INDUSTRIAL PRODUCTION OF SUCCINIC ACID – A STEPWISE APPROACH

John Villadsen

Department of Chemical and Biochemical Engineering, DTU, 2800 Lyngby, Denmark

jv@kt.dtu.dk

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The production of aliphatic carboxylic acids by fermentation processes has become one of the targets of the emerging bio-industry by which bulk chemicals are synthesized from renewable raw materials. The 3 – carbon lactic acid has been the front runner with an annual production of more than 200000 ton. 3-hydroxy propanoic acid and propenoic acid (acrylic acid) are now studied in massive industrial research programs. The primary use of all three will be as monomers in the polymer industry. Butanedioic acid (succinic acid) is a 4-carbon di-carboxylic acid with great potential in the polymer industry, and also for production of an important solvent (1, 4 butane diol) and of many other intermediates. Right now about ten demonstration plants with capacity from 10000 to 30000 ton/year are being built by large chemical companies in the USA, in Europe and in the Far East. The bulk price of succinic acid is from 1600 to 2000 US $/ton, a price high enough to merit the use of high grade glucose (e.g. from sugar cane) as raw material to avoid a risk of having impurities in the product which either makes it unsuitable for polymer production or will require expensive purification steps.

The current industrial interest in succinic acid provides an excellent opportunity to study how a commercial production process is established – at least a score of patents and many recent academic papers illustrate which research topics are of critical importance. Is the development of a strain of high potential yield on sugar the primary goal? Or is fast kinetics of the strain that presumably leads to high productivity the goal? Downstream processing, bio-remediation and the right quality of the final product (fine crystals of the highly water soluble, white succinic acid) are other issues treated in the copious literature from 2005 to the present.

In the present study the large scale production of succinic acid (SA) is considered from the point of view of all the objectives cited above. First the metabolic network of typical succinic acid producers is considered with the aim of selecting a strain for which the catabolic network gives a high yield, $Y_{s,SA}$ C-mol SA per C-mol glucose, without loss of carbon to fermentation products such as acetic acid. The decrease of yield due to a necessary biomass production is analyzed. Next the kinetics of the process is considered, and the importance of maintenance SA-production is demonstrated. Having found the kinetics for the selected stoichiometry, design of a commercial reactors, either a steady state CSTR or a fed-batch reactor, can be done. Product inhibition is seen to be a major problem for the selected strain. This might best be solved by genetic engineering of the production strain, but as an alternative it is shown how the product inhibition problem can be solved by re-engineering the process design. In the alternative design a large part of the capital cost and the operational costs will be in down-stream processing. The use of electrically facilitated membrane processes is shown to give SA of the desired high purity, but at a rather high cost.

The study demonstrates how bioengineering must work hand-in-hand with molecular biology to reach the ultimate goal of modern biotechnology: To produce bio-chemicals from sustainable raw materials as cheap as, or even cheaper than from oil-based raw materials. Process intensification will become a key-word for the evolution of a competitive Bio-Industry