistent performance of *P. fluorescens* in controlling weed populations across different soil types and environmental conditions. Variability in microbial activity and phosphate-solubilizing efficiency has hindered its widespread application as a weed control agent and phosphate provider. Furthermore, integrating *P. fluorescens* into existing weed management and fertilization strategies requires careful consideration of compatibility with agrochemical inputs and other farming practices, leading to logistical and economic challenges in its implementation. Despite all the challenges, there ares some significant opportunities for advancing the application of *P. fluorescens* in weed management and phosphate provisioning within agricultural systems. Developments in microbial ecology, biotechnology, and formulation science offer potential for improving the efficacy, consistency, and scalability of *P. fluorescens* based products. By elucidating the mechanisms of action and optimizing formulations, it is possible to develop tailored solutions that maximize the weed control and phosphate solubilization in different agricultural environments. As agricultural practices continue to evolve towards sustainability, harnessing the natural capabilities of beneficial microorganisms such as *P. fluorescens* offers a promising way to reduce chemical use, improve soil health and ensure the long-term productivity and resilience of agricultural ecosystems.

Phosphorus is the second most important macronutrient after nitrogen (N) for plant growth and development. Most of the phosphorus in the soil is in insoluble form and therefore cannot be absorbed by plants. P availability in soil is generally low especially in palm oil. This is because P is bound into Fe-phosphate and Al-phosphate in acid soils or $Ca_3(PO_4)^2$ in alkaline soils. Plants cannot absorb P in its bound form and it must be converted into a plant-available form (Suliasih and Rahmat 2007). The interaction between *Pseudomonas fluorescens* and oil palm plants could yield significant benefits for plant growth, including the possibility of increased phosphate uptake. These bacteria can increase phosphate availability in the soil by producing organic acids or phosphatase enzymes, which break down insoluble phosphate compounds into forms that are more easily absorbed by plants. In addition, *P. fluorescens* can also play a role in soil pathogen control, helping oil palm plants to grow healthier and more efficiently absorb nutrients, including phosphate. By stimulating the plant's defense system and accelerating nutrient cycling in the soil through organic matter decomposition, this bacterium can also help increase phosphate uptake by oil palm plants.

P. fluorescens affects oil palm plant growth and development through a complex mechanism of action. It increases nutrient availability by producing organic acids and enzymes that helps in the dissolution of nutrients in the soil, allowing plants to absorb nutrients more efficiently. In addition, *P. fluorescens* acts as a biological control agent against soil pathogens, maintaining plant health and preventing diseases that can inhibit growth. The bacterial strain can also stimulate the plant's defense system, increasing resistance to pathogen attack and environmental stress. In addition, these bacteria increase the ability of plants to absorb water and nutrients from the soil by improving the root system and nutrient absorption efficiency. *P. fluorescens* has a significant ability to increase phosphate availability in soil, either through phosphate solubilization or other mechanisms. One of the main mechanisms is the production of organic acids, such as citric acid and gluconic acid, which can reduce the pH around plant roots. This decrease in pH increases the solubility of phosphate compounds that are generally less soluble in neutral or alkaline soil pH, thus making phosphate more easily taken up by plants. In addition, *P. fluorescens* also produces phosphatase enzymes that can convert organic phosphate compounds into inorganic forms that can be absorbed by plants. Through this combination of mechanisms, *P. fluorescens* plays an important role in increasing phosphate availability in the soil, making a significant contribution to plant growth and development as well as overall farmland productivity. With sufficient phosphate availability, oil palm plants can experience faster and healthier growth, producing leaves that are more vigorous. This is demonstrated in a study by Suliasih and Rahmat (2007), which explains that the addition of *P. fluorecens* to phosphate-rich picovskaya agar, shows the results of the formation of a wide clear zone. This shows that Pseudomonas is a phosphate solubilizing bacteria that can help the absorption and availability of phosphate in plants. As the palm oil industry increasingly shifts towards sustainable cultivation practices, *P. fluorescens* as bioagent has gained significant attention, due to its potential to enhance plant growth and its ability to control harmful weeds and pathogens. Nevertheless its application specifically in oil palm plantations remains limited by several factors that impede its widespread adoption. Several characteristics of *Pseudomonas* species allow them to function as plant growth promoters and biocontrol agents. These features include their strong ability to compete in the rhizosphere, rapid colonization, production of various root elongation, bioactive compounds and their responses to environmental stress (Mehmood *et al.* 2023).

On the current trends, *Pseudomonas* studies are more focused on horticulture crops for daily foods, such as tomato and artichoke. On a study done by Ullah *et al.* (2022), the bacterial strains applied notably enhanced the transfer of potassium (K), calcium (Ca), magnesium (Mg), and zinc (Zn) from the soil to the plant shoots at wheat and rice cultivation. In another study done by Isma *et al.* (2015), the pure culture of Pseudomonas GanoEB3 has demonstrated the ability to inhibit the growth of G. Boninense in vitro and has proven effective in controlling *G. Boninense* infection in oil palm seedlings; *Pseudomonas* GanoEB3 has the capability to decrease the incidence of *G. Boninense* disease by reducing the number of dead seedlings in oil palm. Study done by Kalbuadi *et al.* (2024) investigates the effect of beneficial microbes on macronutrient uptake on oil palm seedling growth, one of the macronutrients being phosphorus. The results show that a significant difference on the nutrient uptake increased due to the influence of *P. fluorescens.* Another benefit is that after 3–4 years of consistent use, biofertilizers are no longer needed, as the initial inocula are sufficient to sustain growth and multiplication on their own (Bumandalai and Tserennadmid 2019).

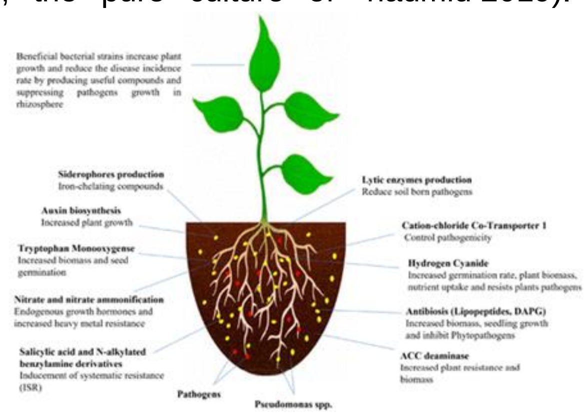

Figure 1 Systematic explanation of multifaceted *Pseudomonas* roles on plant growth.

Table 1 Macronutrient content in oil palm seedlings leaves at 6 MAP (Kalbuadi *et al.* 2024)

Treatments	**P (%)**
P0	0.50 b
P1	0.55 b
P2	0.66 a
P3	0.68 a
P4	0.68 a
P5	0.70 a
P6	0.68 a
P7	0.74 1
CV (%)	7.9

*) The Duncan's new multiple range test at = 0.05 finds no statistically significant difference between means in the same column and following the same letter.

Despite these promising findings on the effectiveness of *Pseudomonas* as a biofertilizer, there are still notable challenges that need to be addressed to fully realize its benefits in agricultural systems. The ability of *Pseudomonas* species to solubilize phosphate, a key point on bioagent, can differ due to genetic variability. Not all strains possess the ideal genetic mechanisms for consistent phosphate solubilization (Ou *et al.* 2022). The widespread use of *Pseudomonas* biofertilizers in large-scale agricultural systems may require significant optimization efforts. These include the development of appropriate formulations and efficient delivery methods to ensure the biofertilizer's effectiveness under diverse field conditions. However, such advancements can be resource-intensive, potentially driving up production and distribution costs. As a result, the overall expense for farmers may increase, posing an economic challenge for those looking to adopt biofertilizers as part of their sustainable farming practices. Balancing cost-effectiveness with optimization is therefore crucial for the broader adoption of *Pseudomonas* biofertilizers in large-scale agriculture (Yaashikaa *et al.* 2020).

