Technology Networks
Applied Sciences

9 Oct 2023

A Green Approach To Upcycle Vegetable Waste

Daphne Ng, PhD, Nanyang Technological University, Singapore

Scientists at Nanyang Technological University (NTU) Singapore have devised an environmentally friendly method that turns vegetable waste into health and personal care products. Their approach could give vegetable waste a new lease of life and make the extraction of beneficial plant compounds more sustainable and cost effective.

The study was published in *Separation and Purification Technology* in 2023.

Giving vegetable waste a new lease of life

Millions of tons of food waste are discarded annually around the world, with fruits and vegetables making up more than one third of it. Vegetable waste is generated at various stages of the food supply chain. Farmers often cut off the outer leaves as they are harvested for leafy vegetables like kale to sell aesthetically pleasing vegetables with no signs of damage or yellowing. When the vegetables reach the supermarket, large quantities are also rejected due to their size, shape or color imperfections. These practices result in the disposal of substantial amounts of edible vegetables.

Vegetables contain many beneficial compounds that can also be extracted and added to food or cosmetics. Cruciferous vegetables such as kale are considered superfoods as they contain high levels of phytochemicals that have many health benefits.

Organic solvents and pressurized carbon dioxide are commonly used to extract and recover these compounds from plants. However, these solvents are often toxic, volatile or not economically viable when used on an industrial scale.

Solvents made from plant-based metabolites, called natural deep eutectic solvents (NADESs), could be safer alternatives for extracting phytochemicals. Unlike organic solvents, NADESs do not evaporate quickly and are biodegradable. They are also able to dissolve a wide range of natural products.

Extracting beneficial compounds from vegetable waste

Researchers led by Prof. Hu Xiao from NTU's School of Materials Science and Engineering, and a program director in the Nanyang Environment and Water Research Institute (NEWRI), tested the ability of NADESs with various formulations to extract phytochemicals from kale.

Figure 1: Kale in various forms. *Credit: NTU Singapore.*

First, the kale waste was blended into a paste or dried and ground into a powder (Figure 1). The researchers then mixed the kale paste (or powder) with their specially formulated NADES and stirred it at room temperature before filtering the mixture to extract the beneficial compounds.

When the NADES mixture is allowed to stand, it naturally separates into layers, facilitating the easy extraction of phytochemicals from kale (polyphenols, carotenoids and chlorophylls) without heating, unlike current energy-intensive industrial methods (Figure 2).

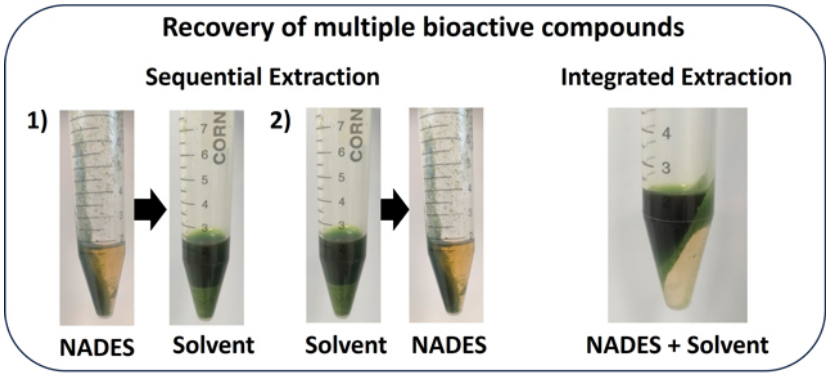

Figure 2: The NADES (orange layer) and ethyl acetate solvents (green layer) can be added sequentially or simultaneously to extract various bioactive compounds from kale waste. *Credit: NTU Singapore.*

As heating is not required, the NTU method prevents the temperature-sensitive phytochemicals from degrading. The extraction process is quick and can be completed within 30 minutes.

First author Dr. Lee Sze Ying, a research fellow at the Environmental Chemistry and Materials Program at NEWRI at the time of the study, said, "Our extraction approach is unique because it allows for the simultaneous recovery and separation of multiple valuable compounds from the vegetable waste in a single process without using heat."

The key findings of the study are:

- The green solvent system gave the highest yield of polyphenols, more than two times higher than conventional methanol methods.
- The polyphenol extract was stable in the new green solvent system, retaining 91.7% and 88.6% of the original contents after 30 days of storage at 4 and 25 ^{o}C, respectively.
- Other green solvents such as ethyl acetate can be added to the solvent mixture to obtain a polyphenol-rich extract and an extract rich in carotenoids and chlorophylls.

Growing industrial applications of plant compounds

The researchers say that manufacturers can add the extract directly into the formula of their cosmetic products without further processing, reducing production time.

Prof. Hu, the corresponding author, said, “The use of non-toxic and naturally derived solvents in our method makes it a food-safe technique. At the same time, our method preserves the potency of the extracted active ingredients, making it highly attractive for industry adoption. The extracted nutrients can be used for applications in personal care products, cosmetics, food supplements and even herbal medicinal ingredients.”

However, one of the major limitations of using NADESs as solvents is that they are highly viscous, which hinders the diffusion of the compounds into the mixture, thus reducing extraction efficiency. To make NADESs less viscous and improve extraction efficiency, water is usually added to dilute the solvents during the extraction process.

In the study, the researchers found that almost all bioactive compounds were more effectively recovered from the wet kale paste than the dried powder, as the water in the paste diluted the NADESs. This simplifies the extraction process as no additional water is required, and also removes the need for an energy-intensive step to dry the kale waste.

Co-author Dr. Liang Yen Nan, senior research fellow, Environmental Chemistry and Materials Program at NEWRI, explained, “Our method essentially manipulates the chemical nature of NADES and other green solvents to maximize the extraction efficiency of the bioactive compounds found in kale. This approach induces simultaneous recovery of multiple phytochemicals from the kale and can easily be adapted for use in other types of vegetable and fruit wastes. Moreover, we have demonstrated that our approach remains viable even if we were to eliminate the energy-intensive freeze-drying of the kale waste, making our technology greener, cheaper and scalable for industry use.”

Seeding a sustainable future for food waste

The team has filed a patent in Singapore for the innovation. For their next steps, the researchers are investigating if their newly developed method can extract beneficial compounds from other types of fruits and vegetables, like dragon fruit, spinach, lettuce and other medicinal plants. The team is exploring new partnerships to scale up their technology towards commercialization.

Reference: Lee SY, Liang YN, Stuckey DC and Hu X. Single-step extraction of bioactive compounds from cruciferous vegetable (kale) waste using natural deep eutectic solvents. Sep. Purif. Technol. 2023;317(123677). doi:10.1016/j.seppur.2023.123677

https://www.technologynetworks.com/applied-sciences/articles/a-green-approach-to-upcycle-vegetable-waste-379661