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Future-Ready Construction and Facility Management:
Driving Research and Innovation for a Smart Built Environment

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UTILIZATION OF BLACK LIQUOR FROM DELIGNIFICATION OF OIL PALM EMPTY FRUIT BUNCH (OPEFB) AS CONDUCTIVE CARBON MATERIAL VIA PYROLYSIS METHOD

Ronaldus Heritarto[1]*, Nelis Cahyani Gulo[1]

[1] Department of Chemical Engineering, Faculty of Engineering, Universitas Pamulang, Indonesia

*Corresponding author: ronaldusheritarto@students.unila.ac.id

Abstract
This study explores the utilization of lignin derived from black liquor—an alkaline byproduct of oil palm empty fruit bunch (OPEFB) delignification—for producing conductive carbon material through pyrolysis. The research aims to reduce environmental pollution caused by untreated black liquor and to convert it into valuable carbon material suitable for electrochemical energy storage applications. The delignification process used 0.2 M NaOH at pH 13–14, resulting in lignin-rich black liquor. The pyrolysis process was conducted at various temperatures ranging from 500°C to 800°C. The carbon obtained was characterized using CHN analysis to determine elemental composition and cyclic voltammetry (CV) to evaluate electrochemical performance. Results indicated that higher temperatures led to a significant decrease in carbon content due to carbonization, with the optimal pyrolysis temperature ranging between 600°C and 800°C. Cyclic voltammetry results demonstrated electrochemical activity suitable for supercapacitor materials, although capacitance values were relatively low. Further activation and characterization, including SEM and FTIR, are recommended to enhance surface area and identify functional groups for improved performance.

Keywords: Black liquor, lignin, pyrolysis, conductive carbon, cyclic voltammetry

1. INTRODUCTION

Oil palm empty fruit bunch (OPEFB) constitutes approximately 21% of fresh fruit bunches and represents a major agro-industrial residue in Indonesia. It contains high lignin content, which can be extracted through delignification using sodium hydroxide (NaOH) solution, producing black liquor as a byproduct. This highly alkaline waste (pH 13–14) poses environmental hazards if discharged untreated. However, lignin within black liquor can serve as a precursor for carbon materials. The increasing demand for sustainable energy storage materials has encouraged the conversion of lignin-rich waste into biochar or conductive carbon for supercapacitor applications. Therefore, this research focuses on the transformation of lignin from OPEFB black liquor into conductive carbon using the pyrolysis method, contributing to waste reduction and renewable material development.

2. LITERATURE REVIEW

According to Sugiawati et al. (2021), OPEFB contains approximately 66.97% holocellulose and 24.45% lignin. Previous studies by Prasetyo et al. (2023) demonstrated that delignification using hydroxyl radicals under alkaline conditions effectively dissolves lignin. Murti et al. (2024) reported that KOH-activated biochar derived from oil palm waste exhibited good electrochemical properties suitable for

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energy storage applications. However, few studies have examined direct pyrolysis of lignin extracted from black liquor without prior activation. This study addresses this gap by examining the physicochemical and electrochemical properties of carbon obtained from varying pyrolysis temperatures.

3. METHODOLOGY

The research began with delignification of OPEFB using 0.2 M NaOH at 90°C for 1 hour to separate lignin and obtain black liquor. The black liquor was dried and pyrolyzed in a nitrogen atmosphere at temperatures of 500°C, 600°C, 700°C, and 800°C. The resulting carbon was characterized using CHN analysis (to determine carbon, hydrogen, and nitrogen content) and cyclic voltammetry (CV) using a Metrohm PGSTAT302N potentiostat in a three-electrode system (working, reference, and counter electrodes) with 1 M KOH electrolyte. The CV test was conducted in a voltage range of -1.5 V to +1.5 V at scan rates of 0.1 mV s^{-1} to 0.2 mV s^{-1}.

4. FINDING AND DISCUSSION

The CHN analysis revealed that the carbon composition decreased as the pyrolysis temperature increased due to carbonization, where organic compounds decomposed into simpler carbon structures. The optimal temperature for obtaining stable carbon was found to be between 600°C and 800°C. The cyclic voltammetry results showed that the obtained carbon exhibited electrochemical activity, indicating its potential for use in supercapacitors. However, the capacitance values remained low, indicating a limited surface area and porosity. These results highlight the need for activation processes, such as KOH treatment, and further characterization using SEM and FTIR to analyze the surface morphology and functional groups.

5. CONCLUSION

The study concludes that pyrolysis of lignin-rich black liquor from OPEFB is an effective method for producing conductive carbon materials with potential applications in energy storage. The optimal pyrolysis temperature ranges from 600°C to 800°C, yielding carbon with significant electrochemical properties. To enhance performance, further activation and surface modification are necessary. This research contributes to the sustainable valorization of waste and the development of green materials for electrochemical applications.

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