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Pengaruh Suhu dan Laju Alir Umpan terhadap Yield dan Karakteristik Produk pada Pirolisis Termal Kontinu Waste Cooking Oil (WCO)
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INTISARI

Waste cooking oil (WCO) merupakan limbah minyak goreng yang berpotensi mencemari lingkungan apabila tidak dikelola dengan baik, tetapi masih memiliki kandungan rantai hidrokarbon panjang yang dapat dikonversi menjadi bahan bakar cair alternatif. Penelitian ini bertujuan untuk mengetahui pengaruh suhu dan laju alir umpan terhadap distribusi *yield* produk, karakteristik *bio-oil*, komposisi gas, gugus fungsi, *energy recovery* (ER) pada proses pirolisis termal kontinu WCO tanpa katalis.

Penelitian dilakukan menggunakan reaktor pirolisis termal kontinu dengan variasi suhu 450, 500, dan 550 °C serta laju alir umpan 1, 2, 4, dan 6 ml/menit. Produk hasil pirolisis dianalisis berdasarkan *yield bio-oil*, gas, dan residu. Karakteristik *bio-oil* diuji melalui pengukuran densitas, viskositas, dan nilai kalor menggunakan *bomb calorimeter*. Komposisi gas dianalisis menggunakan *gas chromatography* (GC), sedangkan gugus fungsi *bio-oil* dianalisis menggunakan *Fourier transform infrared* (FTIR). Selain itu, dilakukan perhitungan *energy recovery* untuk mengevaluasi pemulihan energi dari bahan baku ke produk pirolisis. Hasil penelitian menunjukkan bahwa peningkatan laju alir umpan cenderung meningkatkan *yield bio-oil* pada setiap suhu, sedangkan peningkatan suhu cenderung menurunkan *yield bio-oil* dan meningkatkan *yield* gas akibat terjadinya reaksi *secondary cracking*. *Yield bio-oil* tertinggi diperoleh pada suhu 450 °C dan laju alir umpan 6 ml/menit, yaitu sebesar 58,65%, dengan *yield* gas 40,29% dan residu 1,06%. Densitas terendah juga diperoleh pada kondisi tersebut, yaitu sebesar 0,858 g/ml. Nilai *higher heating value* (HHV) *bio-oil* berada pada rentang 36,50–41,70 MJ/kg, dengan nilai tertinggi sebesar 41,70 MJ/kg pada suhu 450 °C dan laju alir 2 ml/menit. Hasil FTIR menunjukkan bahwa *bio-oil* masih mengandung gugus hidrokarbon alifatik dan senyawa oksigenat, sedangkan hasil GC menunjukkan bahwa gas pirolisis didominasi oleh CH_4 dan CO_2. *Energy recovery bio-oil* tertinggi diperoleh pada suhu 450 °C dan laju alir 6 ml/menit sebesar 59,51%, total *energy recovery* tertinggi juga diperoleh pada kondisi yang sama sebesar 72,37%. Dengan demikian, kondisi operasi optimum pada penelitian ini adalah suhu 450 °C dan laju alir umpan 6 ml/menit karena mampu memaksimalkan produksi *bio-oil* serta pemulihan energi dalam bentuk produk cair.

Kata kunci: *waste cooking oil*, pirolisis termal kontinu, suhu, laju alir umpan, *energy recovery*

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ABSTRACT

Waste cooking oil (WCO) is a used cooking oil waste that may cause environmental pollution if not properly managed. However, it still contains long-chain hydrocarbon compounds that can be converted into alternative liquid fuel. This study aims to investigate the effect of temperature and feed flow rate on product yield distribution, bio-oil characteristics, gas composition, functional groups, energy recovery (ER) in non-catalytic continuous thermal pyrolysis of WCO.

The experiment was carried out using a continuous thermal pyrolysis reactor at temperature variations of 450, 500, and 550 °C and feed flow rates of 1, 2, 4, and 6 ml/min. The pyrolysis products were evaluated based on the yield of bio-oil, gas, and residue. The bio-oil characteristics were analyzed through density, viscosity, and heating value measurements using a bomb calorimeter. The gas composition was analyzed using gas chromatography (GC), while the functional groups of bio-oil were identified using Fourier transform infrared (FTIR). In addition, energy recovery were calculated to evaluate the energy conversion from feedstock to pyrolysis products.

The results showed that increasing the feed flow rate tended to increase the bio-oil yield at each temperature, while increasing the temperature tended to decrease the bio-oil yield and increase the gas yield due to secondary cracking reactions. The highest bio-oil yield was obtained at 450 °C and a feed flow rate of 6 ml/min, reaching 58.65%, with gas and residue yields of 40.29% and 1.06%, respectively. The lowest density was also obtained under this condition, with a value of 0.858 g/ml. The higher heating value (HHV) of bio-oil ranged from 36.50 to 41.70 MJ/kg, with the highest value of 41.70 MJ/kg obtained at 450 °C and 2 ml/min. The FTIR results showed that the bio-oil still contained aliphatic hydrocarbon groups and oxygenated compounds, while the GC results showed that the pyrolysis gas was dominated by CH_4 and CO_2. The highest bio-oil energy recovery was obtained at 450 °C and 6 ml/min, reaching 59.51%, while the highest total energy recovery was also obtained under the same condition, reaching 72.37%. Therefore, the optimum operating condition in this study was 450 °C with a feed flow rate of 6 ml/min, as it maximized bio-oil production and energy recovery in the liquid product.

Keywords: waste cooking oil, continuous thermal pyrolysis, temperature, feed flow rate, energy recovery