Future studies should focus on genetically engineering *P. fluorescens* strains that specifically target weed growth in oil palm plantations, offering a tailored solution to one of the major challenges in this industry. These engineered strains could greatly improve weed management, reducing reliance on chemical herbicides while promoting a more sustainable agricultural practice. To make such innovations practical, researchers must also investigate methods for large-scale production of these bioagents, ensuring that they are cost-effective and easily accessible to palm oil farmers. Cost-efficiency is especially critical in this context, as high production and application costs could deter adoption in commercial plantations. Furthermore, more research should be conducted on the role of *P. fluorescens* as a biocontrol agent, with particular emphasis on its allelopathic potential to suppress weed growth through competition in the rhizosphere. Given the significant need for sustainable weed control in oil palm cultivation, this bio agent's ability to outcompete weeds presents a promising alternative to chemical solutions. Addressing these scientific and economic aspects will be key to integrating *P. fluorescens* into the future of sustainable palm oil production.

CONCLUSION

The use of *Pseudomonas fluorescens* in oil palm plantations can significantly boost crop productivity and quality by mitigating competition from detrimental weeds. The bacterium employs several mechanisms, including nutrient competition, the production of antibacterial substances, and the stimulation of the plant’s defense system to suppress weed growth. Furthermore, *P. fluorescens* enhances soil phosphate availability by producing organic acids or phosphatase enzymes that convert insoluble phosphate compounds into more plant-absorbable forms. To maximize its effectiveness, it is essential to evaluate the environmental conditions and specific weed problems in the plantation, and to select the *P. fluorescens* strains that are most compatible with the unique conditions and challenges present in the field.

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REFERENCES

BPS RI. 2021. Statistik Kelapa Sawit Indonesia 2020: Survei Perusahaan Perkebunan Tahun 2020. Jakarta: BPS Publishing.

Dahlianah I. 2019. Keanekaragaman jenis gulma di perkebunan kelapa sawit Desa Manggaraya Kecamatan Tanjung Lago Kabupaten Banyuasin. Indobiosains. *1*(1): 30–37.

Dubos B, Snoeck D, Flori A. 2016. Excessive Use of Fertilizer can Increase Leaching Processes and Modify Soil Reserves in Two Ecuadorian Oil Palm Plantations. *Expl Agric*. *53*(2):1–14. DOI: 10.1017/s0014479716000363.

Euler M, Schwarze S, Siregar H, Qaim M. 2016. Oil palm expansion among smallholder farmes in Sumatra, Indonesia. J Agric Econ. *67*(3): 658–676. DOI: 10.1111/1477-9552.12163.

Ibrahim M, Iqbal M, Tang YT, Khan S, Guan DX, Li G. 2022. Phosphorus mobilization in plant–soil environments and inspired strategies for managing phosphorus: a review. Agronomy. *12*(10):25–39. DOI: 10.3390/agronomy12102539.

Anjani IG, Saputri AB, Armeira ANP, Januarita D. 2022. Analisis konsumsi dan produksi minyak kelapa sawit di Indonesia dengan menerapkan metode moving average. *JURIKOM*. *9*(4):1014–1014. DOI: 10.30865/jurikom.v9i4.4506.

Supriatna J, Setiawati MR, Sudirja R, Suherman C, Bonneau X. 2023. Migration from inorganic to organic fertilization for a more sustainable oil palm agro-industry. Heliyon. *9*(12):1–17. DOI: 10.1016/j.heliyon.2023.e22868.

Kalbuadi DN, None D, Pulunggono HB, Santi LP. 2024. Effect of beneficial microbes on macronutrient uptake and oil palm seedling growth in peat soil. *IOP* Conf Ser: Earth Environ Sci. *1308*(1):1–9. DOI:10.1088/1755-1315/1308/1/012029

Khatiwada D, Palmén C, Silveira S. 2018. Evaluating the palm oil demand in Indonesia: production trends, yields, and emerging issues. Biofuels. 12(2):1–13. DOI: 10.1080/17597269.2018.1461520.

Krishna V, Euler M, Siregar H, Matin Q. 2017. Differential livelihood impacts of oil palm expansion in Indonesia. *Agric Econ.* *48*(5): 639–653. DOI: 10.1111/agec.12363.

Latha PC, Gopal H. 2010. Effect of herbicides on soil microorganisms. *Indian J Weed Sci*. *42*: 217–222.

Linu MS, Asok AK, Thampi M, Sreekumar J, Jisha MS. 2019. Plant growth promoting traits of indigenou phosphate solubilizing *Pseudomonas aeruginosa* Isolates from chilli (*Capsicumannuum L.) Rhizosphere*. Communi Soil Sci Plant Anal. *50*(4): 444–457. DOI: 10.1080/00103624.2019.1566469.

Mehmood N, Saeed M, Zafarullah S, Hyder S, Rizvi ZF, Gondal AS, Jamil N, Iqbal R, Ali S, Sezai E, Kupe M. 2023. Multifaceted impacts of plant-beneficial *Pseudomonas* spp. in managing various plant diseases and crop yield improvement. ACS Omega. *8*(25): 22296–22315. DOI: 10.1021/acsomega.3c00870

Bumandalai O, Tserennadmid R. 2019. Effect of *Chlorella vulgaris* as a biofertilizer on germination of tomato and cucumber seeds. Int J Aquat Biol. *7*(2): 95–99. DOI: 10.22034/ijab.v7i2.582

Ou K, He X, Cai K, Zhao W, Jiang X, Ai W, Ding Y, Cao Y. 2022. Phosphate-solubilizing *Pseudomonas sp.* strain WS32 *Rhizosphere* colonization induced expression changes in wheat roots. Front Microbiol. 13(927889):1-13.

Prasetyo H, Zaman S. 2016. Pengendalian gulma perkebunan kelapa sawit (*Elaeis guineensis Jacq*.) di perkebunan Padang Halaban, Sumatera Utara. Buletin Agrohorti. DOI: 10.29244/agrob.4.1.87-93

Rani L, Thapa K, Kanojia N, Sharma N, Singh S, Grewal AS, Srivastav AL, Kaushal J. 2020. An extensive review on the consequences of chemical pesticides on human health and environment. J Clean Prod. 283(124657). DOI: 10.1016/j.jclepro.2020.124657

Shigetomi Y, Ishimura Y, Yamamoto Y. 2020. Trends in global dependency on the Indonesian palm oil and resultant environmental impacts. *Sci Rep*. *10*(1): 20624.

Suliasih S, Rahmat R. 2007. Phosphatase activity and solubilization of calcium phosphate by phosphate solubilizing bacteria. *Biodiversitas*. *8*(1):23–26. DOI: 10.13057/biodiv/d080105

Thongjua J, Thongjua T. 2016. Effect of herbicides on weed control and plant growth in immature oil palm in the wet season nakhon si thammarat. Int J Agric Technol*.* *12*(1):1385–1396.

Yaashikaa PR, Kumar PS, Varjani S, Tamilselvi S, Saravanan A. 2020. Formulation and combinatorial effect of *Pseudomonas fluorescens* and *Bacillus* coagulans as biocontrol agents. *Biocatal Agric Biotehnol*. *30*:101868. DOI: 10.1016/j.bcab.2020.101868

Zainab N, Amna KAA, Azeem MA, Ali B, Wang T, Shi F, Alghanem SM, Hussain MMF, Hashem M, Alamri S, Latef AAH, Ali OM, Soliman MH, Chaudhary HJ. 2021. PGPR-Mediated plant growth attributes and metal extraction ability of *Sesbania sesban L.* in industrially contaminated soils. Agronomy. *11*(9): 1820.

