Conversion of xylose to targeted volatile fatty acids as a key step in the lignocellulosic carboxylate biorefinery

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An emerging alternative for organic carbon recovery is the production of carboxylates or volatile fatty acids (VFA) by anaerobic fermentation. VFA have market value on their own and are precursors to many added-value compounds. The so-called carboxylate platform consists of the processes whereby residual streams are converted to VFA and, subsequently, to other chemicals, biofuels and biopolymers such as polyhydroxyalkanoates. However, mixed-culture acidogenic fermentation is characterized by yielding a mixture of VFA. This poor selectivity is a serious obstacle in the development of the carboxylate platform; it is essential to understand how targeted VFA can be produced preferentially by manipulating the fermentation conditions, e.g. pH, retention time, substrate blending, reactor type, etc.

As a source of abundant low-cost biomass, lignocellulosic residues are the focus of project CELL4CHEM with the goal of developing a biorefinery scheme that would lead to VFA and medium chain carboxylates, which requires understanding glucose and xylose behaviour in mixed-culture fermentation (figure 1).

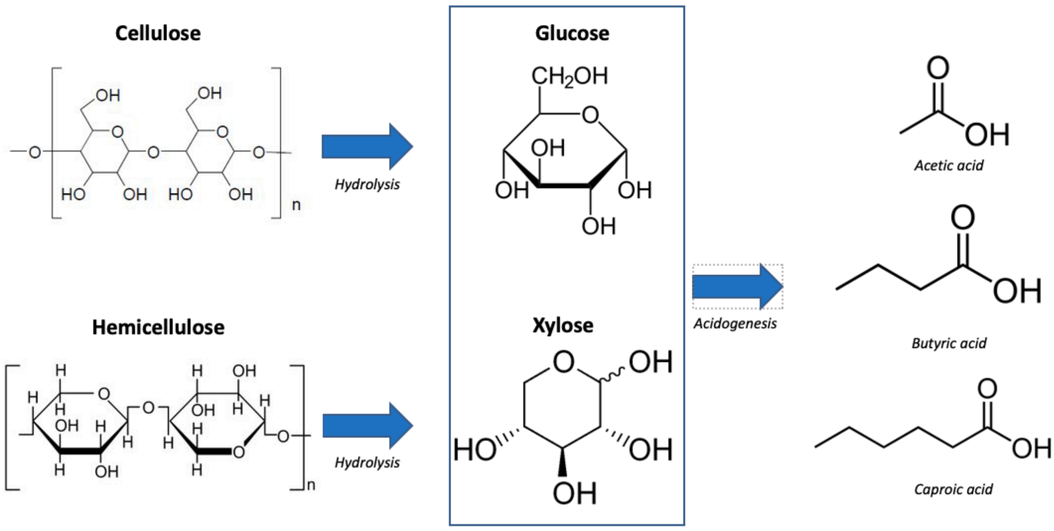

Figure 1. Main steps for anaerobic fermentation from cellulose and hemicellulose fractions

As glucose acidogenic fermentation has been well covered in scientific literature, this contribution focuses on xylose fermentation. By operating both batch and continuous stirred tank reactors (CSTR), the impact of pH, organic loading rate, retention time and substrate blending on the fermentation products were studied. The first two are summarised here.

It was possible to achieve a relatively stable operation at high organic loading rate (22.3 g xylose/L·d) albeit at the expense of a significant fraction of unconsumed substrate which would make these operation conditions uneconomical. As expected significan fractions of lactic acid were obtained at the highest loading rates, which can be used in subsequent transformations to promote the conversion to longer chain VFA. It was seen that pH has little effect on the spectrum of VFA that are produced in CSTR: acetic and butyric acids are the dominant products from pH 4.5 to pH 8 (figure 2). However, in batch mode much less butyric is produced at pH 4 to 8 which is consistent with high substrate at the beginning of the batch leading to kinetically favoured products (i.e. lactic acid) which are subsequently converted into acetic and propionic acids.

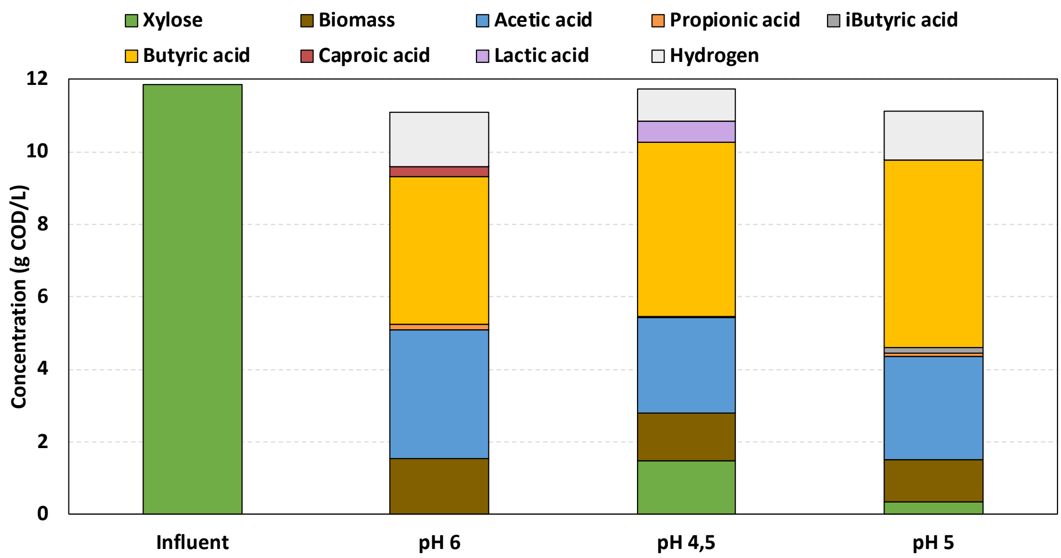

Figure 2. Spectrum of products obtained at CSTR steady state at different pH. Mass of all compounds expressed in grams of chemical oxygen demand

This contribution sheds light on the products of xylose anaerobic fermentation and suggests that kinetic limitations (e.g. high organic loading rate, low retention time, high substrate concentration) are the main variable that can be manipulated to steer xylose fermentation towards desired products, facilitating the introduction of lignocellulosic biomass in the carboxylate platform biorefinery

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