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Research paper

Direct liquefaction of lignin and lignin rich biomasses by heterogenic catalytic hydrogenolysis

Marcus Breunig [a, *], Philipp Gebhart [a], Ursel Hornung [a], Andrea Kruse [b], Eckhard Dinjus [a]

[a] Karlsruhe Institute of Technology (KIT), Institute for Catalysis Research and Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
[b] University Hohenheim, Institute of Agricultural Engineering, Conversion Technology and Life Cycle Assessment of Renewable Resources, Garbenstrasse 9, 70599 Stuttgart, Germany

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ABSTRACT

As part of an ongoing project at Karlsruhe Institute of Technology (KIT), Germany, this work examines the liquefaction of varying feedstocks under conditions of the Bergius process of direct coal liquefaction by high pressure heterogeneous catalytic hydrogenolysis. Applying this process onto renewable resources like lignin and lignin-rich biomass has the potential to produce aromatic components for chemical industry.

The performed experiments investigate the chemical conversion of different lignin types alongside samples of beech bark and beech wood fiber residues from pulp and paper industry using different heterogeneous catalysts and catalyst preparations. Reaction conditions such as catalyst concentration, temperature and concentration of sulfur were varied in order to optimize the conditions of liquefaction for the chosen setup.

It will be shown that lignin and lignin-rich biomass can be liquefied under conditions of direct coal liquefaction using molybdic acid and sulfidic iron catalysts. The liquid oil product can be obtained in good yields up to 60% mass fraction of the input feedstock, consisting of alkylated phenols and alkyl benzenes while removing the majority of hetero atomic functional groups. This can be achieved while producing only a minimal amount of solid residue, reaction water and a valuable gas byproduct.

1. Introduction

Today fossil oil still is one of the most important resources worldwide. According to the International Energy Agency in 2014 the share of oil in the global energy consumption was 31.3% alongside natural gas with 21.2% and coal with 28.6% [1]. Fossil fuels not only are the major source for liquid transportation fuels, but also used for a wide variety of applications in chemical industry. Since this resource is certain to run out in the near future, it is necessary to develop renewable alternatives.

One possible technique, which was already practiced in times of oil shortage, is direct coal liquefaction (DCL). Originally invented by Friedrich Bergius in the beginning 20th century and patented in 1913, DCL is a reliable process for producing liquid hydrocarbons by catalytic hydrogenation of coal [2,3].

In the Bergius Process conversion of coal is carried out in presence of a catalyst at high temperatures and high pressures under hydrogen gas atmosphere using an organic solvent. This kind of hydrogenation can also be used for other feedstocks like e.g. tars or vacuum distillation residues from petrochemical industry [4].

In the future another possible feedstock could be lignin and lignocellulosic biomass. Due to its similar elemental composition and molecular structure lignin is predestined to be used in a liquefaction technology that is already well established for lignite and brown coals.

1.1. Lignin – a possible alternative to fossil resources?

Looking at possible structures of brown coal (Fig. 1) and lignin (Fig. 2) it is obvious that they have certain similarities that should lead to comparable chemical behavior under the conditions of DCL.

Like brown coal, lignin is an amorphous, 3-dimensional

* Corresponding author.
E-mail addresses: marcus.breunig@kit.edu (M. Breunig), philipp.gebhardt@partner.kit.edu (P. Gebhart), ursel.hornung@kit.edu (U. Hornung), Andrea_Kruse@uni-hohenheim.de (A. Kruse), eckhard.dinjus@kit.edu (E. Dinjus).

