Supplemental Information

Production of monosaccharides and whey protein from acid whey waste streams in the dairy industry

Mark J. Lindsay, Theodore W. Walker, James A. Dumesic, Scott A. Rankin, George W. Huber

Section S1: Model fit of experimental data

We conducted nine experiments at 160 ºC to elucidate the kinetic model for acid catalyzed lactose hydrolysis. These experiments were: 1) acid catalyzed lactose hydrolysis, 2) acid catalyzed glucose degradation, 3) acid catalyzed galactose degradation, 4) acid catalyzed lactose + glucose degradation, 5) acid catalyzed lactose + galactose degradation, 6) acid catalyzed glucose + galactose degradation, 7) lactose thermal degradation (or thermal hydrolysis, as it affords glucose and galactose in near quantitative yields), 8) glucose thermal degradation, and 9) galactose thermal degradation. The experimental data and model fit for reactions 1 through 6 are shown in Figure S1, and the experimental data for experiments 7 through 9 are shown in Figure S2. In each reaction, a combination of lactose, glucose, and galactose was added to deionized water to form aqueous sugar solutions with an initial sugar composition for each sugar of 0.11 M. For acid catalyzed reactions, the sulfuric acid concentration was 0.005 M when no lactose was present and 0.0005 M when lactose was present. Model 12, which contains only acid catalyzed lactose hydrolysis and thermal degradation reactions, was used to evaluate the data. The experimental data and the fit from Model 12 are shown in Figure S1. In all cases, the model fits the data reasonably well.

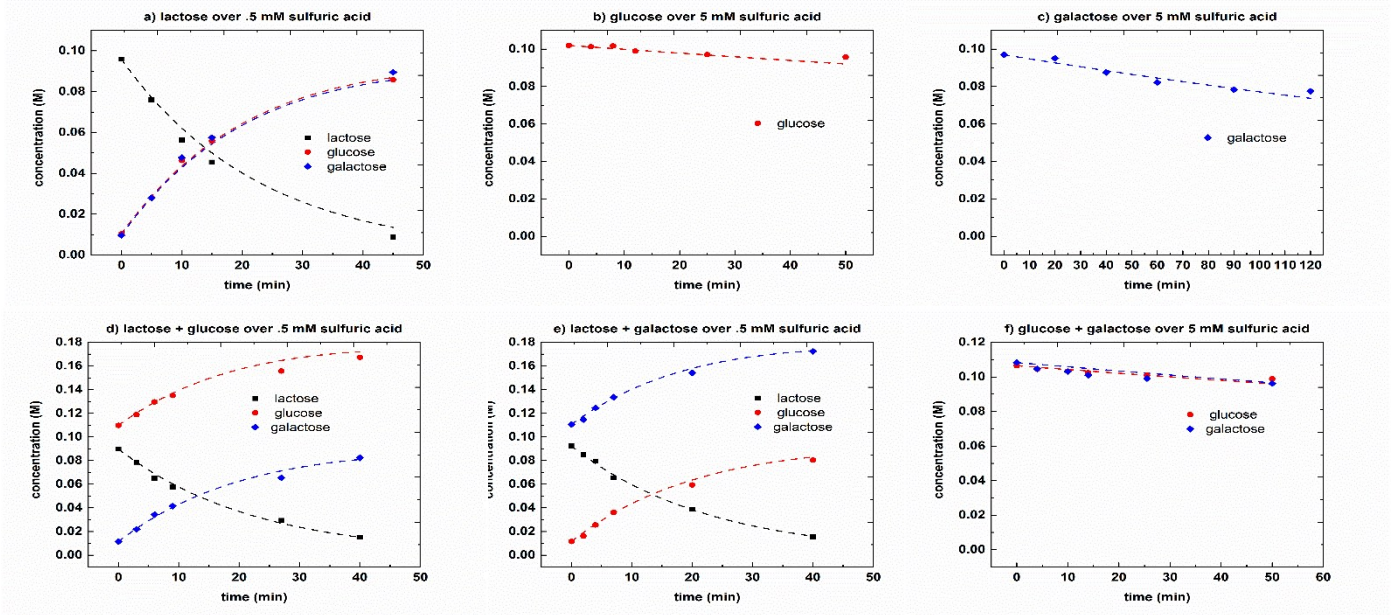

Figure S1. Experimental data and model fit for the following acid-catalyzed experiments: a) acid

catalyzed lactose hydrolysis, b) acid catalyzed glucose degradation, c) acid catalyzed galactose

degradation, d) acid catalyzed lactose + glucose degradation, e) acid catalyzed lactose +

galactose degradation, and f) acid catalyzed glucose + galactose degradation. The dotted lines are

model-predicted concentrations for lactose, glucose, and galactose. *Reaction conditions: 160 ºC,*

0.11 M initial concentration for each sugar, stir rate 400 RPM, 0.005 M H_2SO_4 in acid catalyzed reactions when no lactose present, 0.0005 M H_2SO_4 when lactose present.

