Sustainable energy and chemicals from agricultural by-products

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Extracting energy and chemicals from agricultural by-products/biomass is considered as part of the solution to achieving net-zero targets by 2050. However, there are many barriers in valorisation of lignocellulosic biomass due to its recalcitrant structure; therefore, innovative solutions are needed to make these processes economically viable. This talk will cover two key aspects related to lignocellulosic processing: pretreatment of lignocellulosic materials and process intensification of ethanol production.

The first part covers a novel and scalable pretreatment technology to breakdown lignocellulosic material using renewable energy. This involves the design, characterisation, modelling and applications of a novel plasma-microbubble reactor that forms a dielectric barrier discharge (DBD) at the gas–liquid interface to facilitate the transfer of highly reactive species, both short-lived and long-lived, from the gas plasma into the liquid phase. The use of fluidic oscillation mediated microbubbles enabled efficient dispersion of long-lived reactive species in the liquid and UVC-induced oxidation reactions are triggered by the plasma radiation at the gas-liquid interface. A numerical model was developed to understand the dynamics of the reactor, and the model predictions were compared with the experimental measurements. The potential of this approach was demonstrated by pretreating a 5% (w/w) miscanthus suspension for 3 h, which yielded 0.5% acid soluble lignin and 26% sugar release post hydrolysis. The process consumed 20-fold less energy compared to steam explosion. Furthermore, anaerobic digestion of plasma microbubble pretreated maize produced 18% greater biogas yield in comparison to untreated raw samples.

The second part focuses on process intensification. Product inhibition is a main barrier to the production of bioethanol at industrial scale and is responsible for dilute product streams which are energy intensive to purify. The potential of hot-microbubble clouds generated by fluidic oscillation to continuously remove ethanol from bioreactors at lab scale is presented. *Parageobacillus thermoglucosidasius* (TM242), a thermophilic organism that can utilize a range of sugars derived from lignocellulosic biomass, was selected for this study as future bioethanol production needs to be based on sustainable feedstocks. First, a custom-made microbubble gas-stripping unit containing dilute ethanol-water mixtures was tested in batch and continuous mode to identify the effect of operating parameters on the stripping process. Then, *in situ* and *ex situ* microbubble stripping from the fermentation broth was carried out while monitoring the residual ethanol concentration in a bioreactor operated in fed-batch and continuous mode. In all cases, residual ethanol concentration was maintained below the inhibition threshold for TM242, which is ~2%(v/v), while allowing an ethanol productivity up to 14.9 g L^{-1} h^{-1}.

Keywords: biomass, pretreatment technology, lignocellulosic waste, plasma-microbubble reactor, ethanol