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Short communication

The bubble-induced mixing in starch-to-ethanol fermenters

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ABSTRACT

China launched an important production of fuel-ethanol by fermentation of non-grain feedstock, with cassava mostly used as starch source. The industrial fermenters have diameters and liquid levels between 6 and 16 m. The mixing of the fermentation broth is important for the efficient operation. Mixing is commonly achieved by the combined action of (i) an external recycle flow, and (ii) the gas-induced mixing by CO_2-bubbles formed during the bio-reaction. To avoid solids sedimentation, flat-bottom fermenters add mechanical impellers. Whereas the effects of impellers and external recycle flow can be predicted by CFD, the characteristics of the gas bubbles, and their mixing action have not yet been fully studied, despite being of paramount importance in the design of the fermenters. The research investigates the bubble-induced mixing in a two-dimensional scaled-down experimental rig. Experimental results are used to define the dominant parameters of a model approach to bubble-induced mixing. The liquid mixing data can moreover be used to validate complex CFD approaches to the overall mixing.

Keywords: Fermentation; Starch; Mixing; Bubbles; Model; Tracer experiments

1. Introducing the three-phase nature of fermenters

1.1. *Research background*

A number of chemical, biochemical and physical processes are of 3-phase nature and involve the interaction between a gas, a liquid and a solid phase, with solids being suspended in the liquid. Typical biochemical examples are the Upflow Aerobic/Anaerobic Sludge Blanket reactor in waste water treatment (biomass flocs, water, air or biogas) (e.g. Leitao et al., 2011; Latif et al., 2011), the digestion of sewage sludge (biomass flocs, water, biogas) (e.g. Appels et al., 2008; Bridgeman, 2012; Donoso-Bravo and Fdz-Polanco, 2010), or the anaerobic fermentation of biomass to bio-ethanol, where the fermentation of cassava starch is a typical example of industrial use in China with plants of the COFCO Group (Behai) (Liu and Liu, 2010) and of the YEDAO Group (Hainan) (Xie and Li, 2010) as large-scale applications. These industrial applications use multiple fermenters, operated in parallel, and either with 5° sloping flat bottom (COFCO) or with a conical outlet (YEDAO). The withdrawal point is located at the lowest point of the 5° sloping flat bottom (COFCO), or at the apex of the cone (YEDAO). A recycle pump conveys about 15% of the tank volume to the top of the tank, via a tubular heat exchanger, to cool the broth to 30 °C. The flat-bottom COFCO-fermenters use 4 identical horizontal-shaft impellers, installed 0.8 m above the bottom of the tank. The conical YEDAO-design uses no impellers. The COFCO-design has been previously illustrated and described (Zhang et al., 2011). The initial mash-suspension contains cassava and water in a ratio of 1:2.5. Amylase is added. The average density of the mash is ~1050 kg/m^3, for an initial cassava content of 28.6 wt% .The whole batch fermentation process usually lasts up to 65 h, at 32–28 °C. The initial viscosity of the cassava sweet mash is 700 cP (0.7 Pa s). Ethanol is accumulating along with the biological metabolism, while the viscosity of the mash fluid decreases from 700 cP to 300 cP. The bio-reaction is anaerobic, and CO_2 is produced as a by-product. The mixing process in the fermenter is hence of a complex nature, involving gas, liquid and solids (the cassava).

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