With insects to the circular economy

InBiRa: Insect biorefinery turns food leftovers into new products

Insect larvae can convert food leftovers and waste into secondary raw materials for technical products and cosmetics. Researchers are looking to establish an insect biorefinery for this purpose at the Fraunhofer IGB in Stuttgart. The InBiRa project is financed with a total of 3.8 million euros in EU and Baden-Württemberg state funding.

Dr. Susanne Zibek has been head of the Bioprocess Engineering research group at Fraunhofer IGB since 2008. She studied chemical engineering and technical biology.
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"Food should not actually become waste," says Dr. Susanne Zibek, head of the Bioprocess Engineering research group at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. "But if it does, we could use it in a higher-value way than we do at the moment." Currently, waste and residual streams from the food sector such as surplus food from supermarkets or leftovers from kitchens and canteens, as well as organic waste, are composted or fermented into biogas. In 2020, a total of 10.9 million tonnes of food from across the production and food chain were treated in this way in Germany.[1)] The researchers plan to use InBiRa to intervene in this process and introduce an intermediate step: first, black soldier fly larvae will be fed the food residues and further processed. The insects are rich in protein, fat and chitin, which the researchers then want to convert into secondary raw materials and use for manufacturing various technical and cosmetic products. "The larvae are able to utilise 33 to 50 percent of the food waste," explains Heinrich Katz from Brandenburg-based Hermetia Baruth GmbH, whose contribution to the InBiRa project is the biological and technical expertise for insect fattening.

The Fraunhofer IGB has planned the biorefinery in cooperation with five project partners. It is being set up and operated on the institute's premises in Stuttgart-Vaihingen. The process is as follows: first, PreZero Stiftung & Co. KG from Neckarsulm delivers the food leftovers. They are then chopped up and analysed by the Institute for Sanitary Engineering, Water Quality and Solid Waste Management (ISWA) at the University of Stuttgart. Finally, the waste residues are processed into new feed mixtures for the larvae.

Feeding in three complex stages

"We have planned several complex stages," says Zibek. The first step involves investigating how an optimal food mixture can be produced for the larvae from fruit, vegetables, baked goods and dairy products. The second step involves examining the food waste from canteens and dining halls. "It's a broad mixture of all kinds of things," says Zibek. "The various mixtures usually also contain meat scraps." Under German law, farm animals – and the larvae used in the biorefinery are considered farm animals – must not be fed meat or fish. "In this case, this makes no sense at all," says Heinrich Katz. "Because in their natural habitat, these insects feed on animal remains." That is why the researchers have applied for an exemption with the

intention of investigating how safe the process is for humans and the environment. The third and most complicated stage is the organic waste bin which also contains a broad mixture of organic waste, as well as contaminants.

Heinrich Katz and his team, who have been researching and developing insect biotechnology for 15 years, are in charge of insect fattening. Katz and Zibek have known each other for a long time, from lectures and other projects. Together they developed the vision of an insect biorefinery and initiated the project. Zibek is overall project coordinator. Larvae fattening works as follows: the adult females lay eggs, from which the larvae hatch. 10 percent of the larvae develop into adults, which again lay eggs from which larvae hatch. Thus the cycle continues.

Black soldier fly Hermetia illucens. This dipterous insect, which belongs to the Stratiomyidae family (in German Waffenfliegen, 'armed flies'), is believed to have originated in South America. Thanks to humans, it is now distributed throughout the world. Adults have neither mouth nor sting, so they do not eat and do not transmit diseases. They only live for a few days.
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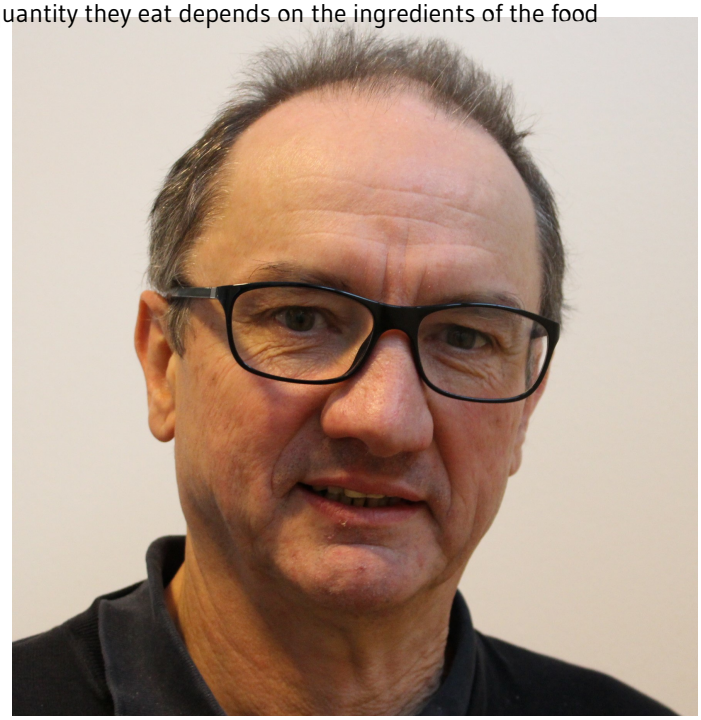
The other 90 percent are fattened on the different feed mixtures in tubs and their growth assessed. Within 14 days, eight kilos of larval mass develop from one gramme of freshly hatched larvae. As they grow, the animals consume 10 to 30 kilos of food residues. The exact quantity they eat depends on the ingredients of the food waste. "The larvae require a certain initial ambient temperature," Katz explains. The heat is initially supplied, but as the animals start to grow they start to generate heat themselves as they move around. From then on, the heat generated needs to be dissipated to stop the insects overheating. This excess heat is used to warm the other tubs. Fresh air is also supplied and carbon dioxide and ammonia are removed and disposed of. After a maximum of 14 days, the larvae are separated from faeces, food residues and insect skins on a shaking sieve and then inactivated with hot water.



