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Cellulose conversion to lactic acid over HPAs supported catalysts

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PURPOSE OF THE ABSTRACT
There is a growing interest on replacing traditional chemicals based on fossil raw materials by those obtained from renewable sources. Towards this end, lignocellulosic biomass is one of the most promising alternative resources. Cellulose, the main structural component of biomass, can be converted to valuable platform chemicals such as HMF and lactic acid, via its hydrolysis to glucose. Lactic acid, can be utilized in a wide variety of commercial products in the food industry (buffering agent, preservative or emulsifier), in pharmaceuticals and in plastics and has been gaining even more attention as the starting material for the synthesis of bio-based chemicals such as acrylic acid, 2,3-pentanedione, acetaldehyde etc. [1]. Industrially lactic acid is mainly produced via fermentation in batch reactors, accompanied by the drawbacks of enzymatic processes [2]. Chemically, it may be synthesized from glucose via retro-aldol reaction either under basic conditions or by catalysts with pronounced Lewis acidity [3].
In the present work, the one pot conversion of cellulose to lactic acid was investigated, using bifunctional catalysts with varying ratio of Lewis to Brönsted acid sites. The reaction took place in aqueous medium using metal oxides (Al_2O_3, SiO_2, SiO_2-Al_2O_3, Nb_2O_5, Nb_2O_5-Al_2O_3, Nb_2O_5-SiO_2), Heteropolyacids (HPAs) (TSA, PTA) and supported HPAs on metal oxides (POM/SiO_2, POM/SiO_2-Al_2O_3, POM/Nb_2O_5, POM/Nb_2O_5-Al_2O_3, POM/Nb_2O_5-SiO_2) as catalysts. Among them, HPAs supported on Nb_2O_5 based oxides are innovative materials. The effect of reaction conditions and the catalyst to cellulose ratio for the best performing catalyst were examined and additionally a kinetic study of the reaction was performed.
Based on the experimental results, the type of acidity plays a key role in the one-pot conversion of cellulose to lactic acid. Homogeneous HPAs, with pronounced Brönsted acidity, proved highly selective towards glucose. In contrast, metal oxides demonstrated poor activity, despite their increased Lewis acidity, due to their inability of catalysing efficiently the initial step of cellulose hydrolysis to glucose. However, supported POMs on metal oxide catalysts, with combined Brönsted and Lewis acidity, catalysed effectively both cellulose hydrolysis to glucose and the subsequent glucose conversion to lactic acid. Among them, those with increased ratio of Lewis to Brönsted acid sites resulted in high lactic acid selectivity.

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FIGURES

FIGURE 1

FIGURE 2

KEYWORDS

cellulose | glucose | lactic acid | supported heteropolyacid catalysts

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