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Fractionated catalytic oxidation of lignocellulose to formic acid and cellulose in one reactor setup

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PURPOSE OF THE ABSTRACT

The main objective of this contribution is to show a novel process for a fractionated oxidation of lignocellulosic biomass (e.g. wood) to produce formic acid and cellulose in only one reactor setup, avoiding any pretreatment or further downstream processing of the biomass.

As sustainability is a key market-desire, biomass is gaining economic significance for the production of platform chemicals. The industry supplying this market, which is so far based on fossil resources, is now changing towards a bio-based economy.

Biomass is defined as material of organic origin containing carbon. In order to avoid any dinner plate or fuel tank discussion about using food crops for producing chemicals, lignocellulose seems to be a promising starting material for the production of sustainable platform chemicals.

Polyoxometalates (POMs) are complexes of oxygen and light transition metals like vanadium, molybdenum or tungsten at their highest oxidation state. POMs have a wide structural and chemical variability leading to different catalytic properties. Recent studies on polyoxometalate catalysts enabled a system for the selective oxidation of lignocellulosic biomass to formic acid (OxFA process).

Using the Lindqvist-type polyoxometalate K₅V₃W₃O₁₉ as a homogeneous catalyst in aqueous media, we are able to selectively oxidize the hemicellulose and lignin fractions to formic acid while the cellulose fraction remains untapped. Using this catalyst system, it was for the first time possible to produce FA and high-grade cellulose in only one reactor setup, avoiding any pretreatment or further downstream processing of the biomass. Furthermore, we could optimize the process conditions with the help of a Box-Behnken design of experiments. Thereby improved conditions showed an output of formic acid from lignin three times higher compared with the initial parameters. Furthermore, recycling of the catalyst has been carried out successfully without observing significant changes in vanadium species. Finally, we investigated the conversion of different real biomasses (hardwood, softwood and algae) leading to new structure-performance relationships.

FIGURES

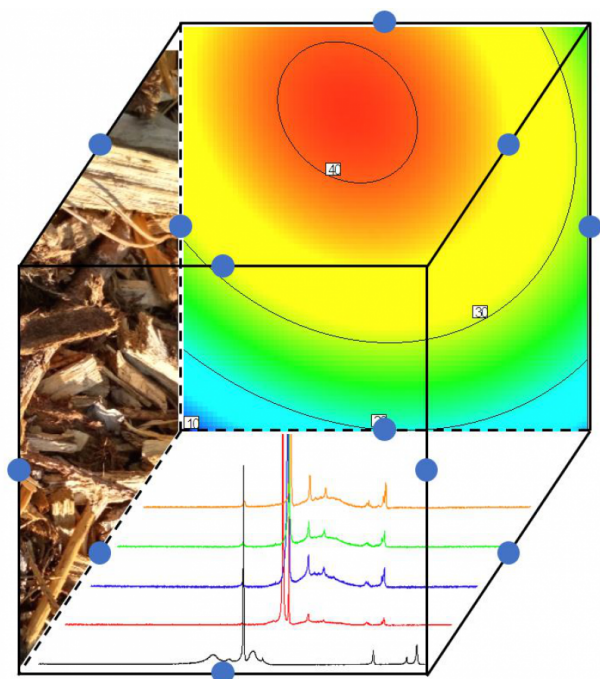


FIGURE 1

Fractionated oxidation of lignocellulosic biomass
Optimization of wood oxidation to formic acid and
cellulose catalyzed by V-containing Lindqvist-POM
catalyst by DoE

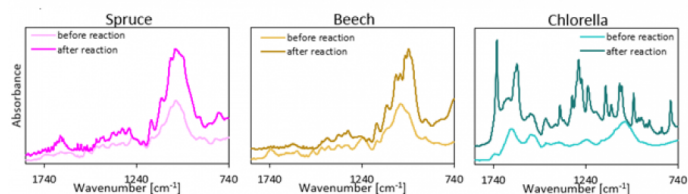


FIGURE 2

: FTIR spectra of the substrates beech, spruce and
chlorella

Reaction conditions: 10-fold, 4 mmol substrate, 0.1
mmol K5V3W3O19 catalyst, 10 g water, 115 °C, 50
bar oxygen pressure, 1100 rpm stirrer speed, 72
hours reaction time).

KEYWORDS

Biomass | Oxidation | Homogeneous catalysis | Design of Experiments

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