NEWS RELEASE

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Hair finds new roots as urban farming growth medium

The clumps of discarded hair on the salon floor could one day help to grow your lunchtime salad, thanks to scientists from **Nanyang Technological University, Singapore (NTU Singapore)**, who have created the growth medium used in urban farming – known as hydroponics substrates – using keratin extracted from human hair.

In hydroponics, crops are grown without soil, using a substrate that acts as both a support structure and a reservoir for water and nutrients. The keratin-based substrates developed by the NTU research team have been tested with crops such as microgreens and leafy vegetables, including the Chinese cabbage bok choy and arugula leaves, also known as rocket.

In their study, the NTU researchers first extracted keratin from human hair gathered from hair salons. The keratin solution is mixed with cellulose fibres to strengthen it, which is then dried into a spongy substrate.

The substrate is sustainable, biodegradable, and eco-friendly as it is made from waste material and becomes a source of nutrients for the plants as it degrades. The yield from this keratin-based substrate is comparable to materials currently available on the market, according to laboratory tests.

Professor Ng Kee Woei, **Associate Chair (Research)** at **NTU's School of Materials Science and Engineering (MSE)**, who led the research, said: "Besides hair, livestock farming produces large amounts of keratin as biowastes, as it is found abundantly in wool, horns, hooves, and feathers. Since keratin can be extracted from many types of farm wastes, developing keratin-based hydroponic substrates could be an important strategy for recycling farm wastes as part of sustainable agriculture."

The researchers hope their substrate offers a renewable alternative to current commercial offerings, such as those made from rockwool, polyurethane and phenolic foams which are not sustainable and do not provide nutrition to plants.

The findings of this proof-of-concept study were published in the peer-reviewed scientific journal *ACS Sustainable Chemistry & Engineering*. The study has its origin

in the **NTU-Harvard Initiative for Sustainable Nanotechnology**, a collaboration with Harvard University's T.H. Chan School of Public Health in the United States.

Hair today, crop tomorrow

Keratin is composed of amino acids that are a source of nutrients for plant growth. These amino acids can also bind other types of nutrients and release them under controlled conditions. Keratin therefore has great potential as a growth medium used in hydroponics and urban agriculture, where the timely release of nutrients and water is essential.

However, keratin is not strong enough by itself to form a substrate. The researchers mixed it with cellulose fibres to strengthen its structure and improve its water-swelling capabilities. The cellulose was extracted from softwood pulp, meaning the final product is sustainable.

The resulting keratin-cellulose substrate contains a highly interconnected pore structure, which allows for improved capillary action. This lets the substrate draw up the water-based nutrient solution to continuously feed water and nutrients to the plant roots.

"The resultant hydroponic substrates have high porosity and good mechanical resilience under aqueous conditions," said the paper's first author **Dr Zhao Zhitong**, **a research fellow at NTU's MSE**. "In addition, this keratin-based substrate can absorb and retain large quantities of water, making it a promising growth medium to support seed germination and crop growth in hydroponics."

One important property of hydroponic substrates is their ability to retain sufficient water to support crop growth, which can be evaluated by water uptake capacity. **Prof Ng** said: "Our keratin-based substrate can hold water up to 40 times its original weight, which is on par with commercial substrates currently available."

In their experiments, the researchers grew the model plant *Arabidopsis* and vegetables including arugula and bok choy. A gram of human hair can produce about three blocks of substrates of about 1.5cm by 1.5cm by 3cm, or the size of a small ice cube.

Both arugula and bok choy seedlings developed well in keratin-based substrates, with robust root and shoot systems.

"The plants actually grew much longer root systems in the keratin-based substrates than in commercially available phenolic foams, which is a promising sign that vegetable roots can better penetrate keratin-based substrates and more effectively absorb nutrients released from the substrates," said **Prof Ng**.

Customising substrates for maximum nutrient efficiency

To further boost the substrates' nutrient content, co-author **Professor Hu Xiao from NTU's MSE** incorporated nano-nutrients such as copper into the substrates.

These nutrients help enhance seed germination, crop yield and overall plant health by suppressing various types of plant diseases.

"The keratin-based substrate not only offers a sustainable platform for incorporation of different types and forms of plant nutrients, but also has several other advantages over existing products. One advantage is to allow better flexibility to tailor nutrient release profile to suit the growth of specific crop. This technology has great potential to significantly enhance the productivity of urban farming to meet society's needs, especially in land-scarce Singapore," said **Prof Hu,** who also leads the environmental chemistry and materials effort at NTU's Nanyang Environment and Water Research Institute.

In its current form, the keratin substrate developed by the research team can last between four to eight weeks, depending on conditions. It also leaves no waste behind, unlike commercial substrates currently available in the market that do not degrade and become solid waste after harvest.

The keratin can also be extracted from poultry feathers, which contain proteins that behave similarly to the proteins in human hair.

This NTU innovation is currently being further developed with funding from the National Research Foundation's Campus for Research Excellence and Technological Enterprise (CREATE).

The research team is in talks with industry partners, including local urban farms, to perform large-scale field tests. One such test aims to tweak the composition of the substrate to accommodate different types of vegetable crops, including those with thicker roots.

Another test they aim to perform is developing various types of keratin-based substrates that combine different nutrients which are released at different rates to stimulate crop growth. The team's vision is to customize keratin-substrate compositions to meet requirements of different crops, in order to maximise yield.

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Notes to Editor:

Paper titled "*Sustainable Nutrient Substrates for Enhanced Seedling Development in Hydroponics*", published in *ACS Sustainable Chemistry & Engineering*, 23 June 2022. DOI: 10.1021/acssuschemeng.2c01668

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About Nanyang Technological University, Singapore

A research-intensive public university, Nanyang Technological University, Singapore (NTU Singapore) has 33,000 undergraduate and postgraduate students in the Engineering, Business, Science, Medicine, Humanities, Arts, & Social Sciences, and Graduate colleges.

NTU is also home to world-renowned autonomous institutes – the National Institute of Education, S Rajaratnam School of International Studies, Earth Observatory of Singapore, and Singapore Centre for Environmental Life Sciences Engineering – and various leading research centres such as the Nanyang Environment & Water Research Institute (NEWRI) and Energy Research Institute @ NTU (ERI@N).

Under the NTU Smart Campus vision, the University harnesses the power of digital technology and tech-enabled solutions to support better learning and living experiences, the discovery of new knowledge, and the sustainability of resources.

Ranked amongst the world's top universities, the University's main campus is also frequently listed among the world's most beautiful. Known for its sustainability, over 95% of its building projects are certified Green Mark Platinum. Apart from its main campus, NTU also has a medical campus in Novena, Singapore's healthcare district.

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