Pilot Scale-up Strategies for Biobased Acetal Monomers in High-performance Polymers

S. B. Wigmans[1,2], J. Behaghel de Bueren[1], M. Rolland[1], J. Luterbacher[1], R. Marti[2]

[1]Institute of Chemical Sciences and Engineering, Ecole Polytechnique Fédérale de Lausanne, Rte Cantonale, 1015 Lausanne, Switzerland
[2]Institute of Chemical Technology, Haute école d'ingénierie et d'architecture Fribourg, Bd de Pérolles 80, 1700 Fribourg, Switzerland
sylvie.wigmans@hefr.ch

The sustainable transformation of the chemical industry requires scalable processes to replace fossil-derived feedstocks with renewable alternatives that enable defossilization, circularity, and reduced environmental impact. Although many novel biobased molecules have been developed at the laboratory scale, few address the practical challenges of process scale-up and industrial implementation. Scaling these systems is essential to assess their processability, material properties, and economic feasibility under industrially relevant conditions.
Lignocellulosic biomass provides an abundant renewable carbon source, though its heterogeneity complicates efficient valorization. Aldehyde-assisted fractionation (AAF) offers a promising approach by stabilizing reactive intermediates through acetal formation, preserving oxygen functionality, and enhancing biomass utilization efficiency. This strategy has yielded two key monomer platforms: dimethylglyoxylate xylose (DMGX) derived from corncobs [1] and methyl glyoxylate glycerol (MGG) from biodiesel waste. Both enable the production of oxygen-rich polymers with advantages in mechanical strength, biodegradability, and recyclability, making them interesting candidates for sustainable high-performance plastics.

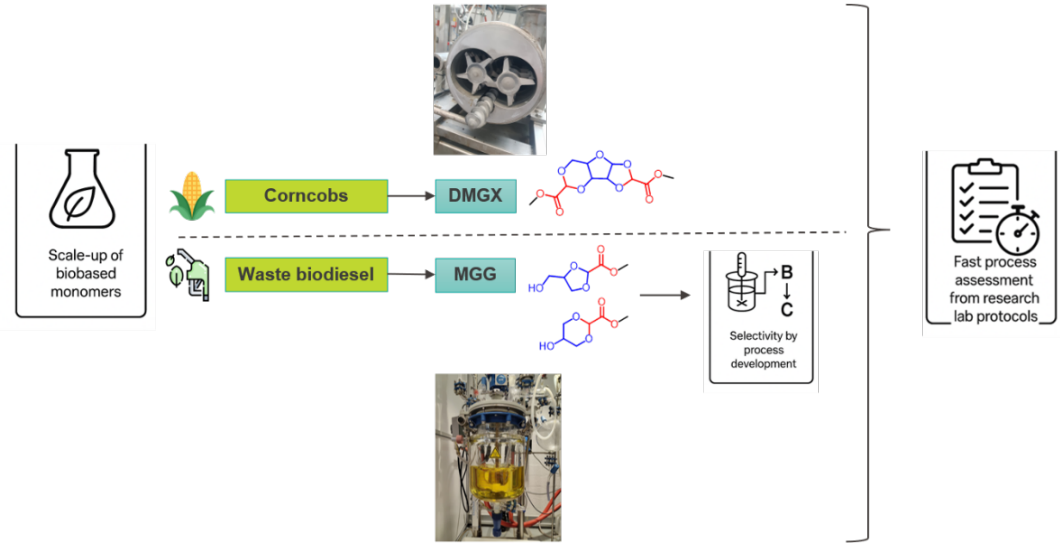

Figure 1. Overview of the pipeline from laboratory to pilot scale based on the DMGX and MGG platform chemicals.

Despite their promise, major barriers remain for scale-up, including the incompatibility of viscous, neat reaction mixtures with conventional batch reactors and the complexity of isomeric mixtures from natural feedstocks. Furthermore, early integration of techno-economic analysis (TEA) is critical to identify cost drivers and process bottlenecks, particularly regarding feedstock purity, solvent recovery, and purification strategies. Here we present our work to develop a scalable process pipeline from laboratory to pilot scale, using DMGX and MGG as case studies. At the HEIA pilot facility in Fribourg, monomers will be produced on a kilogram scale for downstream polymer processing while advancing process-intensification and isomer-selectivity strategies. Collectively, these efforts will deliver robust, scalable protocols for biomass-derived platform chemicals and accelerate their translation into industrially relevant bioplastics.

[1] L. Manker et al., *Nat.Chem.*, **2022**, 14, 976-984