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Internalization of Environmental Externalities: Processing Palm Waste into Renewable Energy

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ABSTRACT

In 2021, the European Union issued a lawsuit at the World Trade Organization (WTO) regarding the halt in palm oil exports. The European Union Parliament considers the palm oil industry in Indonesia to be one of the triggers of deforestation, degradation and other environmental problems. Based on data from the Central Statistics Agency in 2019, the area of oil palm plantations in Indonesia reached 14.3 million hectares and the area of oil palm plantations in the Riau Province was 2.7 million hectares (Yanti and Lestari 2020). This is based on the high demand for oil from palm oil and its derivative products which has an impact on negative externalities due to the extraction process carried out. The Palm Oil Fresh Fruit Bunches (FFB) production process produces many products such as Crude Palm Oil (CPO) and Palm Kernel Oil (PKO). Crude palm oil (CPO) production plays an important role in both the local-global environment and socio-economics. In this case, Internalization of Externalities is needed to minimize dirty oil (palm oil waste) which is detrimental to third parties from the management process carried out. Based on the case study of Panyabungan Village, the externality value for liquid palm oil waste is IDR 146,194,433,- after internalizing the externalities, we get a Total Economic Value (TEV) of IDR 627,602,359,- with the liquid waste and solid waste aspects of palm oil in three locations namely; Jambi, Bengkulu and Kalimantan. As a preventive form of assessing externalities, economic and environmental studies also include a SWOT analysis to develop strategies for the sustainability of palm oil in Indonesia.

Keywords: Externalities, fresh fruit bunches, internalization, palm oil, sustainability.

INTRODUCTION

In 2021, the European Union issued a lawsuit at the World Trade Organization (WTO) regarding the halt in palm oil exports. The European Union Parliament considers the palm oil industry in Indonesia to be one of the triggers of deforestation, degradation and other environmental problems. Deforestation is a problem for major countries in the world. Based on data from the Central Statistics Agency in 2019, the area of oil palm plantations in Indonesia reached 14.3 million hectares and the area of oil palm plantations in the Riau Province was 2.7 million hectares (Yanti and Lestari 2020). In 2019, foreign exchange generated from the palm oil sector was recorded at US$20.2 billion, an increase of $1.6 billion (Ayu KP 2021). This means that palm oil provides benefits in the form of increased foreign exchange for Indonesia. However, it is a common fact that the palm

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oil business contributes significantly to deforestation in countries such as Malaysia and Indonesia (Hendriani *et al.* 2023). According to the investment management institute, Indonesia is the largest producer and exporter of palm oil in the world. However, Indonesia is the country that emits the most greenhouse gases, followed by the United States and the People's Republic of China (Hendriani *et al.* 2023).

In the past 10 years, most of the non-oil palm plantations throughout Indonesia have been converted into oil palm plantations (Ziaulhaq 2022). The forest area reached 119.7 million hectares, the deforestation area was 68.1 million hectares, while the area of oil palm plantations was only 597 thousand hectares or only around 0.9 percent of the deforestation area (PASPI 2014). The increasing amount of land being converted into oil palm plantations results in the resulting large number of externalities. Externalities arise when impacts on the environment that result in social costs and benefits are not considered by the person or group of people who cause these impacts (Utami 2018). Meanwhile, the palm oil fresh fruit bunches (FFB) production process produces main products such as crude palm oil (CPO) and palm kernel oil (PKO). Palm oil producers are required to produce more oil. With the high demand for petroleum from palm oil and its derivative products, this has an impact on negative externalities due to the extraction process carried out.

Potential sources of waste resulting from palm oil processing (extraction) can also be used as energy. Fresh fruit bunches (FFB) produce main products in the form of crude palm oil (CPO) and palm kernel oil (PKO). The results of Crude Palm Oil (CPO) management produce liquid waste and solid waste. Solid waste is in the form of TKKS, fiber waste and ash. Meanwhile, liquid waste can be used as POME. Palm oil activities give rise to externalities in the form of waste. Most of the waste produced is liquid waste which comes from the extraction of the main product crude palm oil (CPO) and if it is not utilized it will cause environmental pollution. However, externalities resulting from these activities are often ignored and not taken into account in the cost components of an activity (Utami 2017).

As a step to change the wasted waste process into something useful and beneficial, treatment is needed that can change costs into opportunities by changing what was originally external costs into internal benefits. This handling can be done through Internalization of Externalities. Internalization of external costs is the process of including these costs in the price of a product or service, so that all costs related to production or consumption are reflected in the market price (Fauziyah 2024). This effort is carried out as a form of accountability for the impacts produced by liquid waste from Palm Oil by providing compensation. The compensation given is not in the form of direct cash costs, this is based on the fact that compensation in the form of money given directly to the polluted party is not an alternative solution to reduce the pollution that occurs. As a form of prevention that can be done, namely by; (1) Examining Palm Oil externalities, (2) Analyzing the internalization of externalities (3) Developing strategies for internalizing externalities.

MATERIALS AND METHODS

This paper is presented using secondary data collection methods obtained from literature, libraries, previous theses, journals, the Central Statistics Agency (BPS) and other sources of information that relate to and support the writing of this paper. The secondary data required includes; (1) Data on the largest palm oil producers in the world, (2) Types of palm oil, (3) Biodiesel needs, (4) Area and production of Indonesian palm oil, (5) Indonesian energy consumption per sector, (6) Percentage of FFB derived capacity, and other supporting data.

Analysis (SWOT) is carried out as a form of formulating and developing strategies to strengthen the strength of the Indonesian Palm Oil market at the global level, weaknesses in the palm oil processing process from upstream to downstream in Indonesia, Opportunities for derivative products produced from palm oil waste, Threats that will occur in the future regarding the environmental impacts resulting from Palm Oil.

The SWOT Matrix can compile and develop 4 types of strategies, namely (A'la 2019): (1) SO (strenghts-opportunities), (2) WO (weaknesses-opportunities), (3) ST (strenghts-threats), (4) WT (weaknesses-threats). Another analysis tool uses Internalization of Externalities. Externality Internalization is the process of incorporating external values (losses) experienced by third parties into production costs. Apart from that, it can also be used as an analytical tool in developing strategies for utilizing palm oil into new, renewable energy. The economic benefit method is also used to complement the value and benefits of renewable energy originating from palm oil waste processing. Economic benefits are benefits that are measured and obtained directly.

Literature Review

Oil palm (*Elaeis guineensis*) is a perennial plant native to humid tropical regions in West and Central Africa that grows between 10 degrees north latitude and 10 degrees south latitude. (Nkongho *et al.* 2015). Palm oil consists of two species, namely Elaeis guineensis, originating from Africa and *Elaeis oleifera* originating from America (Sudaryanti 2017). Oil palm can grow well in a temperature range of 22–33 °C or an average of 27 °C; rainfall 1250–3000 mm per year; even distribution throughout the year (dry months less than 3 months); The length of light required for oil palms is 6 hours per day and the relative humidity is 50–90 percent (PASPI 2014).

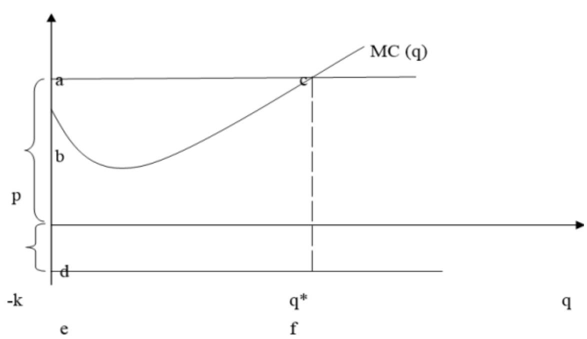
Oil palm plants were imported from Africa to Indonesia in 1884 and then placed in the Bogor Botanical Gardens (Sudaryanti 2017). For the maintenance process, oil palm plants go through three phases, namely seeding (±1 year), maintenance of immature plants (1–4 years) and maintenance of mature plants (4–25 years) (PASPI 2014). Oil palms produce Fresh Fruit Bunches (FFB) which begin to be harvested at the age of 4 years and producton increases as the age of the oil palm increases (PASPI 2014). The peak of FFB production is generally at the age of 8–16 years and is replanted again after the age of 25 years (PASPI 2014).