Heinrich Katz is a mechanical engineer and has been in charge of administration and corporate development at Hermetia Baruth since 2006. With 15 employees, Hermetia produces high-protein feed for carnivorous animals from the larvae of the black soldier fly as a local alternative to fishmeal.
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Fatty acids from local sources

The Institute of Interfacial Process Engineering and Plasma Technology IGVP at the University of Stuttgart and the Fraunhofer IGB subsequently investigate how fats and proteins from the larvae can be separated from each other as sustainably as possible and processed into secondary raw materials. Approximately 100 kilos of fat and 220 kilos of protein can be obtained from one tonne of larvae, which consists of up to 60 percent water. The fat is purified in several steps. It contains fatty acids that are chemically similar to those in palm kernel oil and coconut oil. Thus, they can be produced in Germany as a local alternative to tropical fatty acids. Secondary raw materials are then produced from the fats via various chemical or enzymatic reactions, which are tested by partner companies and processed into biodiesel, lubricants, soap and other detergent substances or epoxides.

The proteins are also first processed so that they can be used in technical applications and in adhesives or care products such as hair masks. "The care products are not vegan," says Zibek. "We have to be transparent about this," she says. But Zibek is sure that there will be other new ideas for using the proteins. In addition to various new processes for scaling up, traditional chemical-technical separation technologies, such as pressing, filtering and extracting, will also be used. "But the temperatures

need to be cooler and the solvents greener," she explains. In addition, the researchers will have to investigate in greater detail how the products can be recycled. For this reason, the Institut für Energie- und Umweltforschung ifeu Heidelberg gGmbH is also accompanying the project and evaluating all the biorefinery's processes from an environmental point of view. "This gives us feedback on whether solvent 1 or 2 is more sustainable, for example, and we can then optimise it," says Zibek.

Using residues from fattening

The larvae of the black soldier fly like to stay close to one another. Body contact and movement create heat, and at the same time the insects clean their grooves.
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The skins of the larvae contain chitin, which is extracted in InBiRa and converted into valuable chitosan.
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The residues from insect fattening are also used. Insect skins consist of up to 40 percent chitin, from which chitosan can be produced. The latter can be used in waterproof coatings. As regards faeces and food residues, the researchers are investigating how fertiliser can be made from them and how good the biogas yield is.

Of course, new systems like these need to have public and industrial sector support and the resulting products must be accepted. This can only happen if information is provided. BIOPRO Baden-Württemberg GmbH is therefore supporting the project by implementing various communication measures. InBiRa is funded by the Baden-Württemberg Ministry of the Environment, Climate Protection and the Energy Sector and the EU Commission as part of the "Bioeconomy Bio-Ab-Cycling" ERDF funding programme with a total of 3.8 million euros. The project was launched in October 2021 and runs until March 2024.

Vision set to become reality

The plants are currently being planned, sizes determined and the individual process units defined for the 17 or more different processes. For this purpose, intensive research has also been conducted into the literature on refinery and conversion concepts. "Purely vegetarian feeding trials on a 10-kg scale have started," reports Katz.

"We are still waiting for the exemption for the trials with food residues containing animal components." The ifeu Institute has already collected data and created an initial model. InBiRa is also struggling with supply difficulties, a common issue across the board. The project is also looking for PhD students for the projects. "We are doing everything we possibly can to turn our vision into reality," says Zibek.

Info box:

InBiRa – the insect biorefinery: from the utilization of organic residues and waste to the manufacture of products such as fuels, cosmetics, detergents and plant fertilisers

Project duration

October 2021 – March 2024

Project partners

- Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, Stuttgart (coordination)
- BIOPRO Baden-Württemberg GmbH, Stuttgart
- Hermetia Baruth GmbH, Baruth/Mark Brandenburg
- ifeu – Institut für Energie- und Umweltforschung Heidelberg gGmbH
- University of Stuttgart, Institute for Interfacial Process Engineering and Plasma Technology
- University of Stuttgart, Institute for Sanitary Engineering, Water Quality and Waste Management
- PreZero Stiftung & Co. KG, Neckarsulm (associated partner)

References:

1) German Federal Statistical Office

Article

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- Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB I Bioprocess Engineering
- Hermetia Baruth GmbH
- Project I The insect biorefinery InBiRa

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biomass | biorefinery | bioreactor | Fraunhofer IGB | waste | value chain | circular economy | insects

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