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RIE NEWS

SG GUIDE TO TECHNOLOGY, INNOVATION & ENTERPRISE

SPECIAL

THE SCIENCE OF CONSUMPTION

FEATURE

THE GLOBAL YOUNG SCIENTISTS SUMMIT 2023

COMMENTARY

FOOD & NUTRITION RESEARCH

FEATURE

TESTING FOR COVID-19 IMMUNITY

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RESEARCH ROUNDUP

NEXT-GEN CLOUD TECH PROGRAMME

The Singapore Management University's (SMU) School of Computing and Information Systems today announced a collaboration with global professional services company, Accenture, and cloud provider, Amazon Web Services (AWS) to launch a new Work-Study Elective Programme. The programme is a six-month commitment from students to learn the latest AWS Cloud technologies and apply classroom knowledge to innovate cloud-based solutions that address real-world challenges.

Those who successfully complete the WSE programme, along with SMU's courses in IT solution architecture and enterprise solution development, will be eligible to apply for an internship opportunity with Accenture.

FIRST ANTIBODY-DRUG CONJUGATE

Singapore's drug discovery efforts reached a new milestone as "EBC-129", the first made-in- Singapore antibody-drug conjugate, was cleared by the U.S. Food and Drug Administration (FDA) to progress into first-in-human studies. EBC-129 is the first made-in-Singapore antibody-drug conjugate (ADC) that is entering clinical development. It is able to selectively target cancer cells across a range of solid tumours.

The ADC and the test to be used for patient selection were discovered and developed through the collaborative efforts of the Agency for Science, Technology and Research (A*STAR)'s Bioprocessing Technology Institute and Institute for Molecular and Cell Biology, the Experimental Drug Development Centre, and the National Cancer Centre Singapore.

Image: SMU, A*STAR

SMART INSOLE FOR WORKPLACE SAFETY

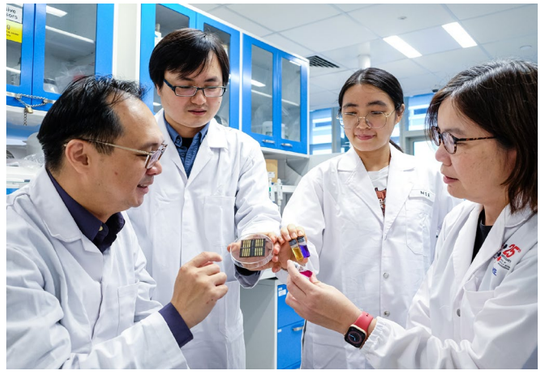
Harnessing the power of research and technology to boost workplace safety, the National University of Singapore's (NUS) Department of Biomedical Engineering as well as Institute for Health Innovation & Technology (iHealthtech), collaborated with NUS start-up, FlexoSense, to develop a smart insole which can track workplace slips, trips and falls (STFs) in real time and is the first of its kind that can detect a person's balance.

The insole will allow companies to identify the location of an incident and highlight STF risk areas in order to implement suitable mitigation measures. The smart insole comprises pressure sensors to track foot pressure and an inertia measurement unit sensor to measure changes in motion. Information gathered from the smart insole can be easily accessed by workers through a mobile application and by company management via a dashboard.

LEAD-FREE PEROVSKITE SOLAR CELLS

Perovskite solar cells release lead when damaged or discarded. The lead comes from the perovskite material and a compound used to make a component of the perovskite solar cell, known as the capping layer, that stabilises the solar cell.

Now, a research team led by scientists from Nanyang Technological University, Singapore (NTU Singapore) has developed a method that enables non-toxic metals to be used in the manufacture of the capping layer. Using the method, the scientists created a 1 inch by 1 inch prototype solar cell capped with a non-toxic zinc-based compound. The researchers are working on scaling up the method to fabricate full-sized solar cells and are in the process of filing a patent with NTUitive, NTU Singapore's innovation and enterprise company.



