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Development of a two pots/one step hybrid process for the synthesis of 5-HMF from D-glucose

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PURPOSE OF THE ABSTRACT

The use of biomass as a raw material is particularly attractive as a potentially competitive strategy to overcome the scarcity of fossil fuels and try to minimize the negative environmental impact associated with their use. Indeed, biomass is the main source of renewable carbon and usable to obtain chemical intermediates. Nevertheless, the transformation of highly functionalized molecules from biomass requires a renewal of the knowledge acquired during the implementation of existing petrochemical processes. Thus, the concept of bio-refinery is currently the focus of many international studies. The conversion of biomass in these new production units requires the design of new processes and the control of these new chemical transformations marking Industrial renewal. The combination of biocatalysis and chemocatalysis, called hybrid catalysis, is part of these new concept that could respond to the emerging challenges of biomass valorization. In this context of hybrid catalysis emergency, we collaborate to develop a new chemoenzymatic process for the 5-hydroxymethylfurfural (5-HMF) production. It is a key platform molecule for biosourced monomers as 2-5-furandicarboxylique acids, a potential substitute for the terephtalic acid used in textiles fibers and food-grades plastics. The 5-HMF production ask for the glucose isomerization into fructose and the fructose dehydration to 5-HMF. This original catalysis coupling process allows to shift the thermodynamic equilibrium of the glucose enzymatic isomerization reaction, theoretically about 50%, by the integration of a simultaneous chemocatalytic fructose dehydration to 5-HMF (Fig. 1 - Left) [1] in a two pots/one step hybrid catalysis system (Fig. 1 - Right) [2,3].

A H-reactor was developed specifically for the implementation of hybrid catalysis for direct conversion of D-glucose to 5-HMF (Fig. 2 - Left). This reactor is made up of two cylindrical chambers linked by a tubing connection whose length can be modified (all in glass and temperature controlled). The left chamber contains the

aqueous donor phase in which the glucose isomerization occurs using an immobilized glucose isomerase introduced in an agitation basket (phase 1). The formed D-fructose is extracted from the aqueous donor phase by formation of a fructoboronate complex [D-Fru-DCPBA] to the organic phase (phase 2). The organic phase is circulating between the two chambers. The D-fructose is then released into the aqueous receiving phase (phase 3). In this aqueous phase the D-fructose dehydration reaction is realized [3]. The D-fructose extraction yield increases during the experiment to reach 96.8% after 32h (Fig. 2 - Right). The isomerization yield increases to reach 79.1% after 32h. The 5-HMF yield increases to reach 30.9% after 32h. The calculation of the glucose conversion after 32h results in 87.7%. From 32h to 51.5h, the pH is not regulated anymore and then the pH decreases resulting in the decrease of the extraction yield. This last reach 92.8%. Isomerization and D-glucose conversion have not evoluated since 32h. The D-fructose dehydration yield continues to increase between 32h and 51.2h until 89.9%. The extraction yield of 96.8% after 32h demonstrates an efficient D-fructose transport in the reactor. The isomerization yield of 79.1% highlights an isomerization equilibrium shift of 29% due to the simultaneous D-fructose extraction from the aqueous donor phase, as explained in our previous study. The carbon balance higher than 90% on D-glucose, D-fructose and 5-HMF in aqueous phases demonstrates the efficiency of the release process. The dehydration yield of 30.9% after 32h validates the feasibility of 5-HMF production by hybrid catalysis process in the H-reactor [3].

FIGURES

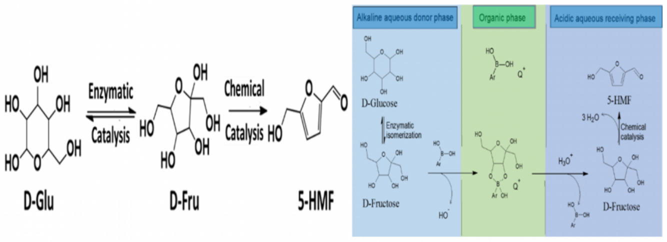

Fig.1: Reaction scheme of the hybrid catalysis process for the glucose transformation (left) and Hybrid catalysis concept developed (right).

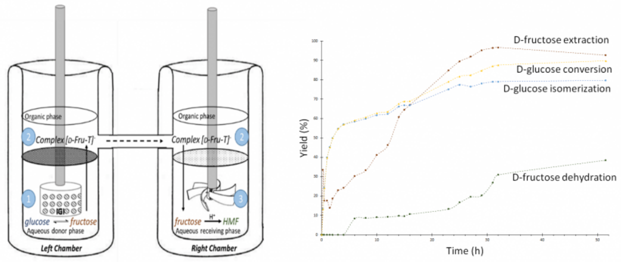

Fig. 2. "H-reactor" for improvement of "2P-1S" hybrid catalysis (left) and graphical representation of isomerization yield, extraction yield, extraction yield, dehydration yield and D-glucose conversion (right).

FIGURE 1

Fig.1: Reaction scheme of the hybrid catalysis process for the glucose transformation (left) and Hybrid catalysis concept developed (right).

Reaction scheme of the hybrid catalysis process for the glucose transformation (left) and Hybrid catalysis concept developed (right).

FIGURE 2

Fig. 2. H-reactor for improvement of 2P-1S hybrid catalysis (left) and graphical representation of isomerization yield, extraction yield, extraction yield, dehydration yield and D-glucose conversion (right).

H-reactor for improvement of 2P-1S hybrid catalysis (left) and graphical representation of isomerization yield, extraction yield, extraction yield, dehydration yield and D-glucose conversion (right).

KEYWORDS

5-HMF | Hybrid catalysis | H-reactor | Two pots/One step hybrid process

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BIBLIOGRAPHY

[1] Gimbernat, A., Guehl, M., Capron, M., Lopes Ferreira, N., Froidevaux, R., Girardon, J.S., Dhulster, P., Delcroix, D and Dumeignil, F. (2017), ChemCatChem 9:2080 – 2084.

[2] Dumeignil, F., Guehl, M., Gimbernat, A., Capron, M., Lopes Ferreira, N., Froidevaux, R., Girardon J.S., Wojcieszak, R., Dhulster, P. and Delcroix, D. (2018), Catalysis Science and Technology 8: 5708-5734.

[3] Gimbernat, A., Guehl, M., Lopes Ferreira, N., Heuson, E., Dhulster, P., Capron, M., Dumeignil, F., Delcroix, D., Girardon, J.S. and Froidevaux, R. (2018), Catalysts 8, 335-355.