Low-cost biomass-based carbon supports for Ni–W catalysts in sustainable ethylene glycol production

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Abstract:

The sustainable production of ethylene glycol (EG), a key platform chemical for polymers and antifreeze formulations, remains a major challenge due to its current dependence on fossil-derived feedstocks and noble-metal catalysts. The one-pot catalytic conversion of wastes into EG offers a compelling alternative, provided that low-cost, hydrothermally stable and highly active catalysts can be developed. Biomass-derived carbons represent attractive supports due to their tunable porosity, surface chemistry, sustainability and reduced environmental footprint. This work focused on the synthesis of glucose-derived and low-cost food waste-derived carbon supported Ni-W catalysts for the sustainable EG production from cellulose/wastes.

Glucose and fruit peel-derived carbons were synthesized by hydrothermal carbonization of glucose, banana and orange peels, followed by a thermal treatment under N_2 atmosphere for 2 h at 700 °C to develop porosity, and were denoted as CG (carbonized glucose), carbonized banana (CB), carbonized orange (CO). Glucose-derived carbons were also prepared by physical activation under CO_2 atmosphere at 700 °C for 2 h (AG_{500}) or at 900 ºC for 2h (AG_{850}) or 6 h (AG_{1700}). Subsequently, Ni-W catalysts were prepared by incipient wetness impregnation of the prepared materials, and evaluated in the hydrolytic hydrogenation of cellulose/waste, for which water (300 mL), ball-milled cellulose/waste (750 mg) and catalyst (300 mg) were added to a 1000 mL Parr reactor under stirring (300 rpm). After heating under nitrogen to 205 ºC, the reaction was initiated by switching to hydrogen (50 bar) and analyzed by HPLC and TOC. The materials were characterized by N_2 adsorption, ICP, TG, EA, XPS, Raman spectroscopy, TEM, SEM-EDS and XRD.

The results demonstrate that the carbon support's textural and surface properties play a decisive role in catalyst performance. Physically activated carbons with higher surface area and microporosity enhanced metal dispersion and promoted the synergistic action between Ni hydrogenation sites and W species responsible for retro-aldol condensation. EG yields >60% were achieved from cellulose over optimized glucose-derived catalysts, while catalysts prepared using fruit peel-derived carbons delivered EG yields of up to 45%, demonstrating for the first time the effectiveness of these materials as both sustainable catalyst supports and enablers for food-waste-to-EG conversion (Figure 1). These findings highlight biomass-derived carbons as powerful, low-cost alternatives to conventional supports, paving the way toward circular and economically viable EG production.

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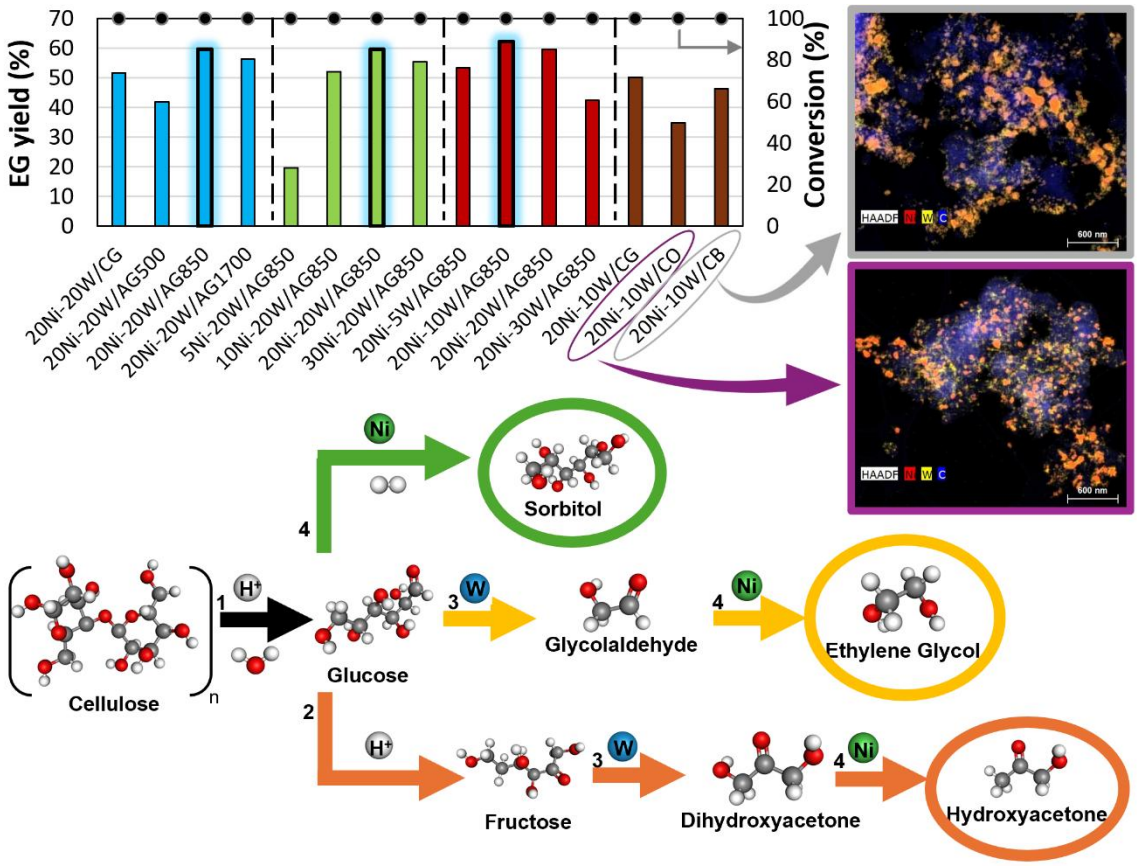

Figure 1 - Cellulose conversion efficiencies, morphological analysis of catalysts obtained by TEM, and the catalytic reaction mechanisms [1 – hydrolysis; 2 – isomerization; 3 – RAC; 4 – hydrogenation].