An environmentally friendly way to turn seafood waste into value-added products

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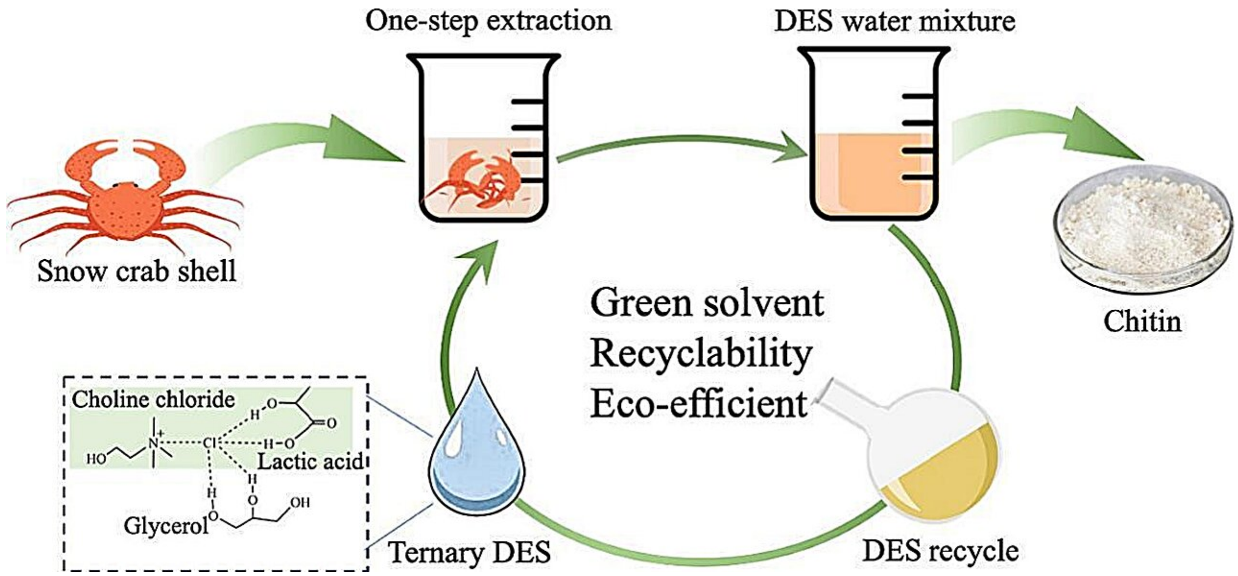

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Reduce, reuse, recycle, and repurpose: These are all ways we can live more sustainably. One tricky aspect of recycling, though, is that sometimes the recycling process is chemically intensive, and this is the case for recycling one of the world's most abundant materials—chitin.

Yangchao Luo from UConn's College of Agriculture, Health, and Natural Resources and his group have tackled this problem and found a way to recover chitin from seafood waste sustainably. Their findings are published in the International Journal of Biological Macromolecules.

Chitin is the second most abundant biological polymer on Earth, with an estimated 100 billion tons produced each year by fungi or creatures like insects and crustaceans, second to cellulose which is created by plants. Just like cellulose, in purified forms, chitin can be used for many things, from food packaging and other durable and compostable single-use materials to fertilizers and cosmetics.

Luo explains that chitin is a new research area he and his group started to explore after a company reached out for help trying to figure out a way to deal with the tons of seafood waste they generate. The company found Luo because he works with a derivative of chitin called chitosan, and they thought he might be able to lend his expertise.

"The typical practice for dealing with seafood waste is to simply dump it into the landfill, or back into the ocean, or to compost it," says Luo.

The trouble with these disposal practices is that the excess nutrients from the materials get into the waterways, which can lead to a process called eutrophication, where algae populations thrive on the excess nutrients while consuming vast amounts of available oxygen. This leads to "dead zones" where marine and aquatic life cannot survive. Finding a way to help reshape this waste stream was an intriguing challenge, says Luo.

"This also interested me because it aligns well with our college's strategic vision. I'm the co-chair of the Ensuring a Vibrant and Sustainable Agricultural Industry and Food Supply Committee. I thought that this is a good topic to explore about sustainability."

