



Technical benefits of using methane as a pyrolysis medium for catalytic pyrolysis of Kraft lignin

Abid Farooq^{a,1}, Su Shiung Lam^{b,1}, Gwang Hoon Rhee^{c,1}, Jechan Lee^d, Moonis Ali Khan^e, Byong-Hun Jeon^f, Young-Kwon Park^{a,*}

^a School of Environmental Engineering, University of Seoul, Seoul 02504, Republic of Korea

^b Higher Institution Centre of Excellence (HiCoE), Institute of Tropical Aquaculture and Fisheries (AKUATROP), Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

^c Department of Mechanical and Information Engineering, University of Seoul, Seoul 02504, Republic of Korea

^d Department of Environmental and Safety Engineering & Department of Energy Systems Research, Ajou University, Suwon 16499, Republic of Korea

^e Chemistry Department, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

^f Department of Earth Resources & Environmental Engineering, Hanyang University, Seoul 04763, Republic of Korea

HIGHLIGHTS

- The kraft lignin was pyrolyzed using different pyrolysis environments.
- N₂, CH₄, and CH₄ decomposition gas product environment were compared.
- Zn/HZSM-5 increased BTX yield compared to HZSM-5.
- Methane decomposition environment showed highest BTX yield.

ARTICLE INFO

Keywords:

Methane decomposition
Aromatics
Zeolites
Kraft Lignin

ABSTRACT

Catalytic fast pyrolysis of low sulfonated Kraft lignin was performed under different atmospheric environments such as N₂, CH₄, and the gas derived from CH₄ decomposition (CH₄-D). The use of Zn- or Mo-loaded HZSM-5 as catalyst led to a higher pyrolytic oil yield compared to parent HZSM-5 in CH₄ and CH₄-D atmospheres. The yields of benzene, toluene, and xylenes were increased by the synergistic effects from metal loading, higher H/C_{eff} ratio, higher acidity, and CH₄ activation. The enhanced CH₄ activation via metal loading resulted in higher methylation of alkyl moieties and 33% increase in the total yield of benzene, toluene, and xylenes in comparison to parent HZSM-5. A higher H/C_{eff} ratio of 6 via CH₄ decomposition led to the formation of a hydro-pyrolysis environment. Moreover, the CH₄-D environment showed H₂/CH₄ ratio of 0.36 in the product gas which warranted the presence of more H₂ under the CH₄-D pyrolysis environment.

1. Introduction

The need for sustainable energy resources has been driven by the depletion of fossil fuels, anthropogenic carbon emissions to the atmosphere, and ever-increasing energy demands. Biomass is a renewable available resource comprising polysaccharides such as cellulose, hemicellulose and aromatic-based lignin (Zoghalmi & Paës, 2019). It continues to attract worldwide attention as a sustainable replacement of fossil fuel for the generation of second generation biofuels and other

chemicals without weakening food security globally (Chandel et al., 2018).

Thermochemical processes, such as pyrolysis (Yu et al., 2022), torrefaction (Fu et al., 2022), liquefaction (Kim et al., 2019) and gasification (Singh Siwal et al., 2020) have been suggested as an effective way to convert biomass into valuable chemicals. In particular, pyrolysis aids in a direct conversion of biomass into bio-oil by the fragmentation of biomass under non-oxidative conditions from medium to high temperature range (400 to 600 °C) (Choi et al., 2018; Ha et al., 2019; Seo et al.,

* Corresponding author.

E-mail address: catalica@uos.ac.kr (Y.-K. Park).

¹ Co-first authors.