INTISARI

Tandan kosong kelapa sawit (TKKS) merupakan limbah biomassa lignoselulosa yang melimpah dan berpotensi dimanfaatkan sebagai sumber selulosa dan lignin bernilai tambah untuk berbagai aplikasi berbasis biomassa. Namun, pemisahan komponen lignoselulosa dari TKKS masih menghadapi kendala akibat kompleksitas struktur lignin–karbohidrat. Metode ekstraksi konvensional seperti perlakuan asam, basa, oksidatif, dan organosolv telah banyak digunakan, tetapi umumnya memiliki keterbatasan berupa penggunaan bahan kimia agresif, konsumsi energi tinggi, potensi degradasi selulosa, serta dampak lingkungan yang kurang menguntungkan. Oleh karena itu, pengembangan metode alternatif yang lebih selektif dan berkelanjutan menjadi penting. Penelitian ini bertujuan untuk mengkaji ekstraksi lignoselulosa TKKS menggunakan *Deep Eutectic Solvent* (DES) berbasis choline chloride–asam oksalat, serta mengevaluasi efektivitas pemanfaatan kembali (recycling) DES terhadap kinerja ekstraksi dan pemisahan lignin. Variasi perlakuan meliputi DES *fresh* dengan penambahan 10% air, DES *recycle* satu siklus, serta DES *recycle* dengan penambahan 25% dan 50% DES *fresh*. Proses ekstraksi dilakukan pada skala laboratorium, diikuti dengan pemisahan lignin melalui presipitasi menggunakan air sebagai antisolven.

Evaluasi hasil dilakukan melalui analisis komposisi lignoselulosa serta karakterisasi struktur menggunakan FTIR dan XRD. Hasil penelitian menunjukkan bahwa DES *fresh* +10% air memberikan kinerja ekstraksi dan pemisahan lignin paling efektif. Penggunaan DES *recycle* tanpa penambahan DES *fresh* menyebabkan penurunan signifikan efektivitas pemisahan lignin, sedangkan penambahan sebagian DES *fresh* mampu memulihkan kinerja ekstraksi yang ditunjukkan oleh terbentuknya kembali lignin hasil presipitasi. Analisis FTIR mengonfirmasi berkurangnya kontribusi lignin dan hemiselulosa pada residu padat kaya selulosa, sementara XRD menunjukkan bahwa struktur kristalin selulosa tipe I tetap terjaga dan lignin hasil presipitasi bersifat amorf. Analisis tekno-ekonomi sederhana menunjukkan bahwa pemanfaatan kembali DES berpotensi menurunkan biaya bahan, meskipun diperlukan penambahan sebagian DES *Fresh* untuk mempertahankan efektivitas proses. Secara keseluruhan, hasil penelitian ini menunjukkan bahwa DES berbasis choline chloride - asam oksalat berpotensi dikembangkan sebagai metode ekstraksi lignoselulosa TKKS yang efisien dan berkelanjutan, dengan prospek untuk dikaji lebih lanjut pada skala yang lebih besar.

Kata kunci : TKKS, HBA, HBD, lignoselulosa, *recycle*

ABSTRAK

Oil palm empty fruit bunches (OPEFB) are abundant lignocellulosic biomass waste and have the potential to be utilized as a source of value-added cellulose and lignin for various biomass-based applications. However, the separation of lignocellulosic components from OPEFB still faces challenges due to the complexity of the lignin-carbohydrate structure. Conventional extraction methods such as acid, base, oxidative, and organosolv treatments have been widely used, but generally have limitations such as the use of aggressive chemicals, high energy consumption, potential cellulose degradation, and unfavorable environmental impacts. Therefore, the development of alternative methods that are more selective and sustainable is important. This study aims to examine the extraction of OPEFB lignocellulose using a choline chloride-oxalic acid-based Deep Eutectic Solvent (DES), and evaluate the effectiveness of DES recycling on lignin extraction and separation performance. Treatment variations include fresh DES with the addition of 10% water, one-cycle recycled DES, and recycled DES with the addition of 25% and 50% fresh DES. The extraction process was carried out on a laboratory scale, followed by lignin separation through precipitation using water as an antisolvent.

The results were evaluated through lignocellulose composition analysis and structural characterization using FTIR and XRD. The results showed that fresh DES with 10% water provided the most effective lignin extraction and separation performance. The use of recycled DES without the addition of fresh DES significantly decreased lignin separation effectiveness, while the addition of a portion of fresh DES restored extraction performance, as indicated by the re-formation of precipitated lignin. FTIR analysis confirmed the reduced contribution of lignin and hemicellulose to the cellulose-rich solid residue, while XRD showed that the crystalline structure of type I cellulose was maintained and the precipitated lignin was amorphous. A simple techno-economic analysis demonstrated that DES reuse has the potential to reduce material costs, although the addition of a portion of fresh DES is required to maintain process effectiveness. Overall, the results of this study indicate that choline chloride-oxalic acid-based DES has the potential to be developed as an efficient and sustainable method for extracting lignocellulose from OPEFB, with the prospect of further study on a larger scale.

Keywords: OPEFB, HBA, HBD, lignocellulose, recycling