Website address:
https://www.biooekonomie-bw.de/en/articles/pm/bacteria-for-the-production-of-better-plastics

Bioeconomy BW

Bacteria for the production of better plastics

Nylon made by bacteria, high-tech plastics from the bioreactor – the Biopolymers/Biomaterials cluster has plans to combine biotechnology with polymer technology and hence boost innovation in traditional industries such as the chemical, automobile, textile technology, packaging and medical engineering industries. New interfaces are opening up for biotechnology as an up-and-coming technology.

The idea is obvious: chitin of insect carapaces, starch in potatoes, glycogen in muscles and cellulose in plant fibres – biological polymers are almost as old as nature itself. In addition, the polymers that are widely used on a daily basis are nothing else than polymers consisting of repeated simple monomers. Why shouldn't it therefore be possible to use biological systems, for example microorganisms, for the production of plastics?

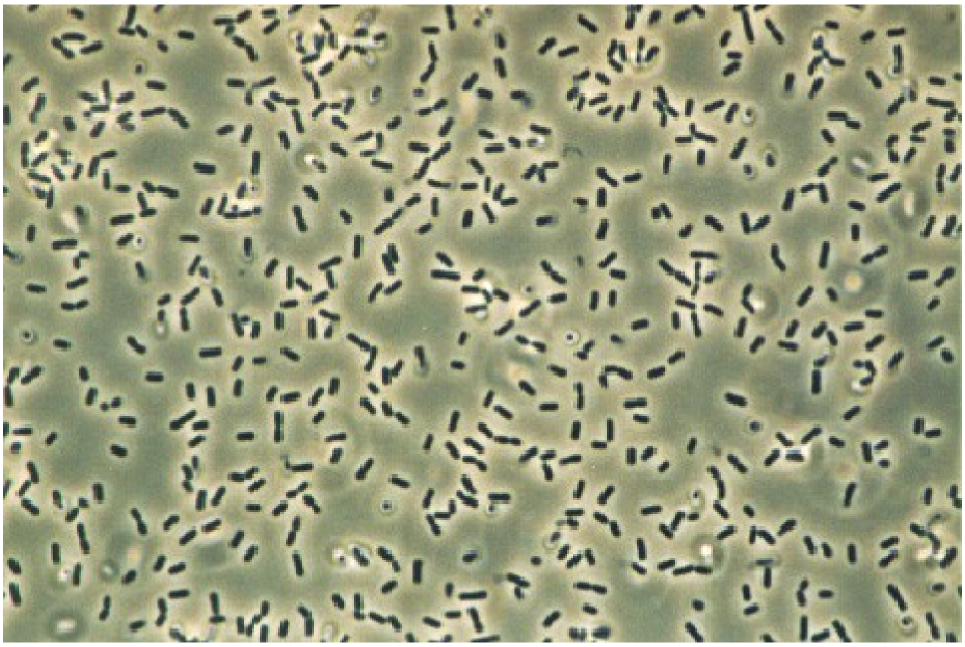
Chitin is the second most common biopolymer on earth. For example, it is present in insect carapaces and is, like all polymers, composed of simple basic constituents. (Photo: Wikipedia)

Biotechnology is becoming part of value creation

In the Biopolymers/Biomaterials cluster, where BIOPRO Baden-Württemberg GmbH achieved success in the German Ministry of Education and Research's (BMBF) "BioIndustrie 2021" competition, there is a great deal of thought being put into this issue. Sixty companies and 35 research institutions have combined forces in the cluster, which has a particular interest in biotechnological methods for producing the versatile polymers used by the medical engineering, plastics, textile and car industries.

Common plastics have two things in common: they have individual constituents, i.e. monomers, and they are mainly produced from petroleum. "These are excellent prerequisites for integrating biotechnological processes into the value creation chain of the plastics producing industry," said Dr. Ralf Kindervater, CEO of BIOPRO Baden-Württemberg GmbH.