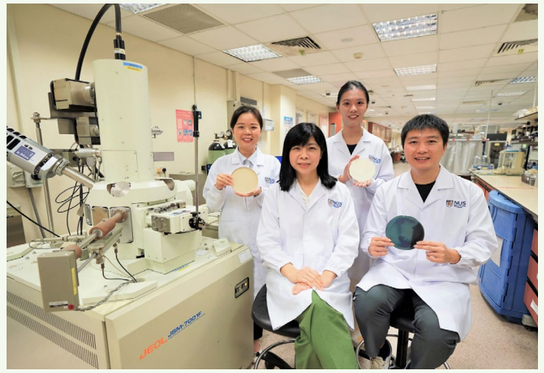
TACKLING LITHIUM-ION BATTERY WASTE

Following a successful proof-of-concept to recycle spent lithium-ion batteries using reagent extracted from fruit peel waste, NTU Singapore is partnering Secure Waste Management Pte Ltd (SWM), a Singapore battery recycling and processing company, to scale up the technology in a pilot plant. The pilot battery recycling plant has the capacity to process up to 2,000 litres of spent shredded battery mixed with fruit peel derived solvents for extraction of electrode materials such as cobalt, lithium, nickel, and manganese.

Located at Neythal Road off Pioneer Road North, the pilot plant has been operational since the last quarter of 2022. Over the course of 2023, NTU and SWM team will work to optimise processes that maximise the extraction yield of valuable metals from battery waste for reuse at pre-commercial scale.

ENERGY-EFFICIENT INORGANIC MEMBRANES

In a ground-breaking achievement, a team of researchers from NUS has developed a revolutionary technique for producing ultrathin inorganic membranes. These freestanding membranes can function without any supporting substrate; a significant advancement in membrane technology. Highly customisable and simple to produce, the inorganic membranes – underpinned by a universal, facile synthesis strategy – have the potential to benefit applications beyond filtration and separation. From energy conversion to catalysis and sensing, the membranes' versatility could transform various sectors and industries that depend on membrane technology. By promoting efficiency and sustainability in industrial processes, the NUS scientists' pioneering research has unveiled new possibilities for overcoming energy challenges in the face of climate change.



Images: NUS, NTU Singapore

FEATURE // ANNUAL EVENT

THE GLOBAL YOUNG SCIENTISTS SUMMIT 2023

With 1,400 participants in attendance, the Global Young Scientists Summit returns in a hybrid format to foster collaboration and inspire young researchers from around the world.

As we emerge from almost three years of life in the COVID-19 pandemic, the Global Young Scientists Summit (GYSS) returns from behind the screen in its 11th year. Held in a hybrid format for the first time with over 300 participants attending in person at the Singapore University of Technology and Design (SUTD), the Summit saw a total of 1,400 participants hailing from 29 countries.

Organised by the National Research Foundation (NRF), the GYSS 2023 took place from January 17 to 20.

Centred on the theme 'Fusion in Session', this year's Summit focused on open collaboration in and out of the lab. Twenty-one distinguished speakers – among them awardees of the Fields Medal, Millennium Technology Prize and Nobel Prize – shared their experiences working with colleagues and industry partners to achieve ground-breaking scientific success.

GYSS 2023 was launched by DPM Heng Swee Keat, who emphasised the key role that science plays in our modern world.

The Summit was launched by Deputy Prime Minister and Coordinating Minister for Economic Policies Mr Heng Swee Keat. In his opening speech, he emphasised the critical role science plays – and has always played – in our modern world. Through climate change, ageing populations and a global pandemic, scientific discovery has proven to be the key towards sustaining humanity as we know it.

Also the Chairman of NRF, DPM Heng stressed the ability of science to bring together people from different backgrounds in pursuit of a common goal.

Fresh insights and inspirational speakers

Swiss astronomer Professor Didier Queloz kicked off the Summit with his plenary lecture on his work discovering extrasolar planets, also known as exoplanets.

In the packed auditorium, Prof Queloz explained how he developed new methods and technologies to detect thousands of planets outside of our solar system. He also described the potential applications of his current work searching for an Earth-like planet.

Prof Didier Queloz, recipient of the 2019 Nobel Prize for Physics, kicked things off with stellar lecture on exoplanets that was out of this world.

The GYSS returned this year bringing back in-person sessions at SUTD while also extending its presence in the virtual space.

The first panel of the Summit saw Prof Queloz joined by fellow Nobel laureates, Professor Aaron Ciechanover and Sir Konstantin Novoselov, to discuss the potential of revolutionary tools in science. Leaders in their respective fields of astrophysics, biochemistry and materials science, the panellists explored the importance of tools – from artificial intelligence to sticky tape.

"The tools available are completely different from when I began my career, but the passion of people remains the same," noted Prof Ciechanover. "Some tools can make things too easy, but truly innovative and driven people will not turn to them. Truly driven people will look to discover and learn on their own."