After producing Fresh Fruit Bunches (FFB), oil palm fruit has economic value. Palm oil is a palm tree that produces food oil, industrial oil and biodiesel (vegetable fuel) (Silitonga *et al.* 2020). Palm kernel shells can be used as fuel and carbon, while palm kernel dregs can be used for animal feed, as well as mesocarp fiber can be processed into medium density fiber-board and processed into food and non-food products (Kurniawan 2012). Palm oil has the highest advantages as an oil producer. Oil productivity per hectare of oil palm can produce around 4.5 tons of oil (PASPI 2014). Crude palm oil (CPO) production plays an important role in both the local-global environment and socio-economics. With the high demand for palm oil in Indonesia, this has resulted in the expansion of palm oil plantations. Oil palm plantations result in various Negative impacts on the environment, such as deforestation, biodiversity and climate change. If not managed well, the expansion of oil palm plantations will continue to destroy forests that should be protected. With so many negative externalities arising from these plantations, it is worth considering the environmental costs resulting from the losses incurred. According to Smith in Sofiana, environmental policy must be given more attention, not only showing concern by monitoring local conditions but also broader international conditions such as global ecological balance, damage to the ozone layer and the greenhouse effect. According to Virdausya, the act of consumption or production of one party has an influence on other parties and no compensation is paid by the party causing it or compensation received by the affected party is called an externality. The theory of externalities in Economics began with the publication of a book entitled The Economics of welfare written by Arthur Pigou

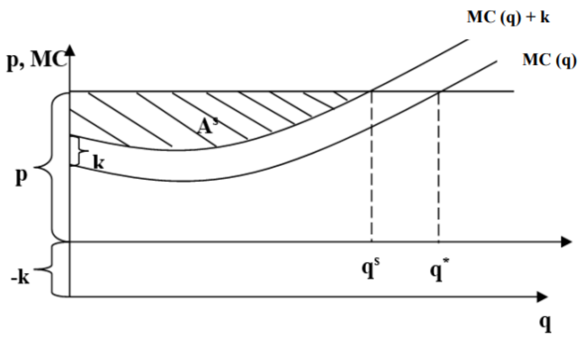
(1920). In the book, Pigou explains that externalities occur when economic activities affect third parties who do not have direct involvement in the economic transaction. Externalities are generally divided into two, namely positive and negative externalities (Dzaki and Sugiri 2015): 1). Positive Externalities will have a beneficial impact on the recipient of the externality. Profits can be made an impact. 2). Negative externalities will have a detrimental impact on the recipient of the externality. This loss means that people who receive externalities will incur additional costs to cover the perceived losses. In this topic, the problem of Palm Oil is included in Negative Externalities. As the amount of damage to the environment increases, the marginal cost of damage due to pollution will also increase. One step that can be taken is to include the costs of environmental pollution due to palm oil processing into the production process. Production prices after including environmental pollution costs will have implications for production prices which will increase. This process is called Internalization of Externalities. Economists have shown that when externalities exist, markets will not be efficient unless these external costs are internalized and economic agents take these costs into account when making decisions (Štreimikienė 2016). In general, the internalization of environmental externalities can be evaluated at different levels along the value chain (Høst-Madsen *et al*. 2014) and later it can be compared between one Palm Oil location and another.

Based on the Figure 1, the external costs borne by society are in the d-e-q*-f area, while the consumer surplus is in the a-b-c area where the surplus does not yet reflect the social surplus. However, if the company carries out waste management, the company will optimize output when the Marginal Social Cost (MC(q)+k) is the same as the Marginal Social Benefit (MC(q)+k =MSB). In the graph above, the internalization of external costs is shown with a quantity that was originally –k to k+A. Based on West Kutai Regency regional regulation (Perda) number 17 of 2009 article 4, regarding waste water quality management. Every person in charge of a business and/or activity that will utilize and/or dispose of waste water is obliged to meet the quality standards for the disposal and/or utilization of waste water in accordance with the provisions of statutory regulations.

Based on West Kutai Regency regional regulation (Perda) number 17 of 2009 article 4, regarding waste water quality management. Every person in charge of a business and/or activity that will utilize and/or dispose of waste water is obliged to meet the quality standards for the disposal and/or utilization of waste water in accordance with the provisions of statutory regulations. The maximum value allowed for COD is 350 mg/L, while for BOD it is 100 mg/L (Melisa and Apriyanto 2020). If the



(a)



(b)

Figure 1 (a) Free market conditions before the internalization of external costs, (b) Free market conditions after internalization of external costs.
(Folmer 2000)

waste measurement results for BOD and COD values are above the maximum limit, the waste must not be disposed of directly into the environment (Sitepu 2021). However, if the BOD and COD values are below the maximum levels, the waste may be disposed of into the environment. Before liquid waste is discharged directly into the environment, it is necessary to first process the liquid waste so that it does not pollute the environment (Sitepu 2021). In this case, there are already maximum limit regulations for the waste water released. Based on West Kutai Regency regional regulation (Perda) number 17 of 2009 article 5, persons in charge of businesses and/or activities are prohibited from giving dirty oil extracted from the IPAL pond (after deoiling pond) to third parties. In this case, internalization of externalities is needed to minimize dirty oil (palm oil waste) which is detrimental to third parties. Based on the regulation of the minister of energy and mineral resources of the Republic of Indonesia No. 24 of 2021, biodiesel financing funds are oil palm plantation funds which are collected, administered, managed, saved and distributed by the fund management agency for the purpose of covering the shortfall between the market index price of oil type fuel. Diesel with the market index price of biodiesel type BBN.

In this case, funds for liquid waste management are produced for the use of Biodiesel has been collected and there are institutions that manage it. For this reason, an internalization of externalities study is needed which can be a recommendation for related institutions to minimize the environmental impacts felt by third parties.

Palm Oil Waste Externalities

Palm oil in the form of fresh fruit bunches (FFB) produces two main products in the form of crude palm oil (CPO) and palm kernel oil (PKO). With the various extraction processes produced, crude palm oil (CPO) produces liquid waste which can then be utilized as POME. Apart from that, crude palm oil (CPO) also produces waste in the form of solid waste (fiber, EFB, ash). Along with progress and the amount of research carried out, innovations are starting to emerge regarding the use of palm oil waste. The process of processing palm oil from upstream to downstream generally produces waste in the process.

The total loss due to externalities that occurred was IDR 146,194,433.00/year (Utami *et al.* 2018). Meanwhile, based on research conducted by Afifah (2016) regarding palm oil solid waste at PT. Sandabi Indah Lestari, North Bengkulu. The direct use value obtained from the sale of palm oil solid waste is idr 350,186,914.47/ month, and the indirect use value is IDR 167,954,040/month, so obtained a total economic value of IDR 518,140,954.47/ month (Afifah 2016). From these 2 cases it can be compared that every palm oil in Indonesia produces waste. Solid and liquid waste is waste that is often found and can have economic value if it is managed and internalized to reduce third party losses.