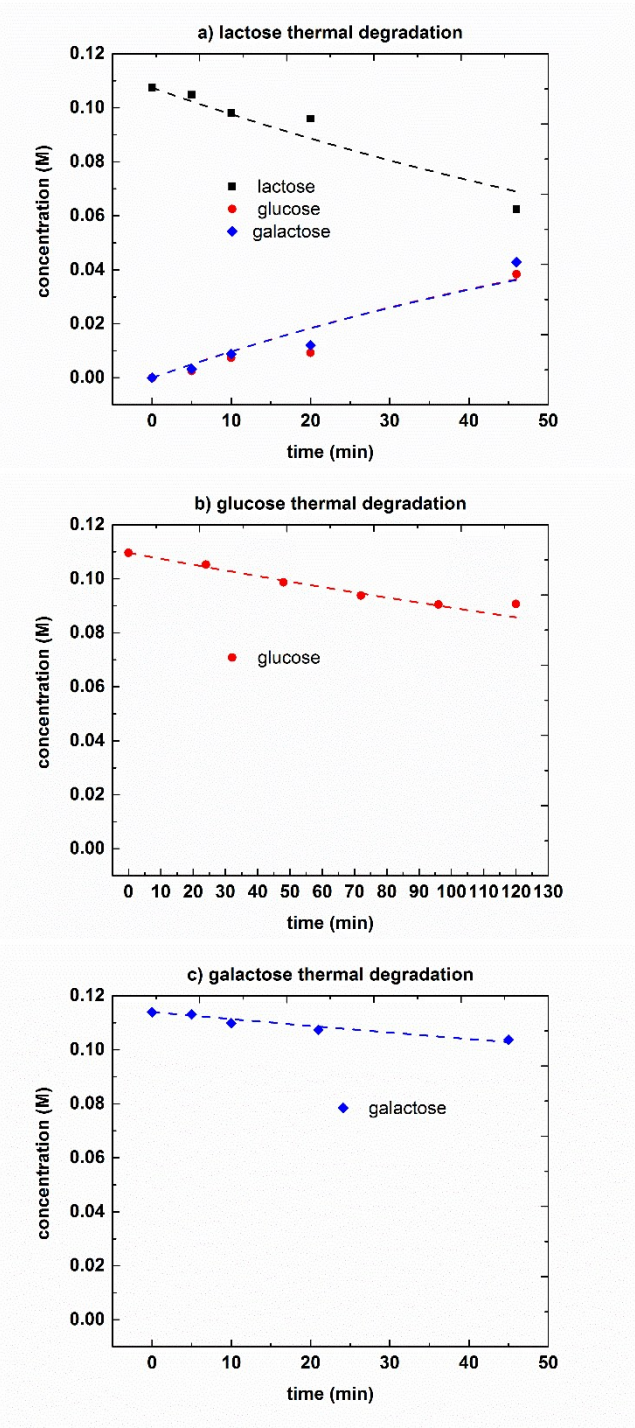

Figure S2. Experimental data and model fit for thermal (non-catalytic) degradation of a) lactose, b) glucose, and c) galactose. The dotted lines are model predicted concentrations for lactose, glucose, or galactose. *Reaction conditions: 160 ºC, 0.11 M initial concentration for each sugar, stir rate 400 RPM.*

Section S2: Model-predicted monosaccharide selectivity

Using Model 12, we calculated the model-predicted monosaccharide selectivity for a temperature range of 100 – 200 ºC and retention times up to 85 minutes for lactose hydrolysis catalyzed by 0.005 M H_2SO_4. Figure S2 shows the heat map of the predicted monosaccharide selectivity. At temperatures below 160, the monosaccharide selectivity remains nearly 100%. The results in Figure 3a agree with this model, as the monosaccharide selectivity at 150 ºC remains above 95% for the entirety of the reaction.

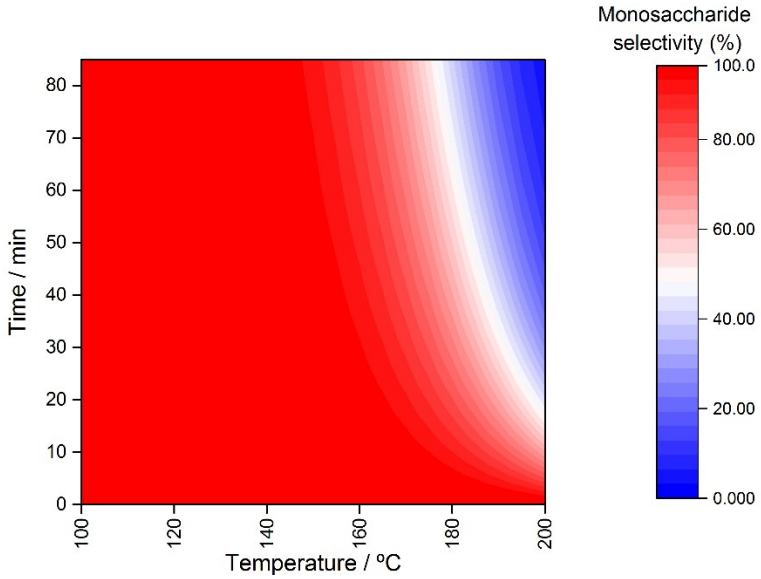

Figure S3. Model-predicted monosaccharide selectivity from acid-catalyzed lactose hydrolysis vs. temperature and reaction time. *Reaction conditions: 0.11 M lactose in water; 0.005 M H_2SO_4.*