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Operational management analysis regarding optimization of making liquid smoke with cyclone distillation technology

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ABSTRACT

This study focuses on evaluating the yield and characteristics of liquid smoke obtained from palm kernel shell, mesocarp fiber, and oil palm frond biomass. The objective of the research is to determine both the percentage yield of liquid smoke produced per gram of palm oil solid waste and characterize the compounds present in the liquid smoke. Solid samples of palm oil waste components (shells, fibers, and fronds) were prepared and subjected to pyrolysis using Distillation Cyclone technology. Liquid smoke produced was then analyzed to determine the concentration of phenolic compounds. The study found that the yield of liquid smoke varied among different palm oil solid waste components, with a higher yield observed from oil palm shell biomass compared to others. Furthermore, the liquid smoke from all three biomass sources exhibited significant concentrations of phenolic compounds, indicating its potential as a natural pesticide ingredient. This research highlights the potential of utilizing palm oil solid waste for value-added products such as liquid smoke, contributing to waste management and sustainable agricultural practices. The findings provide insights for further research and development of eco-friendly pest control solutions utilizing liquid smoke-derived compounds.

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Introduction

The palm oil industry is one of the strategic industries in the Indonesian economy as a foreign exchange earner, driving the national economy, supporting the people's economy, absorbing labor, and the biofuel or biodiesel industry as renewable energy (Irawan & Soesilo, 2021; Saputro et al., 2023). The development of oil palm plantations is followed by the growth of palm oil factories to produce CPO and other derivative products (Rifai et al., 2014; Syahza et al., 2015). Palm oil factories will produce waste in the form of solid waste (Palm Palm Empty Bunches, shells, lint or fiber, sludge or mud, and cake) and liquid waste (condensate from the sterilization process, water from the clarification process, water hydro-cyclone (clay bath), and factory washing water) (Asrul et al., 2023; Purba et al., 2023) In the palm oil or CPO (Crude Palm Oil) processing industry, industrial waste will be obtained. This waste is classified into solid, liquid, and gas waste.

Solid waste consists of empty fruit bunches and palm oil shells. Only around 40% of the shells have been used as an energy source, while empty oil palm stems and bunches are usually scattered throughout plantation areas, thereby increasing the amount of greenhouse gas emissions (Gani et al., 2014; Malvini & Nurjasmi, 2019;

Silaban et al., 2022). Various alternative uses can be made for renewable energy, such as bio-oil from pyrolysis as a substitute for gasoline, diesel and bio-pellet products, and bio briquettes as a substitute for gas (Simanjuntak et al., 2022; Yanti, 2023; Yanti et al., 2018). Liquid smoke is the result of condensation or condensation of combustion vapor which can be obtained through the pyrolysis process from materials containing cellulose components, acid compounds, hemicellulose, and lignin (Leki et al., 2021; Putri et al., 2019; Saputra et al., 2020; Xin et al., 2021b). There are two categories of quality liquid smoke, namely physical and chemical. Physically, it is the volume or specific gravity of liquid smoke, while chemically it is the PH percentage value, acid content percentage value, and phenol content percentage value. The quality of the liquid smoke produced varies due to differences in the materials used, and the influence of pyrolysis temperature and distillation temperature (Ariski & Mikhratunnisa, 2023; Maulina & Silia, 2018). According to Malvini and Nurjasmi (Malvini & Nurjasmi, 2019) liquid smoke contains antifeedant bioactive compounds. These compounds are needed by plants to protect themselves from attacks by pests, microbes, and other organisms.

Liquid smoke is a product obtained from the condensation of pillarized biomass which contains several compounds that function as antibacterial, antifungal and antioxidant so that it can be a natural ingredient to overcome pest and disease problems in plants (Gani et al., 2014; Purba et al., 2023; Xin et al., 2022). Liquid smoke has the main components of acid compounds, phenol derivatives and carbonyls which act as flavourings, colorants, antibacterials and antioxidants (Permanasari et al., 2020; Putranto et al., 2020; Saloko et al., 2014). The chemical composition of liquid smoke mainly depends on the type of wood and wood moisture content, the influence of pyrolysis temperature and the duration of smoke development (Maulina & Silia, 2018; Rathoure et al., 2019; Xin et al., 2021a).

The gap of this research lies in the use of a novel cyclone distillation technology in an effort to optimize the production of liquid smoke from palm solid waste. While the research objective has been set to evaluate the yield of liquid smoke and the characteristics of the compounds in the product, the novelty lies in the technological approach used. With the lack of research using cyclone distillation technology in this context, there is a need to explore the potential of this technology in the production of liquid smoke from palm solid waste. Thus, further research is needed to understand the advantages and limitations of this cyclone distillation technology and compare it with other existing methods. This provides an opportunity to expand knowledge on the process of liquid smoke production from palm solid waste and improve overall production efficiency. The objective of the research is to determine both the percentage yield of liquid smoke produced per gram of palm oil solid waste and characterize the compounds present in the liquid smoke.

