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Production of fuel precursors by aldol condensation of furfural with acetone using hydrotalcite-based MgAl catalysts

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PURPOSE OF THE ABSTRACT

With a decrease in fossil fuel reserves, much effort has been focused on the development of sustainable energy. Nowadays, non-edible biomass based on industrial and forestry wastes, agricultural residues, and municipal solid waste such as sewage sludge could be used as one of the most promising feedstocks for the production of biofuels.

The depolymerization of the biomass results in the formation of a liquid product composed of different oxygenates, which could be split into water-insoluble and water-soluble phases. The last one consists mainly of aldehydes, ketones, alcohols, furans, some aromatics, and sugars [1]. Hydrogenation and deep hydrodeoxygenation reactions were proposed to obtain hydrocarbons from this mixture. However, the average length of the hydrocarbons would be C5-C6. Therefore, it is necessary to increase their carbon chain length to achieve their efficient application in the complex conversion of biomass.

One of the main approaches to produce bulkier compounds includes the use of aldol condensation between aldehydes and ketones. Additionally, crude acetone is also available as a waste product in the production of phenols during the acetone-water fractionation of lignin. The standard procedure for aldol condensation considers the use of either basic or acidic catalysts. The disadvantage of using liquid-phase catalytic systems includes a large amount of waste water produced and corrosion of equipment. Among solid materials, basic MgAl hydrotalcites (HT) have shown high potential as catalysts for the conversion of furfural and acetone [2].

The present work deals with the comparative study of as-prepared (HT), calcined (CHT) and reconstructed (RHT) MgAl materials with the molar ratio Mg/Al=3 as catalysts for aldol condensation of furfural and acetone using a flow reactor with a fixed catalyst bed.

In the first step, we focused on the impact of reaction conditions on the performance of CHT catalysts. The initial conversion of furfural increased with temperature and reached 91 mol.% at 57 °C, WHSVfurfural=4 h-1 and the molar ratio of F:Ac=1:10. Rapid deactivation was observed for all ranges of temperature. The TGA showed that the active sites of the spent catalysts were blocked by carbon deposits. In contrast, HT showed lower initial activity but better stability to deactivation, while RHT demonstrated the highest activity and rapid deactivation rate.

Because water-soluble phases from depolymerized biomass and crude acetone contain a significant amount of water, the activity and stability of the catalyst were investigated using an aqueous furfural-acetone mixture. In the case of HT even the small amount of water in the initial feedstock resulted in the complete deactivation of the catalyst. In opposite, large water content (up to 50 wt.%) increased the activity of RHT and promoted its stable activity.

The presence of other chemicals in an initial feedstock could play a great role in the performance of a catalyst. The addition of organic compounds with different polarities to a reaction system decreased the activity of CHT,

probably due to the competitive adsorption of acetone and the additives. A deactivation rate was similar in the case of nonpolar chemicals as additives; however, it significantly changed depending on the nature of polar protic compounds. The results of our experiments are promising and can be used to increase the yield of condensation products for their further hydrodeoxygenation.

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FIGURES

FIGURE 1

FIGURE 2

KEYWORDS

furfural | aldol condensation | hydrotalcite | fuel

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