At this year's GYSS, six new speakers attended – four in person and two virtually. One of the new speakers, Professor Brian Kobilka, presented in person on the first day of GYSS. In his plenary lecture, he encouraged young scientists to attend a variety of conferences and meet researchers from different fields that could potentially inform their own work.

Another new speaker, Sir David Klenerman, walked participants through his tumultuous 20-year journey with his collaborator, Sir Shankar Balasubramanian, to develop next-generation sequencing.

"The nature of research is you're doing something no one has ever done before, so it's unrealistic to expect it to work the first time," he advised. "As a young person, you just have to get used to experiments not working and find a way to pick yourself up."

The right tools to build trust

Throughout the Summit, participants asked questions about communicating their work to the public and correcting misinformation. On the fourth day, three panellists – Sir David, Professor Valerio Scarani from the National University of Singapore and new GYSS speaker Professor Alison Woollard – shared their experiences communicating their work and offered advice to an excited audience.

In particular, they stressed the importance of communicating openly and understanding your audience. From grant boards to young students, each group comes with preconceptions and beliefs that must be accommodated.

When it comes to communicating complicated topics to members of the public or reviewers outside of their field, Sir David suggests "distilling [the research] down to the essence", rather than getting bogged down with details.

"I think we spend so much time worrying about the details that sometimes it's nice to come up and take a view from the sky and see what you're doing," he explained.

In her plenary lecture, later on in the day, Prof

Young scientists and participants had a rare opportunity to engage with the world's most brilliant minds in science and technology. Here, Sir Tim Hunt, recipient of the 2001 Nobel Prize in Physiology/Medicine, urges aspiring researchers to think outside the box in their academic journeys.

Woollard advised young scientists to think of science communication as storytelling. "We learn from the stories and are entertained," she explained.

"The stories may make us wiser and help us construct our world. By following the story, we're taken on a journey and our neural models may be modified as a result."

World-changing breakthroughs

The annual GYSS is also a celebration of scientific achievements.

As he regaled the audience during his plenary with tales from his famous Friday night experiments, Sir Andre Geim explained how those experiments were done simply out of curiosity. His curiosity paid off when he discovered graphene, a breakthrough that earned him the 2010 Nobel Prize in Physics, which is shared with his close collaborator, Sir Konstantin Novoselov.

With a pencil and Scotch tape, they peeled off layers of pencil lead to determine if making thin films of graphite was possible. What they found instead was a way to isolate a two-dimensional material for the first time. "Sometimes random thoughts and random experiments, as I've tried to persuade you, they do work," chuckled Sir Andre.

Another Nobel laureate awarded for an important discovery is Sir David MacMillan, who co-developed asymmetric organocatalysis. In describing his research, the 2021 Nobel Prize in Chemistry winner also shared with the audience his humble beginnings and personal beliefs, such as democratising opportunities.

Donating his Nobel Prize monetary award, he started The May and Billy MacMillan Foundation – named in honour of his parents – to support the education of underprivileged children in his home country, Scotland. "This is something that's very close to my heart," said Sir David. "Everybody knows that it's up to you what you do with your opportunities, but getting opportunities is the hardest part."

Like Sir Andre and Sir David, whose works have significant real-world impact, Professor Stuart Parkin is another scientific pioneer. The recipient of the 2014 Millennium Technology Prize, Prof Parkin has revolutionised today's digital world with his research on spintronics.

In his plenary lecture, Prof Parkin also discussed racetrack memory, his current research that could advance quantum computing and artificial intelligence applications.

He emphasised, "Racetrack memory is a possible replacement for magnetic disk drives. It would have the same storage capacity, but it would be a million times faster and use 50 to 100 times less energy."

On-site delegates at #GYSS2023 took a tour around Chinatown, Kampong Glam, Little India and the iconic Marina Bay area. Beyond seeing some of the Lion's City's most famous landmarks, they also got to see how science intersects with different aspects of culture, history and daily life in Singapore.

Youthful ambitions

The plenary speakers were not the only ones taking centre stage. This year's Young Scientist Presentation segment saw 10 aspiring scientists across disciplines sharing their research, from finding prospective metal-organic frameworks to determining the presence of microbial life in the atmosphere.

Among the presenters were Dr Mahonri Owen and Dr Cosnet Lerato Rametse, whose respective studies demonstrate the potential of science and technology in improving one's quality of life.

