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Lactic acid production from glycerol in alkaline medium using Pt-based catalysts in continuous flow reaction system

Arthur M. Bruno, Carlos Alberto Chagas, Mariana M.V.M. Souza, Robinson L. Manfro*

Escola de Química, Universidade Federal do Rio de Janeiro - UFRJ, Centro de Tecnologia, Bloco E, sala 206, CEP 21941-909, Rio de Janeir/RJ, Brazil

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ABSTRACT

It was investigated the lactic acid (LA) production from glycerol in alkaline medium (NaOH) employing platinum (0.5 wt% PtO_2) catalysts supported on Al_2O_3, ZnO and MgO in continuous flow reaction system over a period of 30 h. Besides the effect of catalyst supports, it was studied the influence of the temperature/pressure and NaOH/glycerol molar ratio. The catalysts were prepared by incipient wetness method and characterized by XRF, XRD, N_2 adsorption–desorption, TPR, TPD-CO_2 and the dispersion of platinum was determined by H_2 chemisorption. The reactions were performed at 200–260 °C, 20–46 atm, with space velocity (WHSV) of 2 h^{-1}, 10 vol% glycerol solution and NaOH/glycerol molar ratio of 0.5, 0.75 and 1.0. The results of the catalytic tests showed that the main liquid products are lactic acid and 1,2-propanediol (1,2-PDO). Using the Pt/ZnO catalyst at 240 °C/35 atm and NaOH/glycerol molar ratio = 1, it was obtained the highest lactic acid selectivity (~80%) and yield (~68%). However, in this reaction, the lactic acid yield decreases to around 25% if NaOH/glycerol molar ratio is reduced to 0.5. The highest yield to 1,2-propanediol (18.5%) was obtained with Pt/Al_2O_3 catalyst that was associated with the acidity of the catalyst. The catalysts showed excellent stability without evidence of deactivation over the evaluated period.

1. Introduction

The catalytic conversion of renewable raw materials for the synthesis of chemical products with higher added value has attracted much attention in the last two decades due to growing environmental concerns and the excessive demand for fossil fuels, which may be exhausted in few decades [1–3].

Among the renewable fuels, the production of biodiesel stands out. Biodiesel is typically produced by the process of trans-esterification of vegetable oils or animal fats and in this process generates glycerol, which is the main byproduct. The production of a ton of biodiesel results in about 110 kg of crude glycerol or 100 kg of pure glycerol [4]. In Brazil, according to National Agency of Petroleum, Natural Gas and Biofuels (ANP), the production of biodiesel (B100) in 2015 was approximately 4.0 million m^3, generating 400,000 m^3 of crude glycerol and this represents an increase of 16% over the year 2014 [5]. It is expected that the Brazilian production of biodiesel (B100) further grows due to the compulsory use of biodiesel in diesel fuel. From October 2014, the Brazilian government increased the percentage of biodiesel in diesel oil from 5% (B5) to 7% (B7), which is currently maintained. Therefore, a glycerol surplus has been generated in Brazil, and also in the world market.

Glycerol is very useful for the production of a wide variety of chemicals, polymers and fuels. Some of the processes described in the literature include polymerization, esterification, dehydrating to produce acrolein (propenal) and hydroxyacetone (acetol), selective oxidation to dihydroxyacetone, among others [6–8]. Furthermore, the catalytic conversion of glycerol with different metals under hydrogen or inert atmosphere can lead to a wide range of chemical products [9,10]. In addition, aqueous-phase reforming (APR) or steam reforming of glycerol produce hydrogen as the main product [11–13].

The 1,2-propanediol (1,2-PDO) and lactic acid (LA) are two important chemicals that may also be produced by catalytic conversion of glycerol. In particular, LA is an important industrial product, that can be converted to ethanol, propylene glycol, acrylic polymers and polyesters [14]. LA copolymers are used in packaging, with the advantage of being biodegradable [15], and for the manufacture of prosthetic devices, sutures and internal drug dosing, due to biocompatibility [16].

* Corresponding author.
E-mail address: robinson@eq.ufrj.br (R.L. Manfro).

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