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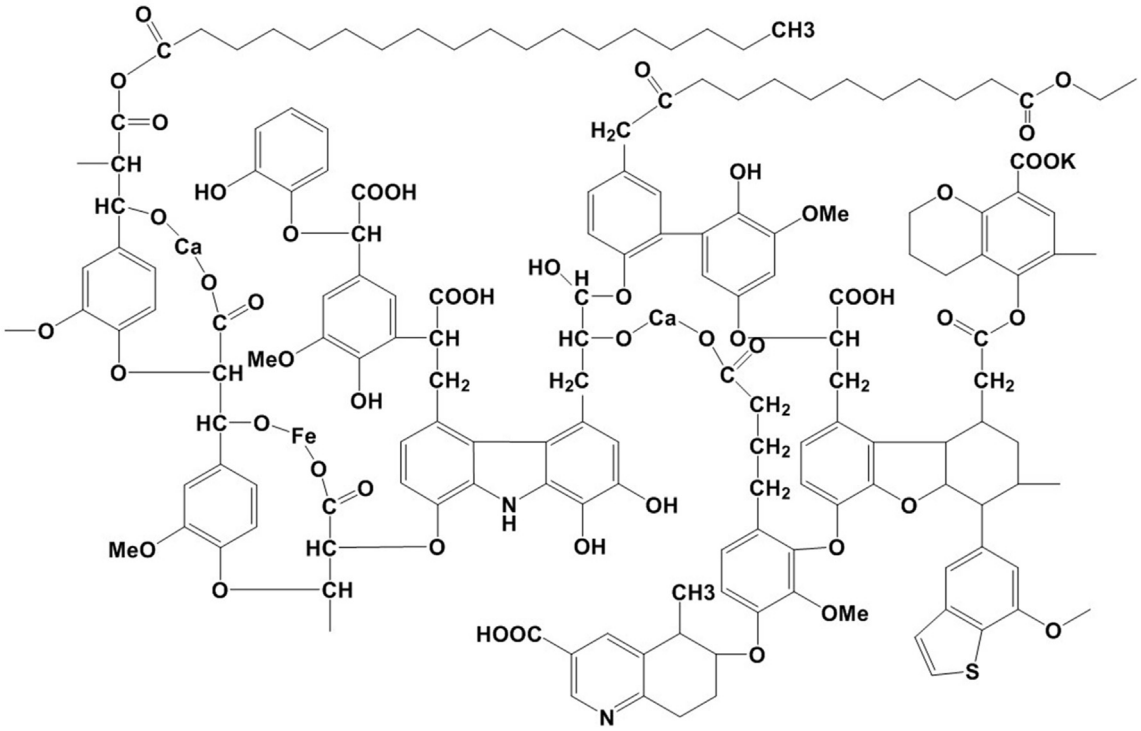

Fig. 1. Possible brown coal structure according to [7].

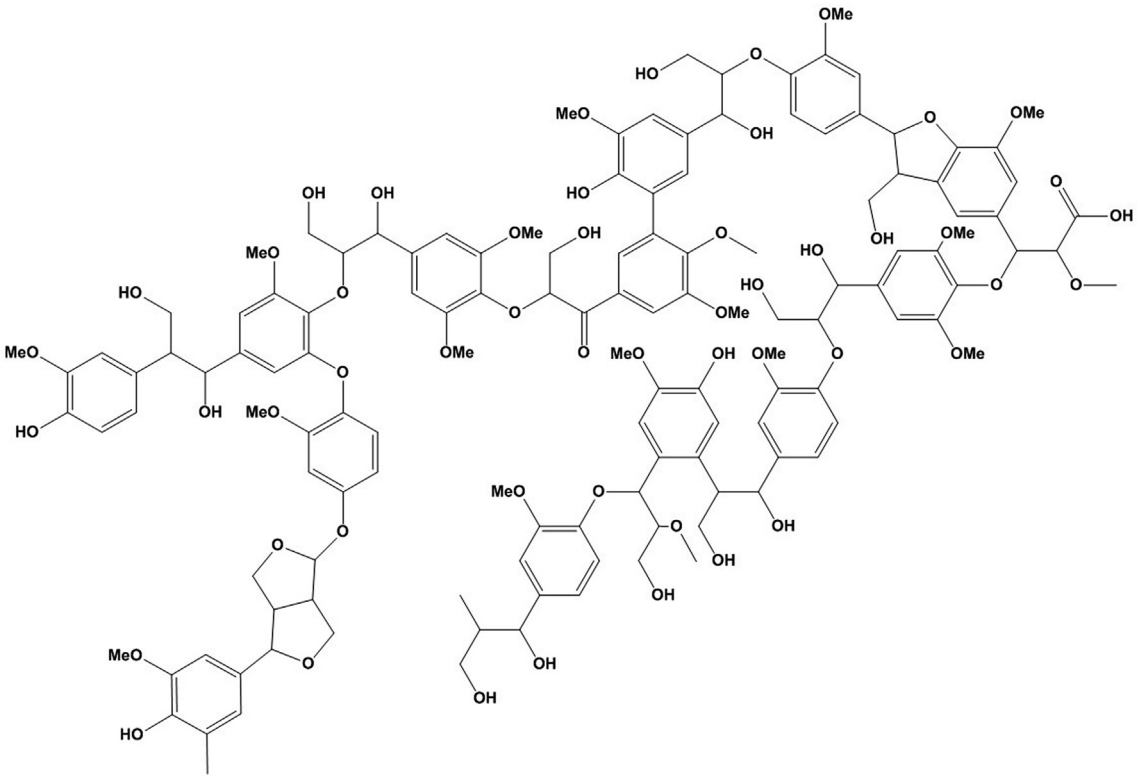

Fig. 2. Possible lignin structure according to [8].

biopolymer. The bridging ether bonds are the first to break in direct liquefaction. Another similarity is the high amount of aromatics and the corresponding contents of oxygen functional groups. Even the elemental composition of lignin and brown coal are alike (Table 1). Based on the similarities, it is reasonable to assume the process of DCL would have efficacy when applied to lignin and lignin-rich

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