Deeply moved by a personal encounter he had with a wheelchair-bound woman, Dr Owen from the University of Waikato, New Zealand strives to create more intuitive and natural prosthetics. His research taps on machine vision and non-invasive neural interface to help amputees and those affected by neurological disorders lead better lives.

Dr Rametse from the University of Cape Town, South Africa, on the other hand, is shedding more light on HIV transmission in the male genitalia. She studies the infection susceptibility of the different anatomical parts of a penis and the effect of medical male circumcision at birth on the skin barrier function.

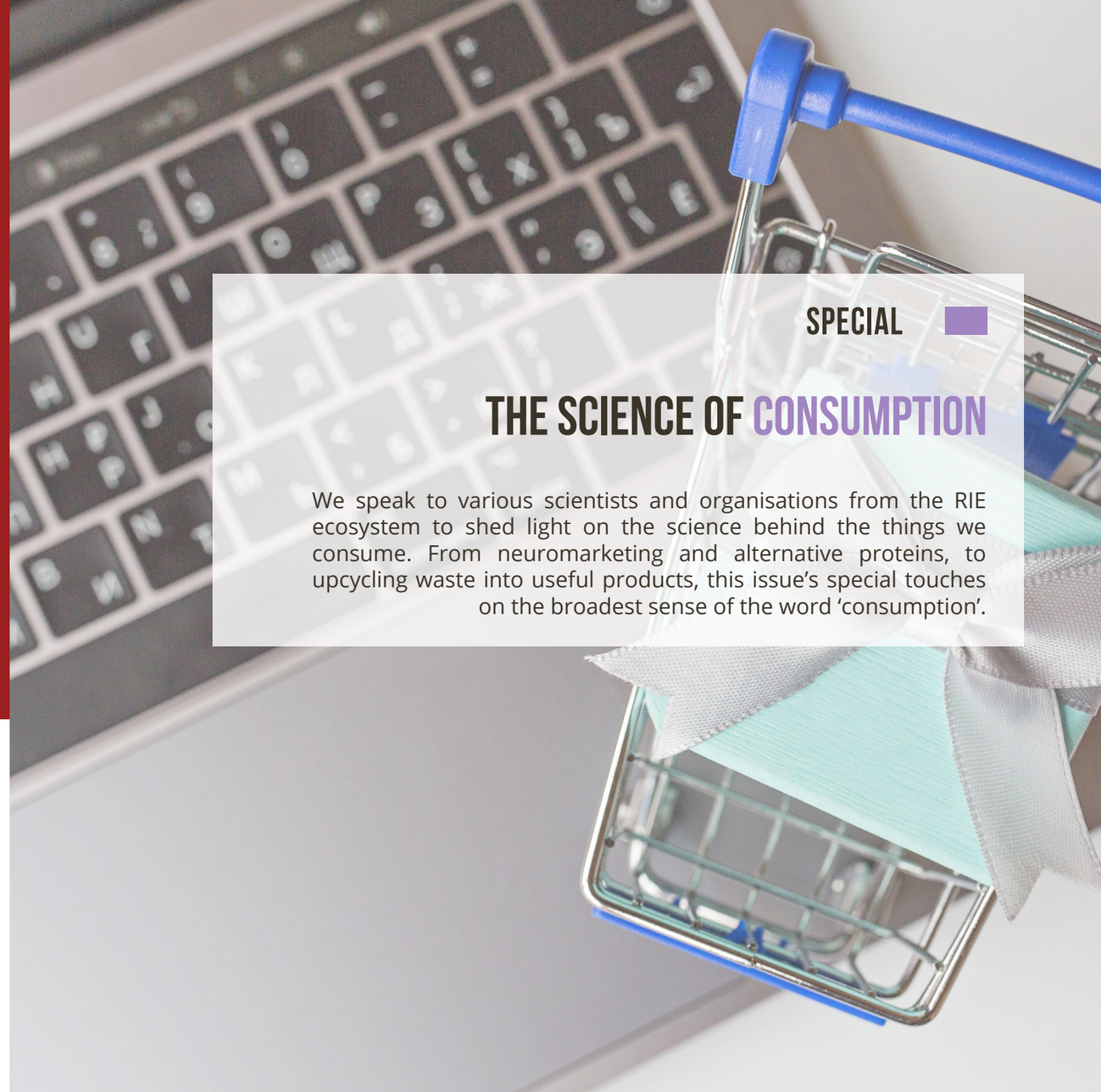
GYSS is not just a melting pot of ideas, it offers participants the opportunity to interact and learn from the speakers as well as engage with their peers.

