Destructive insects produce high-value products from biowaste

October 12 2021, by Susan Langthorp

Credit: AI-generated image (disclaimer)

European researchers and industries are putting insects to work—from termites that destroy wooden buildings to insect larvae that are star "poop" composters. Packaging, cosmetics, pharmaceuticals and animal feed are just some of the products they are beetling away to make for us.

Insects are fascinating. The classic circle of life we all learned about in biology class is made up of four completely different stages—egg, larva, pupa and adult. The butterfly is just one example with a spectacularly beautiful adult and a caterpillar that can grow 100 times its size in the larval stage.

"In a nutshell, insects are prolific eaters and reproducers and, luckily for us, some are brilliant recyclers of waste," said Stéphanie Baumberger, a professor in green chemistry at the Paris Institute of Technology for Life, Food and Environmental Sciences (AgroParisTech), France. She and her team from the Zelcor project capitalized on the termite's ability to digest lignin, the woody material in plant cell walls. Renowned for causing damage to buildings, the whole colony of termites never sleeps and constantly feeds on its staple diet, wood.

Lignin is the main material that gives plants their structure. Without lignin, a plant would not be able to remain upright. In trees, lignin is particularly important as wood and bark are comprised primarily of lignin: it is rigid and doesn't easily decay. But this has a downside; lignin is relatively indestructible and therefore a challenge to efforts to produce sustainable energy and high-value chemicals from biowaste.

Termites: Expert biowaste recyclers

"We fed lignin biowaste to the termites to convert it into high added-value intermediate bioproducts," Prof. Baumberger outlined. "We mainly used waste from lignocellulose biorefineries and also included unused material from wood pulping in paper mills," she added.

Refineries literally do as the word suggests. They refine a product until it is pure. A lignocellulose biorefinery operates with dry biomass materials such as wheat straw, willow, maple, eucalyptus and eastern cottonwood. As the process continues, different intermediate products or side streams are isolated.

So far, so good, but there is a lot of waste produced by a biorefinery that is not readily decomposable. Prof. Baumberger continued: "Lignin waste is known as recalcitrant as it's hard to decompose. Production of these intermediate products that won't break down is a considerable expense in terms of biorefinery operation and carbon footprint."

To deal with the waste from lignin refineries, the Zelcor team designed an innovative termite rearing unit to respect the complex social organization of the colony while maintaining the best living conditions for the insects. The optimal temperature turned out to be 27°C at a sticky humidity of 80%, which is not surprising, as termites thrive in warm humid places.

"The termites we used are not all alike," reported Prof. Baumberger. "To select for the most productive insects, we first screened them to determine which were the most suitable for a bioreactor. Moreover, the insects' diet was optimized. Termites naturally like to feed on material containing a high percentage of cellulose so that feeding them with lignin-rich residues was a challenge," she explained.

Lignin in, cosmetics and packaging cascade out

The high-value products chitin and chitin-derived chitosan are collected out of the rearing unit by separating the different components of the termite. The chitin and chitosan production is part of a cascading transformation of lignocelluloses.

Cascading in this sense means that the side-stream of one transformation stage is used as the feedstock of the next. "This way, the lignocellulose biorefineries become zero waste by integrating with a termite-based bioreactor," said Prof. Baumberger.

"Chitosan is biodegradable, biocompatible, has low toxicity and, to boot, has antimicrobial and antioxidant properties," said Prof. Baumberger. This impressive CV gives it great potential in the medical, cosmetic and food packaging industries.

Moreover, the lignin-extracted products of the first cascading stages provide an alternative to the widespread synthetic additives that have potentially negative impacts on health and the marine environment. Hormone mimic Bisphenol A for example, which may have many toxic effects including infertility and heart disease is present in many plastics in packaging.

High-value end products include chemicals used in skin cream. Chitosan has the capacity to form films and fluid-filled sacs or vesicles. So it's a good candidate for carrying active molecules in cosmetics fixing them on dry skin, for example, for long-lasting effects. "Creams are emulsions of oils with water," Prof. Baumberger explained, "and chitosan makes a framework in this special mixture that traps the active ingredients inside."