RESULTS AND DISCUSSION

Internalization of External Costs of Palm Oil Waste

Based on the estimates for each component of liquid waste and solid waste (external costs), the following is an estimate of the internalization of external costs components. Obtained total economic value (TEV) of IDR 627,602,359 with aspects of liquid waste and solid waste in palm oil in three locations, namely; Jambi, Bengkulu and Kalimantan. In the process of processing palm oil from upstream to downstream generally produces waste in the process. Starting with fresh fruit bunches (FFB) which are produced and divided into 3 cores in FFB, namely flesh, core, and shell. From this fruit, many by-products are produced and often produce waste in the form of solid and liquid. In this paper, waste conversion from a total of 112533.22 tonnes of fresh fruit bunch (FFB) is presented to produce 88,706.80 m^3 of POME waste. If this waste is converted into electrical energy, it will produce an economic profit of IDR 6,903,173. Meanwhile, 1 ton of FFB can produce 5,569.82 mg/L of POME which can be used to make biodiesel. And if converted into economic value, it will produce a profit of IDR 12,382/L. However, in the process of making biodiesel a catalyst is needed to accelerate the manufacturing process through transesterification. The second liquid waste is kernel waste, which produces 65 kg from a total of 1 ton of palm oil FFB. Kernel waste can be used as energy at a selling price of IDR 1,692/kWh. Solid waste has many management alternatives such as fertilizer, biopellets, boiler fuel and others. In conversion into boiler fuel, 1 ton FFB can obtained 0,005 ton shell and 0,135 ton fibre.

SWOT Development as a Form of Internalization of Externalities

As a preventive form of assessing the externalities of economic and environmental studies, a SWOT analysis was created to develop a strategy for the sustainability of palm Oil in Indonesia. In this paper there is not only an analysis model but also a SWOT analysis with the matrix in Figure 3.

Table 2 Internalization of external costs.

Benefit Components	Total Economic Value (Rp/year)
External Cost of Palm Oil Waste:	
a.Liquid Waste (Jambi)	Rp 146.194.433
Total	**Rp 146.194.433**
Economic Benefits of processed waste:	
a. Direct Use Value of Solid Waste (North Bengkulu)	Rp 350.186.914
b.Biodiesel sales value	Rp 70.317.839
c.Electricity utilization value	Rp 60.903.173
Total	**Rp 481.407.926**
TEV	**Rp 627.602.359**

Secondary Data (author's preparation)

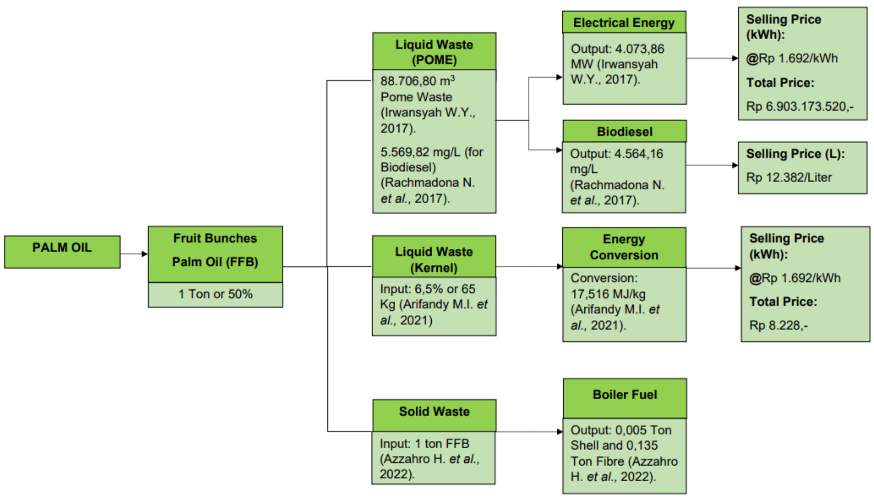


Figure 2 Oil palm tree.

Internal Factors and External Factors	Strength (S)	Weakness (W)
	(a) There are maximum limit regulations for waste water released (COD and BOD). (b) There are already oil palm plantation funds collected by the Fund Management Agency. (c) There are already sanctions for factories that carry out processes that pollute the environment beyond specified limits.	(a) The Market Index Price (HIP) of Biodiesel Vegetable Fuel (BBN) in Indonesia is still quite expensive. (b) Limited infrastructure in terms of adequate equipment such as ponds for the transesterification process in liquid waste (c) Minimal education and training
Opportunity (O)	**Strategy (SO)**	**Strategy (WO)**
(a) High market demand (b) Potential for utilizing solid waste and liquid waste into by-products with economic value (c) Utilization of environmentally friendly energy sources originating from waste	(a) Tighten existing regulations and review regulations related to environmentally friendly palm oil waste management processes (b) Monitoring and evaluating palm oil mills that have managed waste into economically valuable products (c) Facilitate adequate infrastructure	(a) Conduct further studies and research regarding the utilization of palm oil waste by using more affordable tools and materials in order to reduce selling prices (b) Conduct training and education regarding the process of managing palm oil waste by products with economic value (c) Facilitate adequate infrastructure to support the palm oil waste management process
Threat (T)	**Strategy (ST)**	**Strategy (WT)**
(a) Competition for alternative products that are more affordable and environmentally friendly in the global market (b) The impact of climate change affects palm oil production	(a) Strengthen education regarding the importance of using environmentally friendly products by strengthening relevant government regulations (b) Applying practices by conducting studies on all aspects, especially climate predictions during the harvest season.	(a) Develop a pricing strategy that is profitable for exporting countries and increases interest for importing countries (b) Make further studies to diversify environmentally friendly palm oil products.

Figure 3 SWOT analysis.

CONCLUSION

The palm oil industry in Indonesia is one of the triggers for deforestation, degradation and other environmental problems. The increasing amount of land being converted into oil palm plantations results in the resulting large number of externalities. In this case, Internalization of externalities is needed to minimize dirty oil (palm oil waste) which is detrimental to third parties from the management process carried out. Based on the case study of Panyabungan Village, the externality value for liquid palm oil waste is IDR 146,194,433,- after internalizing the exter nalities, we get a total economic value (TEV) of IDR 627,602,359,- with the liquid waste and solid waste aspects of palm oil in three locations namely; Jambi, Bengkulu, and Kalimantan.

REFERENCES

Ayu KP. 2021. Ekspansi perkebunan kelapa sawit di Kalimantan Tengah: mekanisme politik di balik kerusakan ekologi. J Sosiologi. 4(2):61–71.

Abdillah MH, Budi IS. 2021. Pembuatan dan hasil aplikasi bahan pembenah tanah di lahan basah sub-optimal. BPI. 4(1):23–28.

Afifah S. 2016. Analisis Nilai Ekonomi Limbah Industri Kelapa Sawit di PT. Sandabi Indah Lestari Kabupaten Bengkulu Utara. Agrisep. 15(2).

A’la Nurul 2019. Strategi pengembangan usaha perkebunan kelapa sawit pada PT Perkebunan Nusantara I Langsa di Provinisi Aceh. [skripsi]. Institut Pertanian Bogor.

Dzaki A, Sugiri A. 2015. Kajian eksternalitas industri pengasapan ikan di Kelurahan Bandarharjo Kecamatan Semarang Utara. Jurnal Teknik PWK. 4(1):134–144.

Fauziyah S, Mutafarida B, Yuliani. 2024. Internalisasi Biaya Eksternal dalam Penawaran: Perspektif Maqasid Syariah. Khozana: J Islam Econ Bank. 8(2):14–20.

Folmer H, Gabel HL, Opschoor H. 2000. Principles of environmental and resource economics. In: Oates WE, editor. New horizons in environmental econimics. Cheltenham (UK): Edward Elgar Publishing.