Method

Materials and Methods Distillation Equipments

The tools used in this research were pipe rolls, grinders, welding machines, taps, pumps, hoses, sandpaper, gas stoves, and centrifugal blowers. While the main ingredients used are. Stainless steel pipes, stainless steel plates, factory waste and palm oil land as materials for theprocess of making liquid smoke.

Cyclone-Distillation Technology

The series of liquid smoke-making machines based on cyclone-distillation technology in this research has a height of 143 cm and a length of 242 cm. This machine consists of a series of combustion tube components, a cyclone separator, a distillation tube, condenser tube, as shown in Figure 1. Cyclone-distillation technology utilizes the principle of rotating centrifugation of smoke resulting from pyrolysis of oil palm shells from the combustion chamber to separate the ash that is carried away using a centrifugal blower. Inside the condenser tube there is a 12 m long spiral pipe made of stainless steel so that it has a large contact area with the cooling water.

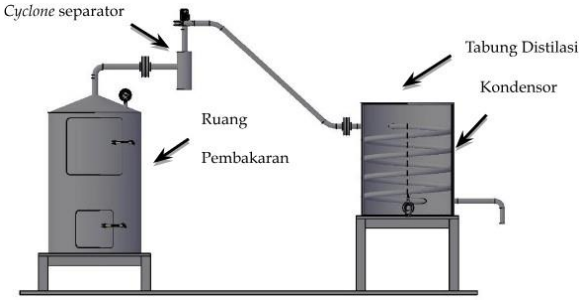

Figure 1. Design of a Cyclone-Distillation Based Liquid Smoke-Making Machine

Liquid Smoke-Making

The working system mechanism of a liquid smoke maker based on cyclone-distillationtechnology can be seen in Figure 2. This machine is designed for an input capacity in theform of waste with a volume of 0.81 m3. Then the oil palm shell pyrolysis process is carried out in the combustion chamber. After that, the smoke produced will be sucked in by the suction blower into the cyclone separator. In this room, the smoke which still contains quite alot of ash and other impurity particles will be separated before going to the condenser. The liquid produced from the condenser is called liquid smoke.

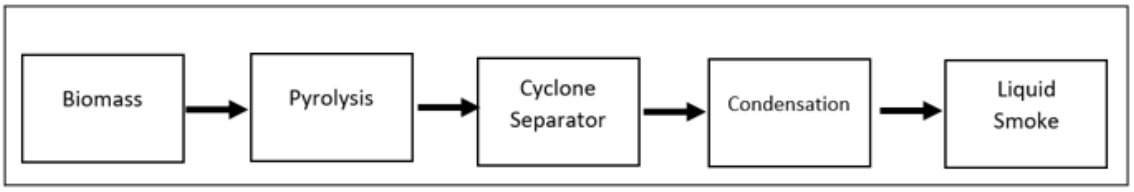

Figure 2. Working System Mechanism

Phenolic Compound Test

The liquid sap obtained is filtered first to remove tar. Then, the solvent and liquid smoke are regulated. Liquid smoke is dissolved using a measured volume. After that, the mixture is put into the three-neck stew. Stirring was carried out with a stirrer speed of 250 rpm for a certain time (t). Extraction is regulated at a certain temperature (T). After that, the raffinate phaseand extract were removed from the separating funnel, then the compounds were precipitated for 2 hours. The two compounds were put into different Erlenmeyer flasks. Next, the extract phase is distilled, then the volume of the remains in the flask is measured. Finally, it was analyzed using a UV-Visible Spectrophotometer and Shimadzu QP 2100 GC-MS brand.

Parameters

In this research, total phenol was tested in liquid smoke using oil palm kernel shells,mesocarp fiber, and oil palm fronds.

Result and Discussion

The yield of liquid smoke produced using a cyclone-distillation based machine was calculated. Based on Figure 3, the yield of liquid smoke made from palm oil shells (26%) hasthe greatest value compared to the yield of fronds (22%) and fibers (17%). Liquid smoke testing carried out using cyclone-distillation technology is carried out to determine whether the liquid smoke produced has the potential to control pest.

