Design of tandem catalyst by co-immobilization of metal and enzyme on mesoporous foam for cascaded synthesis of (R)-phenyl ethyl acetate

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Abstract: Herein, palladium and Cal B lipase were sequentially co-immobilized in the microenvironment of mesocellular foam to mimic biological systems and fully characterized. The in-situ formed racemic 1-phenyl ethanol was then kinetically resolved selectively using lipase immobilized on the same support using vinyl acetate as (R)-phenylethyl acetate. For comparison, a single pot reaction was also conducted. The reaction showed complete conversion in 10 h for hydrogenation step while lipase catalyzed gave 49.11% of selectivity towards R enantiomer with respect to racemic mixture with 100% enantiomeric excess (ee). The designed tandem catalyst avoids the use of multiple supports, purification of intermediate product.

Keywords: Tandem catalysis; Cascade reactions; Enantio-selectivity

1. Introduction

A broad range of catalytic reactions using esterases, alcohol dehydrogenases or lipases in combination with encapsulated gold or ruthenium complexes were used for cascade reactions[1]. Lang et al. constructed novel sequential biosensors by co-immobilizing glucoamylase and glucose oxidase for detection of starch with a limit of 0.003% (w/w)[2]. Gustafsson et al. co-immobilized glucose oxidase and horse radish peroxidase on silica support in a spatially controlled way in association with poly-cationic dendridomers polymer[3]. Co-porphyrin and HNTf2incore and Rh-TsDPEN in shell type of catalyst was used for hydration of terminal alkynes followed by Rh-catalyzed asymmetric transfer hydrogenation in the shell[4]. Dynamic kinetic resolution of racemic alcohols using supramolecular-cluster lipase was demonstrated using oxo-vanadium as a racemizing co-catalyst inside mesoporous silica[5]. Backvall et al. successfully supported palladium and lipase on the single support wherein palladium efficiently racemized primary amines and the dynamic kinetic resolution was catalyzed by lipase[6].The foregoing suggests that there is a great scope for co-immobilization of different moieties, particularly chemical and enzymatic sites on a suitable support can be used in industrially important reactions having chiral centers.

2. Experimental (or Theoretical)

Mesocellular foam (MCF) was synthesized by using TEOS as a source of silica. The wet impregnation method was used for the loading 8% of palladium on the surface of MCF. After loading of palladium, Lipase was immobilized on the support. Catalyst characterization was performed by FTIR, SEM, surface area analyzer, XRD, ICP OES, pulse chemisorption at every stage of the process. The prepared tandem catalyst was employed for enantioselective synthesis of (R)-phenyl ethyl acetate from acetophenone as starting material. Various parameters were optimized by conducting experiments one factor at a time.

3. Results and discussion

The GC analysis of the reaction proved that designed tandem catalyst successfully hydrogenated acetophenone to a racemic mixture of 1-phenyl ethanol which in turn acylated by vinyl acetate on lipase. Figure 1 showed the concentration profile of cascaded synthesis of the (R)-phenyl ethyl acetate using prepared catalyst. Table 1 represent different control experiments and their outcomes for the reaction.

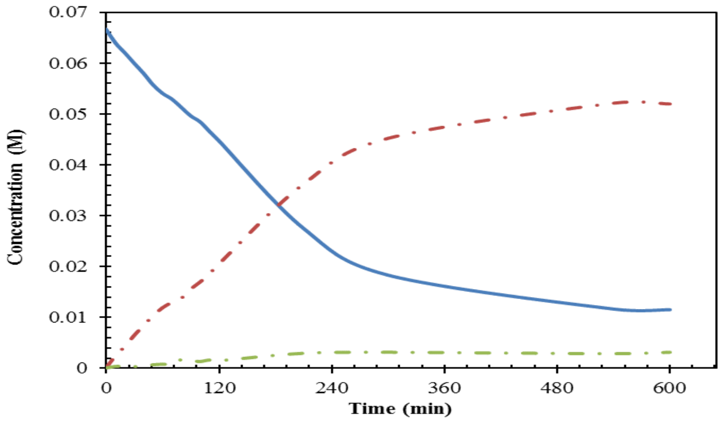

Figure 1: Concentration profile during the progress of reaction

Table 1: Evaluation of different control experiments

Control experiments	Starting reactant	Acetophenone (M)	1-Phenyl ethanol (M)	(R)-phenyl ethyl acetate (M)	Remarks
8% Pd/MCF	Acetophenone	0.0347	0.032	0	Palladium led to the hydrogenation of acetophenone and resulted in the formation of racemic mixture of the 1-phenylethanol. In the absence of lipase further kinetic resolution was not proceeded.
Lipase/ MCF	Acetophenone	0.0667	0	0	As lipase do not have any role to carry out hydrogenation of acetophenone lipase/MCF catalyst could not led to formation of any product.
Lip/Pd/MCF with H_2	1-phenyl ethanol	0	0.06	0.007	Lipase carries out the kinetic resolution of the 1-phenylethanol.
Lip/Pd/MCF without hydrogen	1-phenyl ethanol	0.0389	0.0259	0.00173	In the absence of the hydrogen, the palladium acted as oxidation catalyst which led to formation of acetophenone while simultaneously lipase led to kinetic resolution of the 1-phenylethanol.

4. Conclusions

The lipase-palladium on MCF catalyst was prepared and also employed for the synthesis of (R)-phenyl ethyl acetate in a single pot. In this reaction, hydrogen flow was discontinued after complete hydrogenation and replaced by nitrogen atmosphere with addition of vinyl acetate. The reaction showed complete conversion for hydrogenation step in 10 h and 49.11% selectivity towards R-enantiomer with respect to racemic mixture in 6 h. With the help of the prepared tandem catalyst, it was possible to overcome the use of multiple supports as well as separation of intermediate product in comparison with the reactions performed independently. It also provided the advantage of using a single reactor. Overall, this strategy renders a green and clean process with minimum use of energy and material.

References

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