Hendriani SZ, Ningsih S, Firmansyah R. 2023. Analisis faktor-faktor yang mempengaruhi larangan ekspor minyak kelapa sawit di indonesia selama pandemi: literature review. JEMSI. 9(4):1087–1092.

Kurniawan W. 2012. Urgensi pembangunan agroindustri kelapa sawit berkelanjutan untuk mengurangi pemanasan global. J. Teknik Industri. 2(1):74–83

Melisa, Apriyanto M. 2020. Pengolahan

Limbah Cair Pabrik Kelapa Sawit. J Teknologi Pertanian. 9(2).86–93.

Nkongho RN, Ndjogui E, Levang P. 2015. History of partnership between agro-industries and oil palm smallholders in Cameroon. EDP Sciences. 22(3):1–15. DOI: 10.1051/ocl/2015005.

Palm Oil Agribusiness Strategic Policy Institute (PASPI). 2014. Industri Minyak Sawit Indonesia Berkelanjutan. Medan (ID): Pustaka PPKS Medan.

Silitonga YR, Heryanto R, Taufik N, Indrayana K, Nas Marwayanti, Kusrini N. 2020. Budidaya Kelapa Sawit dan Varietas Kelapa Sawit. Sulawesi Barat (ID): Balai Pengkajian Teknologi Pertanian Sulawesi Barat.

Sitepu BR. 2021. Kajian produk turunan industrial palm oil (IPO) dan pengolahan limbah pada pabrik kelapa sawit skala miniplant. [skripsi]. Institut Pertanian Bogor.

Sudaryanti DA. 2017. Analisis ekonomi pemanfaatan palm oil mill effluent (POME) menjadi biopower. [skripsi]. Institut Pertanian Bogor.

Utami R. 2017. Pengaruh ekspansi perkebunan kelapa sawit terhadap masyarakat dan internalisasi eksternalitas pabrik kelapa sawit. [skripsi]. Institut Pertanian Bogor.

Utami R, Putri E, Ekayani M. 2018. Biaya eksternal dan internalisasi limbah pabrik kelapa sawit. J Pengelolaan Sumberdaya Alam dan Lingkungan. 8(2): 143–150.

Yanti NR, Lestari I. 2020. Potensi limbah padat perkebunan kelapa sawit di Provinsi Riau. Wahana Foresta: Jurnal Kehutanan. 15(2):1–11.

Ziaulhaq W. 2022. The Presence of the Palm Oil Industry on the Community Environment. IJAEA. 1(1):1–12.

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Determination of Carotenoid Bioavailability from Palm Oil Microencapsulation

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ABSTRACT

Indonesia is the largest palm oil supplier in the world with a total production value of 20.97 million tons. Palm oil has a high content of carotenoids that act as antioxidants in the body. However, carotenoids and their derivatives have a conjugated structure that is unstable to oxidation and easily damaged. One of the optimal efforts to maintain the stability of carotenoids is by microencapsulation. This study aims to determine the efficiency of the palm oil microencapsulation method in maintaining the carotenoid components in it. The method used in this research is Systematic Literature Review based on Google Scholar, ScienceDirect, and Springer databases with predetermined inclusion criteria. The results showed that all palm oil microencapsulation methods produced good efficiency values and stable physicochemical characteristics of carotenoids even including other micronutrients such as vitamin E, moisture content, fatty acids, etc. which were also classified as stable. Overall, the supercritical carbon dioxide (SEDS) method produced the best quality while the spray drying method is a good choice for commercial microencapsulation. The conclusion of this study is that microencapsulation is able to protect the bioavailability of carotenoids in palm oil in a stable condition with values that are still within the standard range so as to produce better palm oil products as food ingredients for further use in a food product.

Keywords: Carotenoid, microencapsulation, palm oil

INTRODUCTION

The level of vegetable oil consumption in the world in 2020/2021 reached 209.14 million metric tons with palm oil as the largest supporter of consumption figures, reaching 73.22 million metric tons (GAPKI 2021). Palm oil is produced from oil palm plantations, one of which is Indonesia, which is the largest palm oil supplier in the world with a total production figure of 45.5 million metric tons in the 2022/2023 period (United State Department of Agriculture 2023). This is in line with the high level of palm oil consumption in Indonesia. According to the Indonesian Palm Oil Association's 2023 report, Indonesia's total crude palm oil (CPO) consumption was 20.97 million tons in 2022, an increase of 13.82% from 2021 (Canossa *et al.* 2020). Palm oil contains complex nutrients, such as beta carotene and provitamin A that act as antioxidants in

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the body, either alone or together with other carotenoid compounds such as lycopene, lutein, and others. Palm oil's beta carotene content is proven to be higher than carrots, tomatoes, papaya, and spinach leaves. (Dong *et al.* 2017). In addition to beta carotene, the fat content of palm oil is also good balanced with 50% saturated fat, 39% monounsaturated fat (MUFA), and 11% polyunsaturated fat (PUFA) (Marliyati *et al.* 2021). Cooking oil is mostly used by people as the main ingredient for frying. According to Zhang *et al.* (2020), during the frying process two things will occur, namely cooking and dehydration. Cooking will trigger several heat-induced chemical reactions such as starch gelatinization, protein denaturation, Maillard reaction and caramelization, while dehydration occurs because the frying process occurs at temperatures above 100 °C and water evaporation occurs. This promotes the destruction of carotenoids contained in the oil. Carotenoids and their derivatives have a conjugated structure making them unstable to oxidation and easily degraded when exposed to light, oxygen, acids, and heat during food processing and storage. (Aryayustama *et al.* 2018).

One of the optimal efforts to maintain the carotenoid content in palm oil is the encapsulation process. Encapsulation aims to protect environmentally sensitive substances, protect organoleptic properties such as colour, taste, and odor as well as maintain bioactive content and extend shelf life (Agustin and Wibowo 2023). In addition, several studies have reported that encapsulation is effective in preserving nutrients during processing and increasing the bioavailability of nutrients during digestion (Ananda *et al.* 2023). Research on the application of microencapsulation to palm oil has often been carried out with a variety of different methods such as Spray drying, complex coacervation, Foam-Mat Drying, Solids Content, and supercritical carbon dioxide (SEDS). This study aims to analyse each method of microencapsulation of palm oil by comparing aspects of efficiency and quality of the products produced.

MATERIAL AND METHODS

This research uses a systematic literature review method with keywords related to the research topic, namely “microencapsulation”, “palm oil”, and “carotenoids” within the last 10 years. This search was conducted on various databases, namely ScienceDirect and Google Scholar. The articles selected were those that fell within the inclusion criteria, which included articles with experimental study designs, full-text and accessible articles, and articles that focused on the effectiveness of palm oil microencapsulation or the stability of the concentration of bioactive components in it. All selected articles were then compiled and analysed comprehensively. The article selection process can be seen in the figure below.