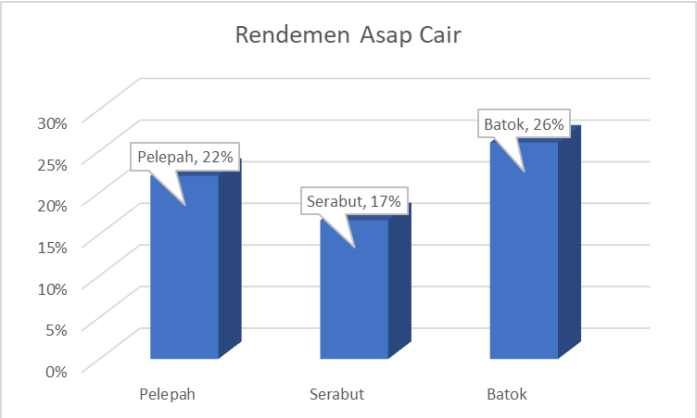

Figure 3. Liquid Smoke Yield

From the results of the phenol content test (Table 1), it can be seen that liquid smoke from palm oil shell biomass has the highest concentration of phenol followed by fiber and frond biomass which has the lowest concentration. The highest lignin content of the three types of biomasses was in oil palm shells at 48.83%, while the lignin content in fibers and fronds was 33.14% and 18.09% respectively. according to Yanti et al 2018. The use of liquid smoke fromthe pyrolysis results of a cyclone distillation device has the potential to be used as a natural insecticide. The concentration of phenol contained in liquid smoke meets the technical requirements for pesticides according to Minister of Agriculture Regulation No. 39/Permentan/SR.330/7/2015, which states that the active ingredient in the form of phenol in pesticides is in the range of ≤ 0.55%.

Table 1. Liquid Smoke Phenol Concentration Based on Biomass

Biomass	Concentration (%)
Pelepah (frond)	19,68
Cangkang (shell)	32,10
Serabut (fiber)	27,62

The data indicates variations in the yield of liquid smoke produced through cyclone-distillation technology based on different sources of oil palm biomass. Palm oil shells have the highest yield at 26%, surpassing fronds (22%) and fibers (17%). This suggests that palm oil shells are more efficient in producing liquid smoke using cyclone-distillation technology. The testing of phenol concentration in liquid smoke highlights significant differences among the three biomass sources. Palm oil shells exhibit the highest phenol concentration (32.10%), while fronds and fibers have lower phenol concentrations (19.68% and 27.62%, respectively). This indicates that liquid smoke from palm oil shells is rich in phenol, a characteristic relevant to pest control. The high lignin content in palm oil shells, reaching 48.83%, underscores the biomass's potential as a valuable feedstock for pyrolysis and cyclone-distillation processes (Irawan & Soesilo, 2021; Yanti, 2023). Lignin, one of the major components of plant cell walls, is known for its complex structure and chemical composition. During pyrolysis, lignin undergoes thermochemical decomposition, leading to the formation of a variety of bioactive compounds, including phenols (Irawan & Soesilo, 2021; Yanti, 2023).

In agricultural settings, phenolic compounds have garnered attention due to their insecticidal properties (Sadeghbeigi, 2020; Saputra et al., 2020). Studies have shown that phenols can disrupt insect physiology, affecting vital processes such as feeding, growth, and reproduction. This makes them promising candidates for natural insecticides, particularly in the context of sustainable pest management practices. The fact that the phenol concentration in liquid smoke derived from palm oil shells meets the technical requirements for pesticides further strengthens the case for its use in pest control (Sadeghbeigi, 2020; Saputra et al., 2020). Liquid smoke obtained through cyclone-distillation processes, particularly from palm oil shells, represents a concentrated source of phenolic compounds with demonstrated insecticidal activity. This makes it a viable and environmentally friendly alternative to synthetic pesticides, which often come with environmental and health concerns. The preference for palm oil shells in liquid smoke production is multifaceted. Not only do they yield higher quantities of liquid smoke compared to other biomass sources, but they also contain a significant concentration of phenolic compounds, making them particularly suitable for insecticidal applications. This highlights the importance of biomass selection in maximizing the efficacy and sustainability of liquid smoke production for pest control purposes.

In summary, the potential use of liquid smoke derived from palm oil shells as a natural insecticide offers a promising avenue for addressing pest issues in agriculture. By leveraging the high lignin content and phenol concentration in palm oil shells, liquid smoke-based insecticides can contribute to sustainable pest management practices while minimizing environmental impact. Further research and development efforts aimed at optimizing production processes and assessing the efficacy and safety of liquid smoke-based insecticides will be crucial in realizing their full potential in agricultural applications.

Conclusion

In this research, the liquid smoke-making machine was able to produce liquid smoke yields from raw palm oil shells (26%), fronds (22%) and fiber (17%). The highest lignin content of the three types of biomass is in oil palm shells at 48.83%, while the lignin content in fibers and fronds is 33.14% and 18.09% respectively (Yanti et al 2018). Utilization of liquid smoke from the results cyclone distillation device pyrolysis has the potential to be used as a natural insecticide. The concentration of phenol contained in liquid smoke meets the technical requirements for pesticides according to Minister of Agriculture Regulation No. 39/Permentan/SR.330/7/2015 states that the active ingredient in the form of phenol in pesticides is in the range of ≤ 0.55%.

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