A highlight of this year's event was the cultural tour around the city of Singapore for on-site participants. From Chinatown to Marina Bay, participants took in the cityscape while swapping personal stories and contacts over local delicacies; it was truly a fusion in session.

"I find it super cool to have the chance to understand a bit better, not only the scientific side of a person that we see but also the human perspective behind it – their stories," said participant Valentin Dunsing from the Human Frontier Science Program.

Catch all the Summit's plenaries and panel discussions on NRF's YouTube, and stay tuned to the GYSS website for more info on the next GYSS in 2024.

GYSS SINGAPORE



SPECIAL

THE SCIENCE OF CONSUMPTION

We speak to various scientists and organisations from the RIE ecosystem to shed light on the science behind the things we consume. From neuromarketing and alternative proteins, to upcycling waste into useful products, this issue's special touches on the broadest sense of the word 'consumption'.

SPECIAL // COMMENTARY

FOOD & NUTRITION

RESEARCH AND TECHNOLOGY

Singapore Institute of Technology's Vice President for Research, **Associate Professor Susanna Leong**, shares some insights in the importance of food science and technology and how the university is driving research in these key areas.

Images: Singapore Institute of Technology

Associate Professor Susanna Leong, Vice President (Research), SIT

Today's global food landscape is changing rapidly fueled by the COVID-19 pandemic, climate change, protectionism trends and global inequality, resulting in wide implications on food security and affordability.

Singapore is also confronted with an ageing population which will require a steady supply of nutritious and affordable food options. We need both human capital and innovative solutions to tackle these challenges. And this is where research institutes and institutes of higher learning are in the best position to support this through translational research coupled with close working relationships with industry partners. The Singapore Institute of Technology (SIT) is already ramping-up momentum in this arena.

With three food-related undergraduate degree programmes under SIT's wings spanning food technology, dietetics and nutrition as well as culinary arts, SIT views its role in training industry-relevant talent and addressing growth opportunities across the food sector through applied research an important and exciting one, given that food systems are on the cusp of a major transformation.

SIT's food research focus encompasses several inter-related areas: (i) alternative protein food production for optimised quality and cost competitiveness, (ii) food waste upcycling, (iii) nutrition and dietetics, and (iv) food structure engineering.

The 1,107 m2 facility at FoodPlant boasts 12 rooms with specialised food production equipment, including the extruder room which companies may use the Twin-Screw Extruder to produce plant-based meat analogues. The facility provides food businesses with a platform to innovate, scale up and commercialise new products

To actualise translation of our food research, SIT's small batch food production facility at FoodPlant actively works with food outfits to transit food prototypes towards commercialisation. In fact, the spirit of translational research excellence necessitates strong relationship with industry partners which is pivotal to ensure ideas nurtured at the lab remain relevant and commercially viable.

Alternative protein is an emerging food megatrend, driven by the need to overcome the inefficiencies of animal agriculture and shift our food systems toward an environmentally-sound path. SIT has been working with food companies to develop new formulation, advance processing of novel food products such as meat substitutes, functional/healthy food products, and understand the use of novel ingredients such as complementary proteins in food matrices.

One of SIT's food research partners is Agrocorp, a leading agricultural commodity and food solutions

provider. Today, SIT and Agrocorp are working to develop greener protein extraction platforms derived from biotech and non-thermal processing methods.

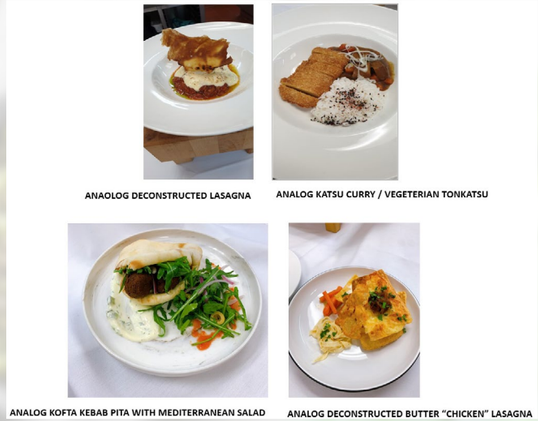
The research is motivated by Agrocorp's desire to move away from traditional extraction practices which are water and solvent intensive and reinforce food circular economy. Preliminary results from this work suggest that clean labelling of future foods can be a reality, driven by enhancement in quality and yield of plant extracts from such 'improved' processes.