RESULT AND DISCUSSION

The success of microencapsulation is influenced by the suitability of the method and the material to be encapsulated. Based on Table 1, there are 7 experimental studies on the application of microencapsulation to palm oil with several different encapsulation methods, namely spray drying, complex coacervation, foam-mat drying, solids content, extrusion, and supercritical carbon dioxide (SEDS). Each study had different types of binders such as maltodextrin (MD), emulsifying starches, and Gum Arabic (GA). Spray drying is the most commonly used method because it has a simple procedure, economical, and produces microcapsules with effective quality and stability to protect the core material (Poshadri 2010). However, this method has the disadvantage that the operation process requires high temperatures to produce microencapsulated products, which can cause damage to food ingredients. Research (Carmona *et al.* 2018) reported the results of palm oil

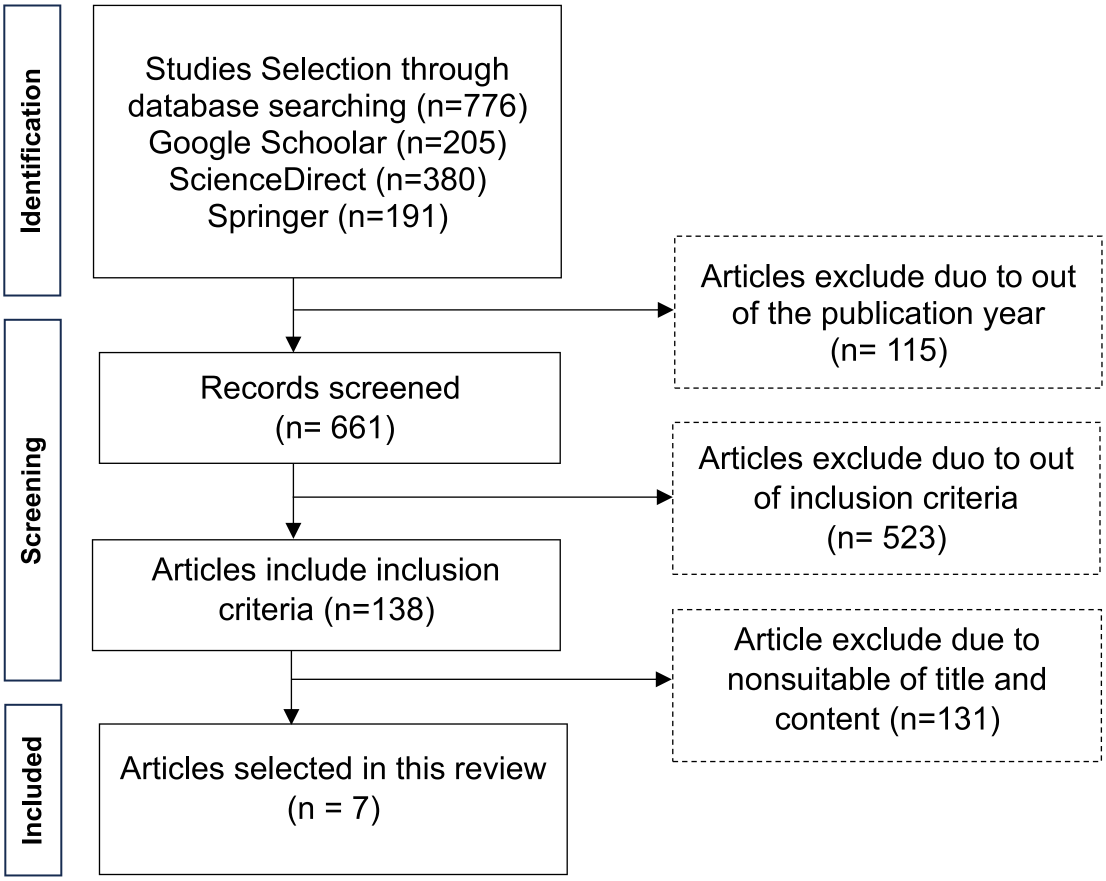

Figure 1 Flow chart selection process of the studies.

Table 1 Article research about effectiveness of carotenoid stability in palm oil microencapsulation.

No	Authors	Wall Material	Microencapsulation Method	Result	Conclusion
1	(Rutz *et al.* 2017)	Chitosan/xaanthan and chitosan/pectin	Complex coacervation	Encapsulation efficiency (EE) of carotenoids. Lyophilization (52.20% (pectin) and 62.41% (xanthan)) and Atomization (22.25% (pectin) and 32.67 (xanthan)). Bioavailability (lyophilization) pectin 39% and Xanthan 50.1%.	The lyophilization drying technique provides more efficient results compared to atomization with a fairly good level of bioavailability
2	(Saputri & Ngatirah 2019)	Na-alginat, pati sagu, *carboxyl methyl cellulose,* and chitason	Foam-mat drying	Sago starch dressing type gave the best results with a moisture content of 2.08%, free fatty acid of 0.63%, peroxide number of 23.61 meq/kg, carotenoid content of 131.61 ppm, encapsulated oil content of 53.62%, solubility of 57.03%, and munshell color of 91 (intense yellow).	Sago dressing can provide resistance to carotenoids, free fatty acids, etc.
3	(Ananda *et al.* 2023)	Carragenan	Supercritical carbon dioxide	Encapsulation effectiveness was 99.42% (fermented) and 99.02% (unfermented). In addition, bioavailability 96.11% (unfermented RPO) 99.69% (fermented RPO).	Microencapsulation is effective in both fermented and unfermented RPO with good bioavailability.
4	(Carmona *et al.* 2018)	Gum arabic	Solids content and spray-drying	The microencapsulation efficiency was 61.37–85.61% and the carotenoid content after microencapsulation was 2775.79 µg/g oil from the total content of 2910.55 µg/g oil.	Microencapsulation as a protection and preservation solution is proven to be effective but is affected by the suitability of the solids content, feed flow rate, and inlet air temperature.

5	(Lee *et al.* 2018)	Sodium caseinate, maltodextrin, and soy lecithin	Solution enhanced-dispersion by supercritical carbon dioxide (SEDS)	The best environmental conditions were at 125 bar pressure and 50°C with carotenoid efficiency retention of 82.7±12.2%; vitamin E efficiency retention of 94.3±8.0%; particle number of 5.81±2.8μm; moisture content of 3.1–4.5%; and microencapsulation efficiency of 92.1±4.3%.	Supercritical carbon dioxide (SEDS) is able to maintain fairly good physicochemistry
6	(Lee *et al.* 2020)	Sodium caseinate, maltodextrin, and soy lecithin	Supercritical carbon dioxide (SEDS) and spray drying (SD)	Supercritical carbon dioxide (SEDS) microencapsulation had the highest stability (9.8-26.5), followed by SD-M (9.2-34.9) and RPO (5.7-56.7); activation energies (Ea,kJ/mol) and absolute average relative deviations (AARDs,%) showed SEDS < SD < RPO. Bioactive concentrations. SEDS-M protects lipid oxidation and vitamin E and SD protects carotenoids.	Supercritical carbon dioxide (SEDS) is better than spray drying (SD) insignificantly.
7	(Ferreira *et al.* 2016)	Cassava starch, gum arabic, and whey protein concentrate (derived from milk)	Spray drying	After encapsulation, the average carotenoid content of crude palm oil was 600.52±16.05 μg/g from 608.39±32.94 μg/g; peroxide number was 11.16±0.00 meq/kg from 3.56±0.19 meq/kg; antioxidant activity was 29.25±1.13% from 56.83±2.49%; and fatty acid profile was 40.89±0.15 from 40.57±0.26.	The spray drying method with cassava starch and gum arabic as coating materials resulted in carotenoid stability that still remained within the standard limits, including in terms of encapsulation efficiency, carotenoids, fatty acids, peroxide number, and antioxidant activity.

Note: One of the most limiting factors of this data is on the different palm oil source used in each study.

encapsulation using the spray drying method with Gum Arabic (GA) dressing, obtained the lowest microencapsulation efficiency of 61.37% and the highest value of 85.61% with a fairly good level of bioavailability (2775.79 µg / 2910.55 µg total carotenoids). These results are influenced by several things, namely having a significant positive relationship with solids, feed flow, and inlet air temperature.

Research by Ferreira *et al.* (2016) reported the results of palm oil micro-encapsulation by spray drying method in the range of 28.66 to 56.96% with efficiency values from 92.77 to 97.89%. The highest efficiency value was obtained with gum arabic (80%) combined with whey protein concentrate (20%). However, the encapsulation process decreased the carotenoid content in palm oil from 608.39 ± 32.94 µg/g to 600.52 ± 16.05 µg/g (not significant). This is because the spray-dryer heat could have promoted isomeri-zation of trans carotenoids to their less com moncis forms.

