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Nature's puzzle: cracking walnuts for a greener tomorrow

EU-funded researchers are exploring how to make strong and sustainable new materials from hard-to-crack nutshells.

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Dr Notburga Gierlinger, an Austrian researcher specialising in the study of the structure and composition of plant materials, is particularly fascinated by nuts.

Confronted with a pistachio or walnut, she would open it with caution, intrigued by how nature could conjure up such strong materials.

"The shells are so hard I am always afraid of using my teeth in case I damage them," said Gierlinger, an associate professor of materials science at the BOKU University of Natural Resources and Life Sciences in Vienna, Austria.

Part of the puzzle

One of Gierlinger's main areas of research includes using a technique called Raman imaging to study the distribution of lignin, cellulose and other biomolecules in plant cell walls. The aim is to understand their mechanical properties and functions.

Further investigation during a five-year EU-backed research project called SCATAPNUT, led Gierlinger and her team to discover that nut shells like pistachio and walnut contain 3D puzzle cells – cells that have unique interlocking structures resembling pieces of a jigsaw puzzle. This contributes to their unusual strength and durability.

Intrigued by her findings, Gierlinger is now leading further EU-funded research in a project called PUZZLE MATERIALS, which is investigating how to make functional materials for industrial applications from pistachio and walnut shells.

The presence of the puzzle cells means the nut shells offer different properties than the fibres commonly found in plants like hemp and wood. Gierlinger and her team are currently exploring what types of new materials could be created using nut shells, as well as the best ways that they could be used.

The specific characteristics of puzzle cells make them particularly interesting for transformation into biodegradable bioplastic.

Going nuts for sustainability

In 2020, the EU adopted a new circular economy action plan as part of the European Green Deal. This includes support for the design of new materials that reduce waste and pressure on the environment.

Gierlinger's proposal would see the use of a current waste material – nut shells – to create new materials that could potentially replace plastics, thus offering a double environmental benefit.

With the average European generating around 186.5 kg of packaging waste in 2022, reusable and compostable materials are needed now more than ever. Gierlinger hopes that a material produced from nut shells could be one of many solutions contributing to the reduction of plastic waste in Europe and globally.

"I think walnut trees might become more important in the future because they are tough, resilient trees with good wood and healthy nuts," she said. "We are always trying to think which products might become more important in a sustainable society."

Her proposal also fits well with Europe's "safe and sustainable by design" voluntary framework, developed to guide the innovation process for safer and more sustainable chemicals and materials.

A sustainable process

Gierlinger and her research team are looking at ways to process discarded shells that are both efficient and environmentally friendly. The first step is to dissolve walnut shells in a solvent to separate the cells and regenerate lignin.

Cellulose from kombucha processing waste or bioreactors is also added to the resulting mass in different volumes, depending on the desired flexibility of the final product. The researchers are looking at different nut material options, including a product resembling leather and one which is more like plastic.

The aim is to produce sustainable, energy-efficient, resource-efficient and biodegradable nut materials with a low carbon and environmental footprint, specifically designed for the packaging and textile sectors.

Paraskevi Charalambous, a biochemical and materials scientist at BOKU, is part of the research team working on this process. One of her notable contributions includes research on solvents with a very low melting point.

The intention is to find a solvent that itself can be recycled, something that Charalambous admits has been challenging.

"It hasn't been easy to get the chemical we use back in its pristine form," she said.

Significant progress has been made since the project started in 2023 and the researchers have been able to produce several samples, including a sample of a nut-leather wallet.

The great advantage of the material, whether it ends up being leather or plastic, is that it is recyclable and compostable. Typically, composite materials – a combination of two materials with different properties – are difficult to recycle because other chemicals are added to adjust the function of the material.

The process used in this case does not do this, so the product can be dissolved again and reused. Gierlinger also said it is possible to compost the material if need be, though she promotes reuse and recycling first.

After deciding on the best path forward, the goal will then be to get these new nutty materials into production. “The next step would be trying to find some companies which are interested,” said Gierlinger.

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More info

- SCATAPNUT
- PUZZLE MATERIALS
- EU circular economy action plan
- EU safe and sustainable by design framework
- EU bio-based products and processes