SIT has also successfully co-developed a few types of plant-based cheese with Agrocorp, helping them optimise existing product formulations and processing aimed at cost reduction, ingredient replacement, product stability as well as taste improvements. The soon-to-be-launched vegan cheese range comprising cheddar, mozzarella and parmesan promises a healthier option as compared to regular plant-based cheeses that are usually just made of oil, starch, and additives.

Healthier alternative plant-based cheese from optimised formulation of ingredients.

A pipeline of other vegan products such as eggs, mayonnaise and cream cheese is also being trialed at FoodPlant for commercialisation. Agrocorp's food technologists are housed in SIT's labs over the duration of this collaboration and work closely with SIT's researchers and students.

The serendipitous conversations and spontaneous cross-disciplinary knowledge and skills exchange are invaluable for building translational research capability while supporting the strategic needs of businesses including talent development.

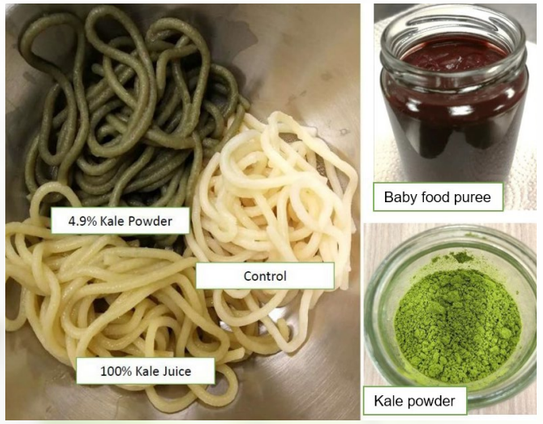


Meat analog dishes jointly created by SIT researchers and CIA student chefs.

Beyond non-dairy milk and cheese products, we are also working on other categories of plant-based meat alternatives. To close the taste gap between animal-based and animal-free meat, we also collaborate with chefs from our university partner, the Culinary Institute of America (CIA), to devise recipes that can elevate the gastronomic appeal of our alternative meat prototypes.

In food waste upcycling, we collaborated with Sustenir Agriculture to demonstrate the viability of converting urban farm waste streams into valuable food ingredients.

Images: Singapore Institute of Technology



Kale powder and examples of developed food products containing valorised kale powder.

One of our chemical engineering faculty, Dr. Cheow Wean Sin, developed a spray drying methodology to efficiently convert under-utilised kale stem from Sustenir into functional powdered ingredients, with preserved nutrient contents, colour and taste. The energy efficiency demonstrated by the drying process is key to enable scalability.

Our team of food technologists and dietitians are now developing food products spanning baby food puree to kale pasta and nutrient supplements from the kale stem powder, which is rich in anti-inflammatory compounds such as glucosinolates.

Fermentation is also another key pillar in food science technologies. SIT is already optimising fermentation technologies to exploit microbial cell factories for food waste valorisation into single cell proteins which can be used as food ingredients or other lucrative bioproducts up-cycling to drive green manufacturing.

An example is the successful genetic re-factoring of a non-conventional "fatty" yeast, *Yarrowia lipolytica*, to produce terpenoids and organic acids from waste cooking oil (WCO). The team successfully produced 55 g/L of itaconic acid, a key building block in the manufacture of synthetic fibres, coatings and cosmetics, with a good potential for commercial production. Further scale-up studies in bioreactors above 100 L are ongoing.

Other bioproducts produced by the team from WCO include optically-pure limonene and amyrin which have industrial applications as flavour and fragrance additives for food and cosmetic products, and active ingredients and adjuvants in drug formulations, respectively.

Besides yeast, the research team led by my colleague, Dr. Adison Wong, is also studying filamentous fungi such as mycelium, which are decomposers of organic compounds, for valorisation of other types of food processing side streams.

It is also important to leverage food as an intervention to increase healthspan by synergising food tech and nutrition capabilities. For example, a sensory evaluation test of high-protein instant plant-based beverages developed in-house was conducted among cancer outpatients at the National Cancer Singapore with different stages of their cancer treatment.

