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Two-step glycerol valorization to 1,2-propanediol as the basis for the construction of a SMART-reactor

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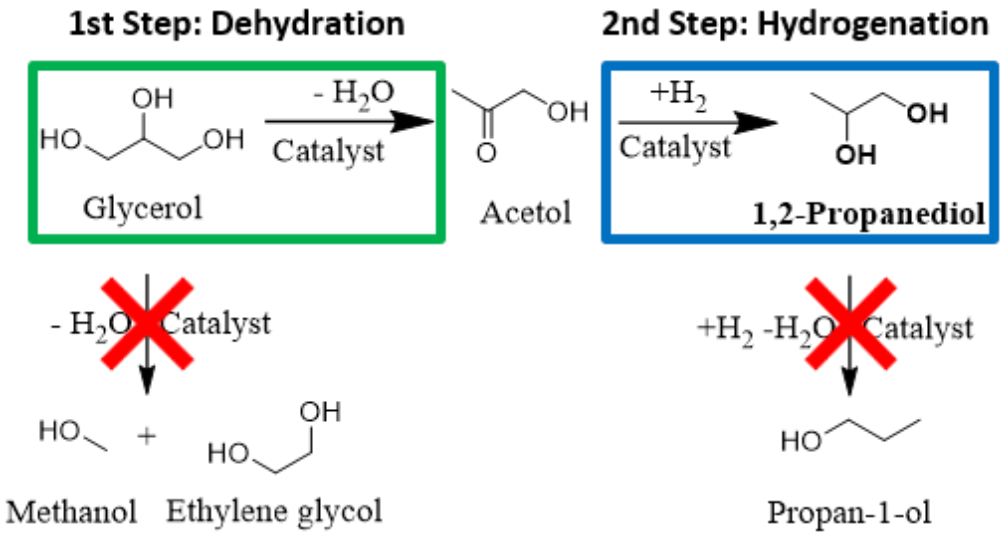
The conversion of surplus bio-based glycerol (GL), generated as a by-product of biodiesel production, into 1,2-propanediol (1,2-PDO) represents an important opportunity for a circular carbon economy. 1,2-PDO is an important platform chemical used in polymers, food, pharmaceuticals, and cosmetics. Therefore, the selective catalytic hydrogenolysis of GL to 1,2-PDO offers a sustainable alternative to conventional fossil-based production processes. However, side reactions, such as the C-C cleavage of GL to ethylene glycol and subsequent hydrogenolysis of 1,2-PDO, must be suppressed.

Therefore, the primary goal of this study is to optimize the conversion of bio-based crude GL to 1,2-PDO through reaction engineering. To this end, we performed comprehensive kinetic and mechanistic studies of the key sub-reactions to determine optimal reaction conditions that increase selectivity and minimize undesired side reactions. The reaction process is monitored over time using pH measurements, liquid and gas chromatography to determine kinetic parameters, conversion, yield, and selectivity. Based on insights from the study of isolated sub-reactions, a novel two-step process is designed to separate the dehydration and hydrogenation reactions.

In this separated process, shown in Figure 1, GL is first dehydrated under conditions that suppress C-C cleavage, followed by a separate hydrogenation step optimized to prevent product degradation.



Overview of the separated approach for glycerol hydrogenolysis to 1,2-PDO.

Both steps are conducted in the same reactor using the same in-house developed catalyst, using Ru-Cu supported on CNTs, but different reaction conditions. pH measurements have been shown to be a cost-effective, real-time analytical method for monitoring reaction progress during this two-step process. These findings establish the basis for designing an autonomous SMART-reactor (**s**ustainable, **m**ultipurpose, **a**utonomous, **r**esilient, **t**ransferable) with in-situ monitoring (e.g. acetol concentration) to switch automatically between the two process steps. The research advances sustainable GL valorization and supports more resilient, flexible biomass-based chemical production.

In conclusion, glycerol valorization to 1,2-propanediol represents a bio-based alternative to the fossil-based production of 1,2-propanediol. This approach contributes both directly and indirectly to circular economy goals and defossilization: directly, by transforming a renewable waste stream into a valuable product and thereby reducing dependence on fossil-based feedstocks; and indirectly, by improving the sustainability and economic viability of the underlying biodiesel production process.