Fischer-Tropsch synthesis over lignin-derived iron-containing carbon fiber catalysts prepared in a single step by electrospinning

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The decline in oil reserves, combined with growing concerns about the effects of climate change, has driven the search for a development of sustainable alternatives for producing liquid fuels, short-chain olefins and high-value-added chemicals. In this context, Fischer-Tropsch synthesis (FTS), using syngas ($CO + CO_2 + H_2$) derived from the gasification of biomass waste and/or CO_2 and H_2 from carbon capture and renewable sources, respectively, emerges as a promising and more sustainable alternative to traditional petroleum-based processes. In addition to this, biomass waste could be used to produce renewable FTS catalyst supports, and as a result both processes of biomass conversion have a positive environmental and economic impact.

This work explores the preparation of iron catalysts immobilized on carbon fibers derived from biomass waste for hydrocarbon production via FTS. The advantages of using structured fibrillar catalysts, over other conformations, are an adequate combination of excellent characteristics, such as a high specific surface area, very small fiber diameter, which confers these catalysts excellent mass and heat transport properties, negligible diffusional limitations, very low pressure drop in fixed-bed reactors and a good flexibility to be adapted to any reactor geometric design.

The catalysts were synthesized in one step by electrospinning, in a coaxial configuration, and using solutions of Alcell® lignin/ethanol/iron nitrate with a mass ratio of 0.86/1/0.01. The lignin fibers were stabilized at 200 ºC with a heating rate of 0.5 ºC/min in an air atmosphere and subsequently carbonized at 500, 650 and 800 ºC, with carbonization times ranging from 0 to 6 hours. The catalytic activity was evaluated after reducing the catalysts in a hydrogen atmosphere (450 ºC, 8 h) in a fixed-bed pressurized reactor under conditions of 20 bar, 340 ºC, 50 $mmol_{CO,STP}$ g_{Fe}^{-1} min^{-1}, and a CO/H_2 ratio of 1. The catalysts were labeled as Fe@CF-X, where FC represents carbon fiber, Fe denotes iron, and X indicates the carbonization time in hours (h). The results are summarized in Table 1.

The prepared catalysts exhibit predominantly microporous structures with specific surface areas ranging from 300 to 400 m^2/g and iron mass contents of 3-4 wt. %. XPS analysis revealed an increase in iron carbide and magnetite phases with longer carbonization times, which enhanced CO conversion, improved selectivity toward long-chain hydrocarbons (C5+) and reduced CH_4 selectivity.

Table 1. CO conversion and product selectivity for FTS after 24 h on stream. Reaction conditions: 340 ºC, 20 bar, $H_2/CO = 1$ y GHSV / mmolCO,STP gFe^{-1} min^{-1} = 50.

Catalyst	XCO %	SCO_2 %	SCH_4 %	SC2-C4 %	SC5+ %
Fe@CF-0	6.8	50.8	19.5	26.1	3.5
Fe@CF-3	50.7	52.9	13.0	29.9	4.1
Fe@CF-6	66.4	51.2	11.4	27.2	10.1

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