Change brings opportunity



Bacteria (Bacillus subtilis) could become the basis of biotechnological plastics production. (Photo: Wikipedia)

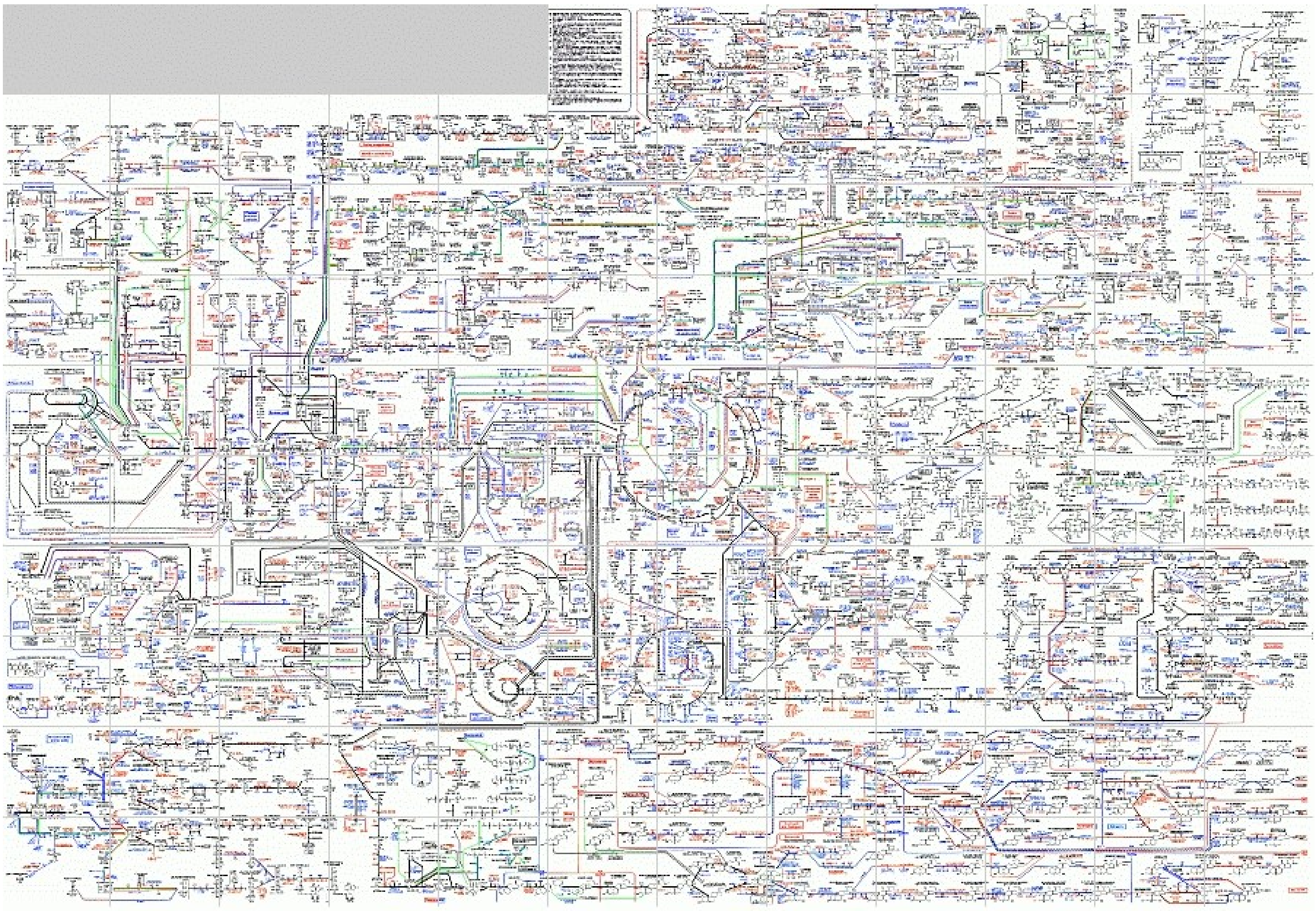
Challenges such as increasing oil prices or the debate on carbon dioxide and climate change are increasing the pressure to innovate faced by industry. Such a coming together of a number of issues also creates opportunities for new technological methods to be created. For example, it may be possible in the future to produce the basic constituents of polymers with biotechnological methods, using microorganisms to effectively assist production. Bacteria have a plethora of biochemical processes and proliferate rapidly in bioreactors. Even the simplest organisms have several hundred different enzymatic reactions. In the final analysis, it is enzymes that harbour the secret of the technological potential of bacteria, fungi or higher cells, no matter whether they are relatively simple microorganisms or more complex mammalian cells, such as the billions of cells in a human body.

