Microbes in organic waste management

H. Insam[1], T. Klammsteiner[1], V. Turan[2], M. Fernández-Delgado Juárez[1], S.M. Podmirseg[1], C.Ebner[3], M.Gomez-Brandòn[4], A.Walter[5], C. Heussler[1], F.Kurzemann[1], U. Plieger[1], S. Masebinu[6], M. Nagler[1], S. Hupfauf[1]

[1]Department of Microbiology, University of Innsbruck, Innsbruck, Tyrol, 6020, Austria
[2]Department of Soil Science and Plant Nutrition, Bingöl University, Bingöl, 12000, Turkey
[3]BioTreaT GmbH, Technikerstr. 21, 6020 Innsbruck, Austria
4Department of Ecology and Animal Biology, University of Vigo, 36310, Vigo, Spain
[5]Management Center. Maximilianstraße, 6020 Innsbruck
[6]Univ. of Johannesburg, Dept. of Mechanical Engineering, Auckland Park Campus, Johannesburg, South Afrika
Keywords: compost, Black Soldier Fly, biomass ash, digestate, biogas, pyrolysis
Presenting author email: heribert.insam@uibk.ac.at

You may remember the joke when one planet met another? The first one asks: "How are you?" "Not so well", the second answered, "I've got the Homo Sapiens." "Don't worry," the other replied, "I had the same, it won't last long." Whenever it comes to the overuse of resources, or the spilling of our environment with wastes or wastewater, microbes may help. Some of the microbial processes that could help to cure the planet, the working group Microbial Resource Management of University of Innsbruck's Department of Microbiology is dealing with. A perfect recycling of organic wastes may contribute considerably to a more sustainable economy. Microorganisms and their turnover processes are the basis of many of the technologies used to treat organic wastes of various origins.

Wherever on the globe people are generating wastewater, they should consider to make use of anaerobic ammonia oxidising bacteria (Wett et al., 2010) and this way save about a third of the energy needed in conventional wastewater treatment. Combined with anaerobic co-digestion of organic wastes, wastewater treatment plants may be converted from energy consumers to energy producers with the additional benefit of reduced volumes of the remaining sewage sludges. Seeded with Anammox communities from the Zillertal, Austria, also the US Blueplains wastewater treatment plant of Washington DC is now a power plant, producing electricity from every piece of fecal matter. To stick with the unappetizing, you may have heard of Fat the Ripper, London's greaseberg from its sewage system, a monster of diapers, wet wipes, and frozen cooking fat that, increasing energy efficiency of wastewater treatment plants, turns into methane gas.

Greasebergs and cattle manure, sewage sludge or other disgusting matter, commonly they are biomethanised thermophilically or mesophilically at 55 or 37 °C degrees, respectively. Recently, however, we found process temperatures of 45°C optimal in terms of methane generation as well as for hygienisation (Hupfauf et al., 2018). Amendment of charcoal may even further enhance the methane potential, as is being currently investigated.

Short-term investigations on the effects of organic recycling products like slurries, composts or digestates are abundant and also being performed in our laboratory, however, long-term effects are rarely studied. In current studies, such long-term effects on the soil and its microbiota, as well as on crop yield are being investigated, and yield estimates are in contrast to the recently published paper that states two-times higher CO_2-equivalent costs for organically versus conventionally grown peas and wheat (Searchinger et al., 2018). Fertilization with composts or other organic residues had positive effects on crop yields and soil carbon pools, and on microbial diversity.

Learning from nature may help to leap forward in another area. Anaerobic fungi like Neocallimastix are known to be indispensable members of the cellulose degrading microbiota in ruminants, ranging from buffaloes to mountain goats. While these would starve to death without these fungi, their utilization in biogas plants is still not possible (Leis et al., 2014). In a major international project we are now attempting to harness these fungi to fibre degradation in biogas plants.

Beyond composting and biomethanisation, two hundred years after the potatoes, the Black Soldier Fly could become the second savior of Europe coming from South America, this time in the fight against the anthropogenic organic wastes. The maggots of this tropical fly feed on organic waste and turn into a self-harvesting protein concentrate, which could ensure a regional cycle as fish or chicken feed or even as a delicacy. A Citizen Science project with 60 students may help to reduce the disgust reaction against insect maggots, so that the consumption of fly maggots in the future may not be limited to the Casu Marzu, the insect-ripened Pecorino, available only under the counter. Startling from a microbiological view - and in the center of our interest - is the microbiota in the gut and on the epicuticle (skin) that apparently protects the maggots from pathogens.

Fast pyrolysis bio-oil (FPBO) is a fuel produced from lignocellulosic biomass. The charcoal produced during pyrolysis is further incinerated to produce process energy. The remaining ash has some potential as a fertilizer but also some inherent risk due to heavy metals (Bougnom et al., 2009, Schönegger et al., 2018). In our research, in greenhouse and field trials these effects of FPBO were evaluated for different feeding substrates like forest residues, bark, *Miscanthus* and wheat straw. No negative effects on microbial or plant growth were found, however, except for *Miscanthus*, all other feed sources exceeded heavy metal limits according to Austrian legislation. In the future, care will have to be taken to optimize input materials to pyrolysis in order to meet requirements for recycling options to avoid landfilling (Probst et al., 2019).

I hope our contributions will serve to manage the superchallenges of the 21st century, the energy crisis, the mountains of waste and climate change.

References.

Bougnom BP., Mair J., Etoa F.X., Insam H. 2009. Composts with wood ash addition: a risk or a chance for ameliorating acid tropical soils? Geoderma 153, 402-407

Hupfauf S., Plattner P., Wagner A.O., Kaufmann R., Insam H., Podmirseg S.M. 2018. Temperature shapes the microbiota in anaerobic digestion and drives efficiency to a maximum at 45 °C. Bioresource Technology 269, 309-318

Leis S., Dresch P., Peintner U., Fliegerova K., Sandbichler A.M., Insam H., Podmirseg S.M. 2014. Finding a robust strain for biomethanation: anaerobic fungi (Neocallimastigomycota) from the Alpine ibex (*Capra ibex*) and their associated methanogens. Anaerobe 29, 34-42

Probst M., Fernández-Delgado Juárez M., Gómez-Brandón M., Turan V., Insam H. 2019. Ashes derived from fast pyrolysis bio-oil production of different waste streams may be suited as soil amendment. This issue

Schiemenz K., Kern J., Paulsen H.M., Bachmann S., Eichler-Löbermann B. 2011. Phosphorus fertilizing effects of biomass ashes. In: Knapp BA., Insam H. (Eds.), Recycling of biomass ashes. Springer, Berlin, pp. 1-16

Schönegger D., Gómez-Brandón M., Mazzie, T., Insam, H., Hermanns R., Leijenhorst E., Bardelli T., Fernández-Delgado Juárez M. 2018. Phosphorus fertilising potential of fly ash and effects on soil microbiota and crop. Resources, Conservation and Recycling 134, 262-270

Searchinger T.D., Wirsenius, S., Beringer T., Dumas P. 2018. Assessing the efficiency of changes in land use for mitigating climate change. Nature 564, 249-253

Podmirseg S.M., Schoen M.A., Murthy S., Insam H., Wett B. 2010. Quantitative and qualitative effects of bioaugmentation on ammonia oxidizers at a two-step WWTP. Water Science & Technology 61, 1003-1009

Wett, B., Podmirseg, S.M., Gómez-Brandón, M., Hell, M., Nyhuis, G., Bott, C., Murthy, S. 2015. Expanding DEMON Sidestream Deammonification Technology Towards Mainstream Application. Water Environment Research 87, 2084-2089