Food packaging can also be a benefactor. A layer of chitosan offers the option of those antioxidant and antimicrobial additive carriers in food. Improvement of the preservation of food means a longer shelf life. Moreover, chitosan is also biodegradable, and it has low toxicity. Its antimicrobial activity makes it a possible candidate for being a constituent of capsules, coatings and gels for aromatic essential oils.

"A fusion of private companies such as Ynsect with the academic prowess of the institutes INRAE and Université Paris-Est Créteil Val de Marne gave the synergy for the initiative to be a resounding success," emphasized Prof. Baumberger. "We have developed the foundation of new value chains to create sustainable products from bio-based waste in only four years."

Nature's recyclers are 'picky' eaters

Insect larvae can also convert waste resources into useful products. Scientists at the InDIRECT project have used two notorious waste breakdown candidates from the 6-legged world. "Our approach was to use the larvae of the black soldier fly and the lesser mealworm to transform different forms of biowaste—green leaves, fruit, vegetables, for example—into a homogenous mixture which is then converted into useful products," said Dr. Leen Bastiaens, researcher in sustainable chemistry at VITO, the Flemish Institute for Technological Research, in Belgium.

The black soldier fly, Hermetia illucens, isn't a pest like the housefly. Its eco-job in the environment is to break down decaying material, returning its nutrients to the soil. An adult female lays up to 600 eggs at a time and the larvae can use a variety of organic matter for food and, like the caterpillar, have a voracious appetite.

Also a decomposer, the lesser mealworm, Alphitobius diaperinus, is actually a beetle. Living in grain-processing plants where it's very unwelcome, it is also commonly found in poultry houses where it harbors several pathogens and parasites dangerous to the birds.

Like the black soldier fly, the lesser mealworm's "claim to fame" in the research world comes about due to its ability to break down a range of organic waste.

Food for the insects and their larvae had to be optimized. "Not all side streams are suitable for insect growth," remarked Dr. Bastiaens. "No insect digestive models are known that could be used to balance the feed in a theoretical way, so we had to try different food regimes. However, we had to be careful. Even though black soldier fly larvae like fruit, they definitely don't like banana skins because of the fibers," she reported.

Dr. Bastiaens' team also used the direct approach when whole larvae are used as feedstock. "We produced over one ton of larvae during the project. This was possible as we had two insect farms operational during the project—one at pilot level for the black soldier fly and the other for the lesser mealworm operated at pilot and industrial level," she explained.

High-value products were plentiful from the biorefineries. "The larvae are able to concentrate the proteins and lipids, and as such to upgrade these compounds," said Dr. Bastiaens.

Chitin is extracted from the rigid external covering from the larvae, the exoskeleton, and then transformed into various useful molecules, chitin derivatives, including chitosan. Dr. Bastiaens told us of extra work on chitosan that the team completed: "We demonstrated the antimicrobial properties of different chitosan oligopolymers, mixtures of two or more short molecule chains. Interestingly, the shorter the chain, the more bioactive they are."

Both the protein- and lipid-enriched fractions showed great promise as bioactive ingredients for animal feed applications. Moreover, insect proteins could replace phenol, a constituent in the resin in plywood used for furniture. Its replacement means cleaner waterways as phenol is a recognized pollutant.

InDIRECT finished in 2019 but the work continues with the Petsect project funded by the Flemish government. Now the researchers are focusing on pet food made up of insect larvae. Project partner VITO continues to refine products made up of the chitin exoskeleton of the larvae. Dr. Bastiaens summed up her feelings about the work her team completed: "For me, the most exciting part of the research is that all the stakeholders and end users came together to tailor the products according to market demand."

Using insects to break down woody waste creates a whole panoply of sustainable products. This work is set to increase the economic viability of bio-based industries and facilitate the move away from a society dependent on fossil fuels towards a circular economy where waste is seen as a valuable resource.

Provided by Horizon: The EU Research & Innovation Magazine

Citation: Destructive insects produce high-value products from biowaste (2021, October 12) retrieved 20 June 2024 from https://phys.org/news/2021-10-destructive-insects-high-value-products-biowaste.html