Nexant
Chem Systems

PERP Program – New Report Alert

June 2002

Chem Systems' Process Evaluation/Research Planning program has published a new report, ***Biotech Routes to Lactic Acid/Polylactic Acid (00/01S3)***.

The lactic acid market is currently at a watershed with the commercial reality of polylactide polymers and lactate esters. Global lactic acid demand was around 86,000 tons in 2001 with the market dominated by the food and beverage sector and the personal care industry. Lactic acid has a wide range of beneficial end-uses in these sectors relating to food preservation, flavor enhancement, deep skin treatment, etc. More specialized lactic acid end-uses include dialysis media and pharmaceutical intermediates. Unparalleled global demand growth of up to 14 percent per year is possible provided polylactides and lactate esters are commercially successful.

Lactic acid is mainly produced through fermentation processes although synthetic routes also exist. Today Musashino in Japan is the only synthetic lactic acid producer. The scale of lactic acid production has been rising significantly in order to supply feedstock for the production of polylactide polymer, principally the Cargill Dow NATUREWORKS® plant. Polylactides are not a new concept. However, in the past producers have been small scale preparing materials with biodegradability/compostability as the major demand driver. Polylactide synthesis proceeds via a lactide intermediate that can use either chiral form of lactic acid or combinations thereof to produce polymers with tailored properties for fibers, thermoforming, even injection and blow molding grades. Commercial development has paid close attention to polymer processability and performance in addition to biodegradability.

NATUREWORKS® will be produced at 140,000 tons per year in Blair, Nebraska. Integration of the corn value chain with Cargill, Purac and Cargill Dow can in effect give polylactide a very competitive cost of production and therefore a price that could compete with certain polymers derived from petrochemical means.

In addition, large volume, low cost lactic acid could also give rise to the successful commercial development of cost competitive lactate esters (methyl, ethyl, butyl, etc) as substitutes to those derived from petrochemical sources such as MEK, IPA, etc.

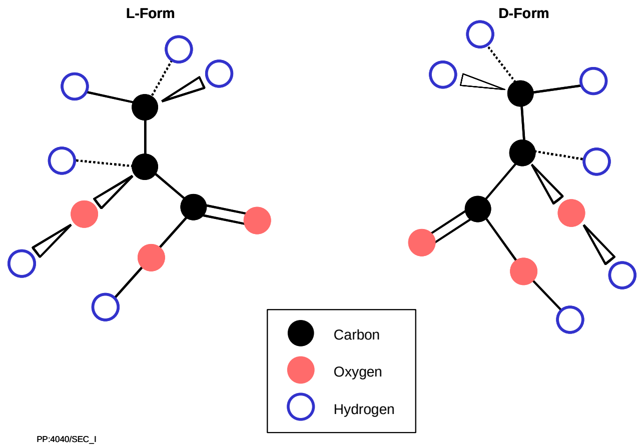
In considering how large these lactic acid complexes could become, Cargill Dow has publicly stated its belief that a 500,000 tons per year polylactide market will exist in the world by 2010 and two additional polylactide plants are being considered. Nexant/Chem Systems has proposed a potential "Mega" complex for combined lactic acid, polylactide with world-scale ester solvent production with overall economies of scale making the products potentially cost competitive with those derived from petrochemical feedstock.

Lactic Acid

Lactic acid or 2-hydroxypropionic acid is an "Alpha-Hydroxy-acid" (AHA) and was discovered by the Swedish Scientist Scheel in 1780 being first isolated from sour milk. This gave rise to a whole series of claims and counter claims in the academic literature concerning Scheels' findings. The French scientist Fremy produced lactic acid by fermentation and this gave birth to industrial production in 1881.

Lactic acid exists as in racemate form, made up of stereo-isomers as shown below.

LACTIC ACID STEREO ISOMERS



The isolated acid is a white crystalline solid which is hygroscopic. As this is the case it is typically manufactured and consumed as a concentrated solution of around 88 percent weight. In this form lactic acid exists not only as individual molecules, but oligomers and polymers. In addition, lactic acid can self-esterify providing a mixture of esters in equilibrium with acid and oligomers. Hence, purifying lactic acid can be a challenge. Synthetic lactic acid made from petrochemical feedstocks is optically inactive, i.e. a racemate mixture. Lactic acid made biochemically by fermentation is optically active and suitable organisms can selectively produce laevo- or dextro- rotatory enantiomers. However, salts of lactic acid tend to be found in the laevo state only.

Lactic acid is mainly consumed in foodstuffs where it plays an important role in food preservation, shelf life and flavor enhancement/control. In cosmetics it is used for deep skin treatments. Classical history often depicts Queen Cleopatra of Egypt bathing in asses milk as a beauty treatment. It is also known that women at the court of King Louis XIV (the “Sun King”) washed their faces in old wine. These natural beauty treatments contained lactic acid and tartartic acid, respectively. The action of these chemicals was of an exfoliating nature, i.e. an early form of cosmetic dermatology.