Luo tasked two Ph.D. students in his research group to begin addressing this problem, and they started by reading about current chitin processing methods. They quickly learned traditional methods to extract and process chitinous waste using large quantities of strong acids and bases, and it is considered such a polluting industry that there are no facilities that do this processing in the United States.

Since chitin is a very high molecular weight polysaccharide, traditional processing techniques rely on caustic chemicals to break it down. Additionally, it is also very water-intensive because of the need to dilute and neutralize the solvents after the extraction.

In Luo's lab, he says they typically approach these challenges using chemicals found naturally, oftentimes in food. They focused on malic acid, which is found in apples; lactic acid, which can be found in fermented foods; choline chloride, which is a salt often used as a food additive; and glycerol, which is often used as a sugar substitute.

These are all very common and versatile chemicals that are also physiologically and biologically compatible with the environment and chosen with chitin's hydrogen bonds in mind.

"We thought about hydrogen bonds. Many basic types of biomass, including chitin, cannot be dissolved in water because of the existence of strong hydrogen bonds within their molecular structure, so they don't react with water," says Luo.

"From a chemistry perspective, if you want to dissolve something in water or make it water soluble, it must form a hydrogen bond with water. In other words, if this compound cannot form a hydrogen bond with water, it cannot be dissolved, so they don't interact with water."

Luo explains that glycerol acts as a hydrogen donor, and choline chloride acts as a hydrogen acceptor. When paired with either of the acids (malic or lactic acid), the combination of these three components forms a viscous solution called ternary deep eutectic solvents (TDESs).

"We found that such TDESs are particularly effective in disrupting the hydrogen bonds that hold the structural components of the biomass together," Luo says.

"By weakening these bonds, the TDES facilitates the separation of chitin from other constituents like proteins and calcium carbonate. The unique properties of TDESs allow for the selective extraction of chitin and it can be designed to primarily dissolve unwanted components such as proteins and minerals, leaving behind a purified form of chitin."

"This selectivity is due to the specific interactions between the TDES components and the biomass constituents. By precisely adjusting the proportions of the three components in TDES, we can disrupt the hydrogen bonding interactions within the biomass. This approach allows for an innovative method of processing chitinous seafood waste."

When compared with the chitin they purchase from the scientific supply company, he says the lab-purified product is almost identical. Additionally, by adjusting the ratios, they can control the degree to which the chitin is processed and can, therefore, 'fine-tune' the molecular weight of the final product.

"The traditional chemical processes that use a lot of acid and base to process and extract chitin usually produce chitin with a small molecular weight that may have limited applications," Luo says. "With our mild malic acid or lactic acid, we can produce chitin with controllable molecular weight. We can make the molecular weight of 300 to 100,000 kilo Daltons, depending on our purpose for future applications. This is one of the most novel aspects of this technology.

"The other novelty is now we're working on an ultrasonication process that can be incorporated into the extraction process to turn the chitin into nano chitin. The process disentangles the chitin fibers into the nanoscale."

Another benefit of this extraction method is that since the solvents are food-derived and mild, they do not require neutralizing with copious amounts of water before they can be safely disposed of. They can be reused at least three times before they lose their extractive capacity, making the process lower-cost and more environmentally friendly.

Now with a provisional patent with UConn's Technology Commercialization Service, Luo's group is partnering with an agricultural company to test if chitin at different molecular weights and nano chitin can be used for crop production.

"We hypothesize that this nano chitin fiber will be able to be absorbed by the plant for better plant production or biostimulant functions in the soil or as a kind of fertilizer," says Luo.

By collaborating with Assistant Professor of Innovation and Entrepreneurship Minyu Qiao's group, the two teams are applying this approach to other materials, including seaweed, to extract and purify alginate. The typical process for this purification is long and complicated, but Luo says this TDES system reduces the multiday extraction to a process that takes about a few hours. By cleaning up and simplifying these processes, Luo has high hopes for the future with this system,

"We are hoping that we can turn this trash into a treasure—or at least into value-added products."

More information: Yi Wang et al, Glycerol/organic acid-based ternary deep eutectic solvents as a green approach to recover chitin with

different molecular weight from seafood waste, *International Journal of Biological Macromolecules* (2023). DOI: 10.1016/j.ijbiomac.2023.128714

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