Research by Rutz *et al.* (2017) comparing the encapsulation process with atomization (spray drying) and lyophili-zation, the results obtained by the lyophili-zation process have better effectiveness although not significant. In the bioavailability test, the lyophilization method has a value of 39% (pectin dressing) and 50.1% (xanthan dressing) while in atomization microencapsulation no similar measurements were made. This study explicitly states that the lyophilization method is better than atomization or similar to spray drying and proves that micro-encapsulation is able to increase the bioavailability of carotenoids.

The development of microencap-sulation methods continues to occur, one of the latest methods that has proven effective is supercritical carbon dioxide (SEDS). Lee *et al.* (2020) show that super-critical carbon dioxide (SEDS) is more stable than spray drying (SD), which may be due to differences in (i) the encapsula-tion process, (ii) initial surface oil content, and (iii) microcapsule size and morphology. SEDS had the highest oxidative stability ($p<0.05$) during storage (PV: 2.7–9.3 meq/kg), followed by SD (PV: 2.8-10.6 meq/kg) and RPO (PV: 2.6–14.0 meq/kg). Previously, Lee *et al.* (2018) also examined the single effectiveness of supercritical carbon dioxide (SEDS) and obtained the results that the Microencapsulation of red palm oil (o/w) with the SEDS method obtained the best properties at a pressure of 125 bar and a temperature of 50°C, namely with a carotenoid efficiency retention value of 82.7 ± 12.2% with an efficiency value reaching 92.1 ± 4.3%. The study also reported that the SEDS method compared to SD has less oil content, higher microencapsulation value and particle number, and more stable carotenoid bioavailability value.

Research on the effectiveness of supercritical carbon dioxide was also conducted by Ananda *et al.* (2023) which stated that the microencapsulation efficiency reached 99.42% and the unfermented 99.02%. This is also in line with the level of bioavailability of microencapsulated 96.11% in unfermented RPO and 99.69% in fermented RPO. The high rate was influenced by the solvent carrageenan with a high solubility level that covers the core material (palm oil) so as to provide comprehensive protection. Based on this description, the supercritical carbon dioxide method has the most optimal value both in terms of stability and bioavailability of carotenoids produced but the spray drying method has a lower value but is still classified as an effective standard for the microencapsulation process. In addition to the quality aspects of the procedure and the cost required, the spray drying method has a higher efficiency so it is very suitable when used in commercial products.

CONCLUSION

Palm oil is the world's most favourite source of vegetable oil. Palm oil has a high content of carotenoids. However, oil as a high temperature processing material is very susceptible to damage. Microencapsulation is an effort to improve the physicochemical quality of food products. There are several methods that can be used, the supercritical carbon dioxide method has the best effectiveness compared to other methods. However, spray drying can be used as an alternative in commercial foods because it has better efficiency.

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REFERENCES

Agustin DA and Wibowo AA. 2023. Teknologi enkapsulasi: Teknik dan aplikasinya. DISTILAT. *7*(2): 202–209.

Ananda HD, Nuralang N, Susanto NCA, Tarigan IL, Nelson N. 2023. Micro-encapsulation of fermented red palm oil with *L. casei* as nutracetical source. J Rekayasa Kim Lingkung. 17(2): 138–151.

Aryayustama MG, Wartini NM, Suwariani NP. 2018. Stabilitas kadar karotenoid ekstrak buah pandan (*Pandanus Tectorius*) pada cahaya dan suhu penyimpanan. Jurnal Rekayasa dan Manajemen Agroindustri. 6(3):218. DOI: 10.24843/jrma.2018.v06.i03.p05

Canossa VD, Erwinsyah, Wan X, Lixian C, den MV. 2020. Mapping the Palm Oil Value Chain Opportunities for Sustainable Palm Oil in Indonesia and China. China (CN): UNDP China Publishing.

Carmona PAO, Garcia LC, Ribeiro JA de A, Valadares L, Marçal A de F, de França LF, Mendonça S. 2018. Effect of solids content and spray-drying operating conditions on the carotenoids microencapsulation from pressed palm fiber oil extracted with supercritical CO_2. Food Bioproc Tech. 11(9): 1703–1718.

Dong S, Xia H, Wang F, Sun G. 2017. The effect of red palm oil on vitamin a deficiency: A meta-analysis of randomized controlled trials. Nutrients. *9*(12). DOI: 10.3390/nu9121281

Ferreira CD, da Conceição EJL, Machado BAS, Hermes VS, de Oliveira RA, Druzian JI, Nunes IL. 2016. Physicochemical characterization and oxidative stability of micro-encapsulated crude palm oil by spray drying. Food Bioproc Tech. *9*(1):124–136. DOI: 10.1007/s11947-015-1603-z

GAPKI. 2021. Palm industry performance 2021 and outlook 2022. 1.

Lee WJ, Tan CP, Sulaiman R, Hee YY, Chong GH. 2020. Storage stability and degradation kinetics of bioactive compounds in red palm oil micro-capsules produced with solution-enhanced dispersion by supercritical carbon dioxide: A comparison with the spray-drying method. Food Chemistry. 304:125427.

Lee WJ, Tan CP, Sulaiman R, Smith RL, Chong GH. 2018. Microencapsulation of red palm oil as an oil-in-water emulsion with supercritical carbon dioxide solution-enhanced dispersion. J Food Eng. *222*:100–109.

Marliyati SA, Rimbawan, Harianti R. 2021. Karakteristik Fisikokimia Dan Fungsional Minyak Sawit Merah. JGMI. 10(1)83–94.

Poshadri A. 2010. Microencapsulation technology: A review. JOR ANGRAU. 38(1):86–102.

Rutz JK, Borges CD, Zambiazi RC, Crizel-Cardozo MM, Kuck LS, Noreña CPZ. 2017. Microencapsulation of palm oil by complex coacervation for application in food systems. Food Chem. 220:59–66. DOI: 10.1016/j.foodchem.2016.09.194.

Saputri NE, Ngatirah. 2019. Mikroenkapsulasi minyak sawit merah dengan variasi suhu pengeringan dan jenis bahan penyalut dengan metode foam-mat drying (red palm oil microen-

capsulation in various drying heat and coating material by foam-mat drying method). FoodTech. 2(2):35–51.
United State Department of Agriculture. 2023. Indonesia palm oil: Historical revisions using satellite-derived methodology. CIR. 1–11.
Zhang X, Zhang M, Adhikari B. 2020. Recent developments in frying technologies applied to fresh foods. Trends in Food Sci Technol. *98*:68–81.

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Pahan I, Gumbira-Sa'id E,Tambunan M. 2011. The future of palm oil industrial cluster of Riau region Indonesia. Eur J Soc Sci. 24(3):421-431.

Purnamasari MI, Prihatna C, Gunawan AW, Suwanto A. 2012. Isolasi dan identifikasi secara molekuler *Ganoderma* spp. yang berasosiasi dengan penyakit busuk pangkal batang di kelapa sawit. J Fitopatol Indones. 8(1):9-15. DOI: 10.14692/jfi.8.1.9.

Van Duijn G. 2013. Traceability of the palm oil supply chain. Lipid Technol. 25(1):15-18. DOI: 10.1002/lite.201300251.

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Allen C. 2007. Bacteria, bioterrorism, and the geranium ladies of Guatemala. In: Cabezas AL, Reese E, Waller M, editors. Wages of empire: neoliberal policies, repression, and women's poverty. Boulder (US): Paradigm Press. p. 169-177.

Otegui MS. 2007.Endosperm: development and molecular biology. In: Olson OA, editor. Endosperm cell walls: formation, composition, and functions. Heidelberg (DE): Springer. p. 159-178.

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