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Press Release No. 126/2018

19 December 2018

From a plant sugar to toxic hydrogen sulfide

In a doctoral research project conducted at the Department of Biology, the degradation of the dietary sugar sulfoquinovose by anaerobic bacteria to toxic hydrogen sulfide was described for the first time – increased production of hydrogen sulfide in the human intestinal system has been associated with inflammatory bowel disease and colon cancer.

Sulfoquinovose is a sugar found in plants, which contains sulfur. As a constituent of green-vegetable diets, for example in spinach and salad, it is also found in the human intestinal system – an environment without oxygen – and therefore doctoral researcher Anna Burrichter wanted to answer the following question: What happens when anaerobic bacteria degrade sulfoquinovose in the absence of oxygen? She discovered a new type of metabolism that transforms sulfoquinovose into hydrogen sulfide (H_2S). So far, these results have been obtained from a laboratory model system. In future studies, the researchers will have to examine whether sulfoquinovose in the intestine is indeed metabolized to hydrogen sulfide, which is a toxic compound for humans. The study was conducted by the research team of Dr David Schleheck, and the results have been published in the current issue of the journal “Frontiers in Microbiology”.

Anna Burrichter succeeded in discovering an entirely novel bacterial degradation pathway that involves three individual discoveries: the discovery of a new link in the biological sulfur cycle, the discovery of a new type of fermentation in *Escherichia coli*, the best-studied model organism that was also used in this study, and the discovery of a so far unknown energy metabolism in sufite-respiring bacteria, in the *Desulfovibrio* species.

“Without oxygen, the degradation pathways are completely different. In the context of sulfoquinovose, we discovered a novel type of fermentation in *Escherichia coli*,” says Anna Burrichter. Along with the sulfur-containing degradation product that is formed in this first degradation step, dihydroxypropane sulfonate, the researchers found a second bacterium, *Desulfovibrio*, which can utilize this intermediate for anaerobic respiration, the so-called sulfite reduction. This type of respiration with the organically-bound sulfur as electron acceptor instead of oxygen is described in detail for the first time in Anna Burrichter’s thesis. “We thought that hydrogen sulfide may be the end product, but it had never been proven before, and no one knew which bacteria and enzymes may catalyse these reactions”, the biologist says.

The next step now is to transfer the results of the laboratory model to the human intestine. “We want to investigate if these degradation pathways can also be found in the intestine and how much they contribute to the overall production of hydrogen sulfide, depending on the diet”, says David Schleheck, whose research team has been supported by the Heisenberg Programme of the

German Research Foundation (DFG). Previously it was assumed that organosulfonate substrates, such as taurine, are transformed into hydrogen sulfide mainly from meat-rich and high-fat diets. The new findings now suggest that organosulfonates from vegetarian food, that is sulfoquinovose, can be degraded to hydrogen sulfide as well.

Anna Burrichter's doctoral thesis is a promising basis for further research in this area. "Now we know the individual steps of the degradation pathway and the enzymes and genes involved, and therefore, now we know what we have to search for", concludes Anna Burrichter. The production of hydrogen sulfide in general can contribute to inflammatory bowel disease and colon cancer. However, it is also assumed that hydrogen sulfide, at least at low concentrations in the intestine, could as well have beneficial effects for our health. David Schleheck: "To better understand the human microbiome and the effects of hydrogen sulfide, it is essential to know all the pathways that can lead to hydrogen sulfide production. Only then one might be able to better manage the production of hydrogen sulfide in the intestine".

To conduct this study, the research team Microbial Ecolocy collaborated with the teams of Dr Thomas Huhn (Department of Chemistry), Professor Dieter Spiteller (Department of Biology) and Dr Paolo Franchini (Genomics Center).

Key facts:

- Original publication: Anna Burrichter, Karin Denger, Paolo Franchini, Thomas Huhn, Nicolai Müller, Dieter Spiteller and David Schleheck, Anaerobic Degradation of the Plant Sugar Sulfoquinovose Concomitant With H_2S Production: *Escherichia coli* K-12 and *Desulfovibrio* sp. Strain DF1 as Co-culture Model. Frontiers in Microbiology, November 2018, Volume 9. https://www.frontiersin.org/articles/10.3389/fmicb.2018.02792/full
- The bacterial degradation of the plant sugar sulfoquinovose to hydrogen sulfide is described for the first time.
- Study was conducted in the context of biologist Anna Burrichter's doctoral thesis.
- Collaboration of researchers from the Departments of Biology and Chemistry and the Konstanz Research School Chemical Biology (KoRS-CB).
- Funded by the Heisenberg Programme of the German Research Foundation (DFG), the Konstanz Research School Chemical Biology (KoRS-CB) and the Konstanz Young Scholar Fund (YSF).

Note to editors:
You can download photos here:

https://cms.uni-konstanz.de/fileadmin/pi/fileserver/2018/Bilder/Von_pflanzlicher_Sulfoquinovose.jpg
Caption:
The picture shows the degradation of sulfoquinovose (SQ) by *Escherichia coli* to a sulfur-containing intermediate (DHPS), which is excreted. Another bacterium, *Desulfovibrio*, utilizes this intermediate for anaerobic respiration and produces toxic hydrogen sulfide (H_2S).
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https://cms.uni-konstanz.de/fileadmin/pi/fileserver/2018/Bilder/Von_pflanzlicher_Sulfoquinovose_Team.jpg
Caption:
Anna Burrichter, Dr. Daniel Schleheck.
Photo: University of Konstanz

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