“Fermentative Production of Succinic Acid” is the title of one of the projects being worked on by the Biopolymers/Biomaterials cluster in Baden-Württemberg. Researchers from BASF SE, one of the project partners, have isolated a bacterium with highly promising properties, including the ability to use glycerine (a waste product of biodiesel production) as substrate for the efficient production of succinic acid.

If current predictions are correct, manufacturers of biobased materials for use in the chemical industry can look forward to profitable times. In 2008, the turnover generated by biobased materials amounted to around 1.15 billion euros worldwide. According to estimates published by market analysts from the Frost & Sullivan consultancy at the time, the turnover in 2015 was set to reach around 3.3 billion euros.

It can be safely assumed that these estimates are still valid today. A technological revolution in the oil-based chemistry sector that would effectively put a stop to biobased methods, is nowhere in sight. In contrast, there is ample evidence that biobased materials, and the field of biochemistry, will blow the wind of change into the petrochemical sector. Bio-succinic acid might be one such promising case.

Several candidates, one favourite

Succinic acid is an intermediary product of the tri-carboxylic acid cycle. This is worth pointing out because the tri-carboxylic acid cycle plays a key role in energy metabolism, in particular in higher cells and many microorganisms. The tri-carboxylic acid cycle is well characterised and its major reactions and side reactions are known in detail.

Nevertheless, it is quite difficult to select microorganisms that are optimally suited for the production of succinic acid; metabolic engineering and biotechnological modification are used to drive the bacteria to maximum efficiency. The Actinobacillus succinogenes, Corynebacterium glutamicum, Anaerobiospirillum succiniproducens, Mannheimia succiniproducens as well as the microbiologists’ most popular bacteria, Escherichia coli, are well-known and well-established bacterial production strains that can produce succinic acid.

Researchers involved in the Biopolymers/Biomaterials cluster are investigating another bacterium that revealed promising characteristics that are valuable for the production of succinic acid. The bacterium was isolated by the cluster’s project partner BASF in Ludwigshafen and given the name Basfia succiniciproducens. The bacteria, which normally live in the rumen of cows, will most likely be cultivated in bioreactors in the future.

Versatile and expandable

The new strain is very versatile with regard to the substrates that it can use for the production of succinic acid. Since the bacteria are not only able to use C6 sugars, but also C5 (xylose) and C3 substrates (glycerine), it is highly likely in the long run that they will be able to withstand the price fluctuations of the raw materials market, which is increasingly shifting towards volatile substances. For example, if the bacteria are fed with strongly reduced glycerine, they need to fixate one CO2 molecule from the air for each of the C3 molecules in order to create a C4 constituent of succinic acid. Thus, CO2 becomes an important raw material in the production of succinic acid. In addition, hardly any side products are produced. Grown on glucose, the succinic acid yield of the new strain is
similar to that of other strains.

BASF is convinced that the new strain is an excellent choice. In order to boost the potential of the new production strain, BASF is working in partnership with renowned companies and researchers in the BMBF-funded Biopolymers/Biomaterials cluster. Professor Wittmann from the Institute of Bioprocess Engineering at the TU Braunschweig focuses on the substance flows of Basfia succiniciproducens and uses metabolic engineering to develop high-performance production organisms. The exploration of this potential is one of the major tasks of the cluster project.

In order to be able to compete with petrochemically produced succinic acid and gain market access to new value creation chains as a platform chemical, the fermentation method needs to be highly effective and cost-efficient. BASF has started working in cooperation with the Dutch company PURAC, the world's largest producer of lactic acid through fermentation. It is envisaged that this partnership will quickly move the cluster results onto the industrial scale.

From a niche market to the mega-market of basic substances

With a production quantity of about 30,000 tons per year, succinic acid is still a niche product. Nevertheless, the chemical industry is extremely interested in this molecule for its ability to be processed into many other basic substances, thus fulfilling a decisive criterion of turning substances into platform chemicals. The reason the chemical industry finds platform chemicals so interesting is because they make production processes more flexible. Succinic acid can be converted into ten important basic substances, including 1,4-butanediol. It is also an important basic compound for the production of polyamides and polyester.

At present, one kilogram of succinic acid costs between two and three euros. If it becomes possible to produce the biobased variant of the molecule more cheaply, the market for succinic acid will grow enormously.

In addition, biologically produced succinic acid has a positive side effect. During biotechnological production, the microorganisms take up carbon dioxide. However, this remains just a side effect – succinic acid cannot be expected to play a major role as a climate-protecting CO2 sink.