Energy optimization of the evaporation process towards upconcentration of bio-based carboxylic acids

Balachandran S., Hogie J., Meers E., De Meester S.

Department of Green Chemistry and Technology, Ghent University, Kortrijk, 8500, Belgium

Keywords: Carboxylic acids recovery, multiple effect evaporator, ASPEN simulation, anaerobic digestion, organic fraction of municipal solid waste

Presenting author email: Srija.Balachandran@UGent.be

Short chain carboxylic acids, also known as volatile fatty acids (VFAs), such as acetic, propionic, butyric, lactic acid etc. are carbon compounds containing six or fewer carbon atoms (Bhatt et al (2020)). They find extensive applications in food, cosmetics, pharmaceuticals, and textiles industries, biofuel production, bioplastic synthesis, etc. (Aghapour Aktij et al (2020)). Currently, about 90% of VFAs production origins from fossil-based synthetic routes (Atasoy et al (2018)). Nowadays, due to an increasing awareness of the environmental impacts, there is a growing attention on the biological route towards VFA production such as dark fermentation (DF) and anaerobic digestion (AD) (Li et al (2016), Zacharof and Lovitt, (2013), Aghapour Aktij et al (2020), Bhatt et al (2020)). AD can be defined as a process in which a group of microorganisms in an oxygen-free environment break the organic matter and produce biogas as a final product using VFAs as an intermediate product (Atasoy et al (2018)). The DF process is an altered form of AD process where the biogas production is inhibited resulting into VFAs as the final product. However, there are some shortcomings related to these biological routes of VFA production.

The main drawback of the biological route is the cost for VFA recovery, accounting nearly up to 60% of the production cost (Li et al (2016)). Fermentative production results into a mixture of acids and fermentation residues. The mixture of acids is present in the fermented effluent in a low concentration, typically between 1 and 3 wt%. Furthermore, they have high water solubility and form an azeotropic mixture with water. In addition, the presence of a high solid content in the fermentation broth pose technical and economic challenges, which prevent the large scale production of VFAs (Aghapour Aktij et al (2020), Atasoy et al (2018), Outram and Zhang, (2018)). Therefore, there is a need for development of an energy efficient technology that ensures a separation of VFAs from the complex streams to yield products of high quality with high degree of purity. This offers a huge opportunity to enable substitution of fossil-based carbon (Aghapour Aktij et al (2020)).

The focus of this research work is to investigate the potential of the evaporation process for purification of VFAs from the fermentation broth by detailed ASPEN simulation. An organic fraction of municipal solid waste (OFMSW) is chosen as a substrate, which is first treated by the DF process, in which a mixture of VFAs is produced. The fermentation broth then undergoes a solid-liquid separation. The liquid fraction (LF) is sent to the recovery step, which is the evaporation process and the solid fraction is further subjected to the AD process, where biogas is produced. The biogas, mainly originating from the second fermenter, is used for generation of heat and electricity in the combined heat and power plant. The heat available is used to concentrate the LF in the recovery step. The study optimizes the use of the available energy from the biogas and proposes the best possible multiple effect evaporator configuration for achieving the maximum VFA upconcentration. This study further includes the influence of salts on the evaporation process, and identifies opportunities for thermal integration.

References

1. Aghapour Aktij, S.; Zirehpour, A.; Mollahosseini, A.; Taherzadeh, M., Tiraferri, A.; Rahimpour, A., 2020, ‘Feasibility of membrane processes for the recovery and purification of bio-based volatile fatty acids: A comprehensive review’, Journal of Industrial and Engineering Chemistry, 81, 24-40. https://doi.org/10.1016/j.jiec.2019.09.009
2. Atasoy, M.; Owusu-Agyeman, I.; Plaza, E.; Cetecioglu, Z., 2018, ‘Bio-based volatile fatty acid production and recovery from waste streams: current status and future challenges’ Bioresource Technology, 268, 773-786, https://doi.org/10.1016/j.biortech.2018.07.042
3. Bhatt, A.; Ren, Z.; Tao, L., 2020. ‘Value proposition of untapped wet wastes: carboxylic acid production through anaerobic digestion’, iScience, 23(6),101221, https://doi.org/10.1016/j.isci.2020.101221
4. Li, Q.; Jiang, X.; Feng, X.; Wang, J.; Sun, C.; Zhang, H.; Xian, M.; Liu, H., 2016, ‘Recovery processes of organic acids from fermentation broths in the biomass-based industry, Journal of Microbiology and Biotechnology, 26(1), 1-8, doi: 10.4014/jmb.1505.05049

5. Outram, V.; Zhang, Y., 2018, ‘Solvent-free membrane extraction of volatile fatty acids from acidogenic fermentation’, Bioresource Technology, 270, 400-408, https://doi.org/10.1016/j.biortech.2018.09.057.
6. Zacharof, M.; Lovitt, R., 2013, ‘Complex effluent streams as a potential source of volatile fatty acids, Waste and Biomass Valorisation, 4(3), 557-581, https://doi.org/10.1007/s12649-013-9202-6

Acknowledgement

The project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie agreement No 864077.