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Effects of experimental conditions and of addition of natural minerals on syngas production from lignin by oxy-gasification: Comparison of bench- and pilot scale gasification

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HIGHLIGHTS

- Oxygen blown gasification of spent lignin from a second-generation cellulosic ethanol plant.
- Oxy-gasification of a biomass fraction (lignin) with high tendency for tar formation.
- Oxy-gasification of a biomass fraction with high contents of silica and alkaline metals.
- Confirmation of bench-scale oxy-gasification results at pilot-scale.
- Hot syngas cleaning and upgrading in a two fixed bed catalytic reactors installation.

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ABSTRACT

Gasification of spent lignin pellets was used to obtain a gas suitable for energy production. Spent lignin was obtained from second-generation cellulosic ethanol demo plant using wheat straw as feedstock. Gasification of lignin did not give rise to any feeding problems, thus no significant changes were needed in the existing gasification installation. The rise of temperature and steam flow rate favoured the formation of H_2, while hydrocarbons (C_nH_m) and tar contents decreased. The increase of equivalent ratio (ER) also decreased hydrocarbons and tar contents, but syngas higher heating value (HHV) was reduced. The use of natural minerals improved lignin gasification. The presence of dolomite led to the highest H_2 and to the lowest C_nH_m and tar contents. Results obtained at bench-scale were confirmed at pilot-scale, as similar trends were obtained. However, as the residence time in pilot gasifier was higher, greater gas yields with higher H_2 and CH_4 concentrations were obtained, while tar contents decreased. After syngas hot cleaning and upgrading, the final syngas composition showed to be suitable for a wide range of applications (e.g. energy production and synthesis of chemicals), since it was substantially enriched in hydrogen, whereas tar and heavier gaseous hydrocarbons were completely destroyed.

1. Introduction

Lignocellulosic (LC) materials are mainly composed of cellulose, hemicelluloses and lignins. During hydrothermal processing of LC biomass fractionation, followed by enzymatic hydrolysis operation units of second generation bioethanol production, cellulose is hydrolysed and hemicelluloses are depolymerized forming oligomers and monomers, releasing lignins as spent solids. Lignin is the worlds' second most abundant natural polymer containing valuable aromatic (phenolic) structures. Lignins are constituted by phenolic compounds, whose precursors are three aromatic alcohols: p-coumaryl, coniferyl and sinapyl alcohols, which are linked together with about two-third of ether bonds (C–O–C) and around one–third of C–C bonds [1]. Lignin structure presents several functional groups: methoxyl, phenolic hydroxyl, aliphatic hydroxyl, benzyl alcohol, noncyclic benzyl ether and carbonyl groups [2]. Lignin is the main constituent of large residual streams in the pulp and paper sector and future cellulosic bioethanol plants, other biorefineries, etc. Only about 2% of lignin based materials is currently used for other applications than combustion. Lignin may be used in different applications and processing: direct application in resins,

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