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Propagated fixed-bed mixed-acid fermentation: Effect of volatile solid loading rate and agitation at near-neutral pH

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HIGHLIGHTS

- ▶ Propagated fixed-bed four-stage fermentations at near-neutral pH.
- ▶ Effect of continuous or periodic mixing and volatile solid loading rate (VSLR).
- ▶ Continuous mixing gave higher yields and selectivities.
- ▶ Increased VSLR and liquid retention time decreased yield, conversion, selectivity.
- ▶ Operating at near-neutral pH achieved better performance than high pH.

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ABSTRACT

To increase conversion and product concentration, mixed-acid fermentation can use a countercurrent strategy where solids and liquids pass in opposite directions through a series of fermentors. To limit the requirement for moving solids, this study employed a propagated fixed-bed fermentation, where solids were stationary and only liquid was transferred. To evaluate the role of agitation, continuous mixing was compared with periodic mixing. The periodically mixed fermentation had similar conversion, but lower yield and selectivity. Increasing volatile solid loading rate from 1.5 to 5.1 g non-acid volatile solids/(L_{liq}·d) and increasing liquid retention time decreased yield, conversion, selectivity, but increased product concentrations. Compared to a previous study at high pH (~9), this study achieved higher performance at near neutral pH (~6.5) and optimal C–N ratios. Compared to countercurrent fermentation, propagated fixed-bed fermentations have similar selectivities and produce similar proportions of acetic acid, but have lower yields, conversion, productivities, and acid concentrations.

1. Introduction

High volatile fuel prices, harmful environmental effects from combusting fossil fuels, and rising food prices from converting starch and sugar crops to biofuels emphasize the need for a clean, economically viable energy source (Davis et al., 2011). Rather than converting food crops to biofuels, processes should employ lignocellulose, the most plentiful form of biomass (Schubert, 2006). One promising technology that converts lignocellose into liquid fuels is the carboxylate platform. Using versatile fermentation configurations, this process ferments any biodegradable feedstock into carboxylic acids (Forrest et al., 2010b; Holtzapple et al., 1999). Through chemical transformations, these acids can be converted to hydrocarbon fuel, offering a potential viable solution to global fuel problems (Agler et al., 2011).

In the fermentation step, a mixed culture of microorganisms is employed in a series of fermentors to digest substrate to produce carboxylic acids that are neutralized with a buffer (e.g., calcium carbonate) to form the corresponding salts. The salts can be concentrated and further processed into industrial chemicals and hydrocarbon fuels (Landoll and Holtzapple, 2011). The carboxylate platform has attractive economics, does not require sterile operating conditions or added enzymes, and has reached the demonstration level of development (Granda et al., 2009; Pham et al., 2010).

Since carboxylate salts are inhibitory and the biomass becomes less reactive as it is digested (Ross and Holtzapple, 2001), high product concentrations and high conversions are achieved using a countercurrent configuration, in which the solid and liquid phases are transferred in opposite directions through a series of fermentors,

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