Mathematics of the metabolism

All higher cells and all microorganisms use enzymes to create simple as well as high-molecular (bio-)chemical compounds. All they require are some nutrients, like for example carbon and nitrogen to safeguard their basic supply. The metabolic activities are part of a complicated network of many individual reactions that occur either one after the other or in parallel. In a single human cell, more than 100,000 different biochemical reactions happen every second.

The metabolism and hence the production behaviour of microorganisms and higher cells can be manipulated by interfering with a broad range of parameters, including nutrient concentration, pH value, concentration of metabolic waste, substance flow from the medium into the microorganisms and vice versa, but also parameters such as aeration and mixing of the culture as well as the selection of a suitable organism. All these parameters have an impact on the production yield and the cost-effectiveness of a biotechnological process. In Escherichia coli, a bacterium that is commonly found in the lower intestine and that is a popular subject of microbiologists, 260 metabolic reactions can be effectively influenced by replacing glucose with succinate as the basic nutrient.

The cluster as ideal structure



The metabolic pathways of a cell are a maze. (Figure: Roche, click on picture for magnification)

It appears that the metabolism of an organism is the lynchpin in biotechnological material production. Systems biology is of particular importance in the characterisation of species-specific properties. Systems biology is based on the idea of describing and simulating biological processes with mathematical models. This means that the technical data of individual metabolic reactions are analysed from which the particularities of entire metabolic pathways can then be deduced. This information makes it possible to select nutrients and other parameters and guide the substance flow in the cell such that a microorganism produces higher yields of a desired chemical substance. Complemented by insights and technologies from the field of molecular genetics, biotechnologists are getting close to made-to-measure metabolisms. Metabolic modelling and metabolic engineering are becoming reality and making it possible to create a cell-based biofactory based on clients' requirements. "At first, it is necessary to identify the central metabolic parameters and define suitable culture conditions and purification processes for the desired monomers," said Kindervater emphasising that "these are strongly interdisciplinary activities, and cluster formation is the perfect solution to such problems."

Effective technological and scientific environment

From the analysis of the technological and scientific environment in Baden-Württemberg it became clear that white biotechnology, systems biology, polymer chemistry and bioprocess engineering have high profiles. "In Freiburg, Stuttgart, Ulm, Hohenheim and Karlsruhe, research has been going on for more than 10 years at the interfaces between bioprocess engineering and polymer chemistry," said Kindervater. Originally, scientists focused, amongst other things, on biologically degradable polymers. Nowadays, the biotechnological knowledge gained on fermentation, microbiology and polymer chemistry can be used for the production of biopolymer and bioplastics constituents. Which traditional sectors might benefit from these developments? "For me, there are several winners," said Kindervater, adding that "these include the car, construction, chemistry, packaging, textile technology and medical engineering industries. Therefore, the cluster involves a broad range of industrial partners, for example the companies Bosch, Fischer, BASF and Daimler."

The cluster has two strategies

The polymer sector mainly uses three groups of plastics:

1. mass plastics such as polyethylene, polypropylene, polystyrene or polyvinyl chloride (PVC) for bottles, foils, packaging, containers or components with no particular requirements

2. technical polymers such as nylon and Teflon

3. high-performance polymers for medicine, aerospace and other high-tech sectors.

This systematically results in two strategic options for the cluster. Kindervater: "The biopolymers cannot compete with mass polymers, which can be cheaply produced from petroleum industry waste. This means that the cluster has to create biopolymer alternatives for the production of technical polymers and high-performance plastics. Another important goal is the development of biopolymers with novel properties. From my point of view, the opportunities for biopolymers clearly arise from the limitations of the classical petroleum chemistry."

Improve known structures

Nylon is an economically very successful polymer. (Photo: Wikipedia/University of Ulm)

Improved polymers through the use of biotechnology – this idea dates back at least 70 years. In 1935, Wallace Carother produced one of the polymer industry's most successful mass products: nylon (a polyamide). Initially, he worked with a variant which is referred to as 5,10-nylon due to its chemical structure. This nylon type has considerably better properties than 6-nylon and 6,6-nylon, which were developed later, but it proved to be too expensive to produce. The times are changing: thanks to biotechnological progress it will in the near future be possible to produce the 5,10-type high-tech nylon considerably cheaper than previously possible. In many cases it is even possible to use the new technologies to improve existing successful structures. The Biopolymers/Biomaterials cluster is working hard to achieve all this.

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Press release

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