Polylactic Acid

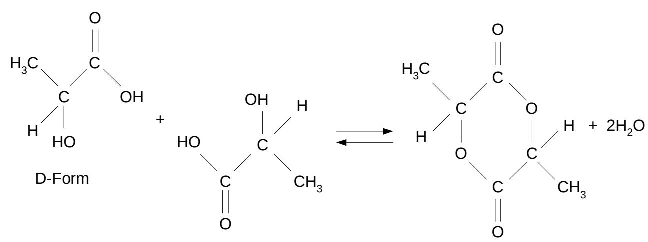
There has been considerable research and development in biopolymers in recent decades using all manner of feedstocks derived through petrochemical and biotransformation processes. Products include amongst others:

- Polylactides
  - NATUREWORKS® (Cargill Dow)
  - ECOPLA® (Original Cargill Product)
  - LACTY® (Shimadzu)
  - HELPON® (Chronopol)
  - LACEA®(Mitsui)

- Other product families include

    - BIOPOL® (ICI/Monsanto)
    - TONE® (DOW, Originally UCC)
    - METABOLIX® (Metabolix)
    - BIONELLE® (Showa High Polymer)
    - MATER-BI® (Novamont)
    - BIOMAX ® (DuPont)

Of these only a few have been commercial successes. NATUREWORKS® technology is based on lactic acid with a synthesis proceeding via a lactide intermediate. This is an important step as the lactide can be made from either or both chiral components – the “D” and “L” forms providing a chiral intermediate which upon opening and polymerization provide different polymers with tailored properties.



Lactic Acid MW=90.08 | Lactic Acid L-Form | Lactide (DL Form) MW=144.13

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The Corn Value Chain

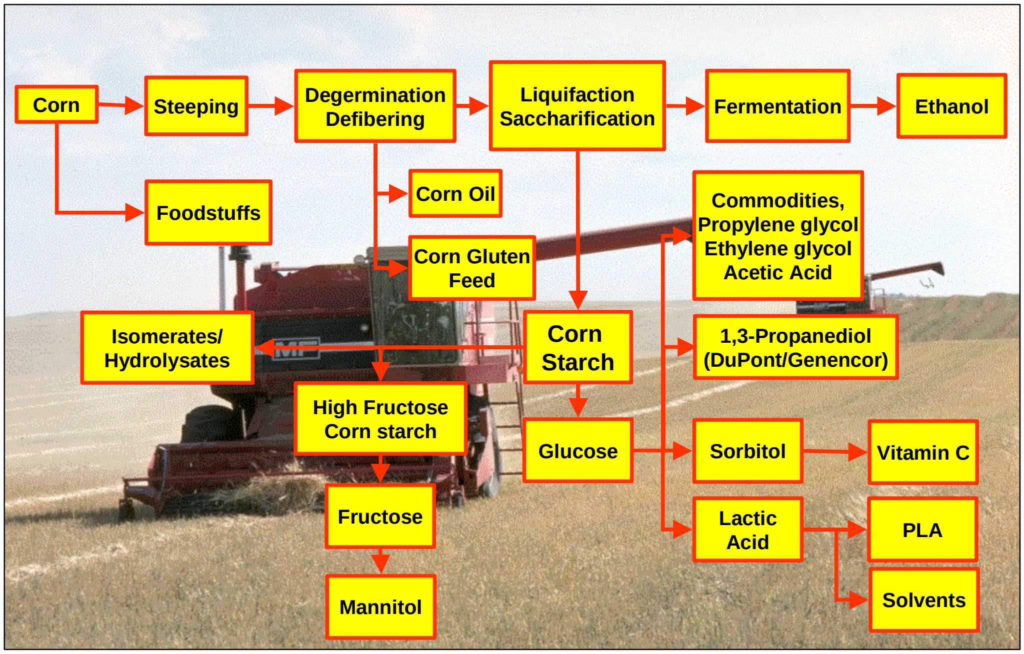
In the United States especially the growth in demand for bio-ethanol from corn has resulted in the development of large “chemicals from corn” complexes. There is a significant business opportunity to further enhance and develop such complexes to produce chemical intermediates and polymers to compete cost effectively with those derived from petrochemical sources. Other processes and chemical products that have been explored in the Nexant/Chem Systems’ PERP Program include:

- Developments in Bioprocessing Technologies: Alternative Routes Specialty Chemicals (96/97S1)
- Biotransformation Routes to 1,3-Propanediol (97/98S4)
- Sorbitol/Ascorbic Acid (97/98S11).

New developments associated with the corn value chain include *acetic acid from glucose* under development by Celanese in collaboration with Diversa.

As the figure below illustrates, there is considerable scope in developing biochemical processes as a means of adding value to corn and other natural products, sugar beet, tapioca, etc.

ENHANCEMENTS TO THE CORN VALUE CHAIN



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This new report from Nexant Chem Systems presents the chemistry, process technology and economics for both the synthetic and biological synthesis of lactic acid and conversion to polylactic acid. In addition, a market outlook for polylactic acid out to 2015 is given.

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