Process Economics Program

Review 2013-10
Adipic Acid from Free Fatty Acids via Verdezyne Fermentation

By Anthony Pavone
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December 2013

Abstract

IHS published PEP Report 284 in 2012 on bio-based adipic acid (ADA), which included an evaluation of Verdezyne process technology using their Generation-1 genetically modified yeast to convert glucose to adipic acid via fermentation. Verdezyne has subsequently developed Generation-2 yeast for adipic acid production from palm oil fatty acid distillate (PFAD). The new generation of genetically modified yeast claims faster productivity, and a tolerance for the high pH environment resulting from high concentrations of adipic acid product (up to 10 weight percent) in the fermentation broth. Given the solubility of adipic acid in water at fermentation temperatures being only 3.5%, the broth is supersaturated with adipic acid crystals. Verdezyne claims that Generation-2 yeast converts 1 mol of PFAD to 1 mol of adipic acid, for a mass consumption of approximately 2 mt PFAD producing 1 mt ADA. Verdezyne also claims adipic acid fermentation production rates of 1 gm/hr-liter, and insensitivity of this rate to the concentration of adipic acid in the fermentation broth.

In this PEP review, we evaluate our understanding of Verdezyne’s Generation-2 yeast technology, and we have modified significant portions of our process design from 2012 to take advantage of the process benefits provided by Verdezyne intellectual property. Conventional bio-based acid processes must operate at low broth acid concentrations given the sensitivity of organisms to low pH, requiring a complicated solution concentration approach. The two approaches most often used are liquid-liquid extraction, or converting the acid to a corresponding salt (often an ammonium salt), to eliminate the acid pH solution problem while allowing reasonably efficient reversion of the salt back to adipic acid. At the Verdezyne 10% adipic acid concentration in fermentation broth, concentration can be effected by three-stage evaporation.

The conventional DuPont/INVISTA adipic acid process converts cyclohexane to adipic acid using a two-step oxidation process in nitric acid. Besides the expensive metallurgy required for handling hot nitric acid (titanium), the conventional process produces significant quantities of by-product succinic acid and glutaric acid. Succinic acid crystallizes at a temperature slightly above adipic acid, while glutaric acid crystallizes at a temperature slightly below adipic acid. To effectively purify adipic acid via crystallization, there is a narrow concentration/temperature window in which to crystallize adipic acid without also crystallizing the other two by-products. In practice, this requires conducting the crystallization at sub-ambient temperatures at high vacuum, in order to remove water from the crystallizer solution as the crystals are precipitating out of solution. The vacuum compression requirement is both highly capital intensive, and highly energy intensive. Since the Verdezyne Generation-2 process produces only mono-carboxylic by-products, the crystallization dilemma is avoided.

In this review we update our understanding of Verdezyne’s Generation-2 adipic acid fermentation from PFAD technology using the approaches described above. We present both the technical aspects (process flow diagrams, equipment lists, material balances), and the corresponding capital cost and operating cost estimates for manufacture at a commercially competitive 160 kty capacity.
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