Formulated with Asian-centric flavours such as black sesame and mushroom porridge, the test would determine the patients' understanding of the importance of nutrition as well as their preferred taste. Dr Verena Tan, SIT's dietitian lead for this study, saw largely positive outcomes in terms of patients' acceptability of SIT's high protein beverages. Follow up studies to evaluate the longer-term impact of plant-based supplements on muscle health are ongoing.

Besides nutrition aspects, texture and structure are

High-protein instant plant-based beverages are just one example of leveraging food as an intervention to increase healthspan.

also important determinants of food sensory and functionality performances.

The intrinsic structural complexity of the majority of modern food materials underpins much of the difficulty in developing new food products that are sustainable, healthy, and delicious.

These microstructures manifest sensorially as the texture of food in-large-part through physical mechanical properties, and the mechanical behaviours dictate and are impacted by industrial processing methods and parameters.

One of my colleagues who focuses on food structures, Dr. Arif Nelson, is working on characterising, understanding, and ultimately linking physical properties to underlying food structures with the aim to help food outfits rationally design food products.

In an ongoing project focused on developing high protein beverages targeting dysphasic consumers, we are helping a company appreciate the effects of different formulation on fluid flow at varying stresses.

> **"It is important to leverage food as an intervention to increase healthspan by synergising food tech and nutrition capabilities.**
>
> Associate Professor Susanna Leong, Vice President (Research), SIT

With this improved understanding of fluid rheology, the company will be able to optimise formulation of beverage drinks with different textures and consistencies based on established scientific correlation to allow re-producibility.

Food and nutrition research are paving the way towards a more sustainable and healthier food system that also provides bring numerous benefits both to consumers and industry. SIT is one of the leading examples in Singapore's ecosystem that is leading the charge in this area through cutting-edge R&D, industry collaborations, and partnership with healthcare providers.

Commentary by:

SINGAPORE INSTITUTE OF TECHNOLOGY

SPECIAL // NEUROMARKETING

THE HIGH-PITCHED SOUND OF HEALTHINESS

The melodies in food commercials affect how we perceive the products' healthiness. NTU's **Professor Gemma Calvert** elaborates.

British scientist, Professor Gemma Calvert is a renowned neuroscientist and pioneer in the field of neuromarketing.

Want to encourage people to eat healthier foods? The answer may lie in pairing commercials for such foods with higher-pitched sonic logos, or 'sogos', which are the short melodies that firms create to support the marketing of their products.

In a new study by NTU's Nanyang Business School, participants associated higher-pitched sogos with healthier food products, and lower-pitched sogos with unhealthy ones. They were asked to match images of healthy and unhealthy food to sogos of different pitches.

"The research shows that retailers of alternative meat proteins and other health foods could connote their products' health benefits without the hard sell, but by simply incorporating high frequency components into their sogos and jingles," said Professor Gemma Calvert from the business school, who led the study.

Governments could also make use of the findings. "Given that people are often confused by the morass of information on food labels, using simple techniques that convey healthiness can make us choose healthier options when that is our shopping goal."

Prof Calvert is one of the pioneers of the field of neuromarketing, which analyses consumers' subconscious thoughts and feelings about brands, products, advertisements and other types of marketing materials, using techniques from cognitive psychology and neuroscience.

She said, "We assume that high-frequency sogos and healthiness are matched because high-pitched sounds and being healthy are linked to smallness and lightness, while low-frequency and less healthful indicators are associated because both connote largeness and heaviness."

The research has other implications too. "We don't always want to eat healthily. Sometimes, we want to treat ourselves to something that is high in fat, sugar or salt. Companies that sell such foods can adopt low-pitched sogos to highlight to consumers where they can satisfy their urges. It works both ways," she shared.

The underlying lesson is that sogos should set the right expectations. "The brain is a hard task-master. If you use high-pitched sogos but deliver high-fat, greasy hamburgers, consumers' brains will not be happy."

The study also found that the participants associated more stimulating visuals in commercials with healthy foods, and less vivid ones with unhealthy foods. "Based on what we know about how the brain combines information from different senses, you could use stimulating visuals and higher-pitched sogos to get a super additive effect in conveying healthiness," she said.

The researchers plan to further their work by investigating, among other things, how certain speech sounds within brand names can enhance the perceived sweetness of a product, make carbonated drinks seem more sparkling, and even connote that something is a luxury.

"We are also exploring how certain visual cues, such as the packaging shape, can convey the product's benefits without having to spell it out in a long message on the pack. Successful marketing is about making life easier for consumers – including for their brains."

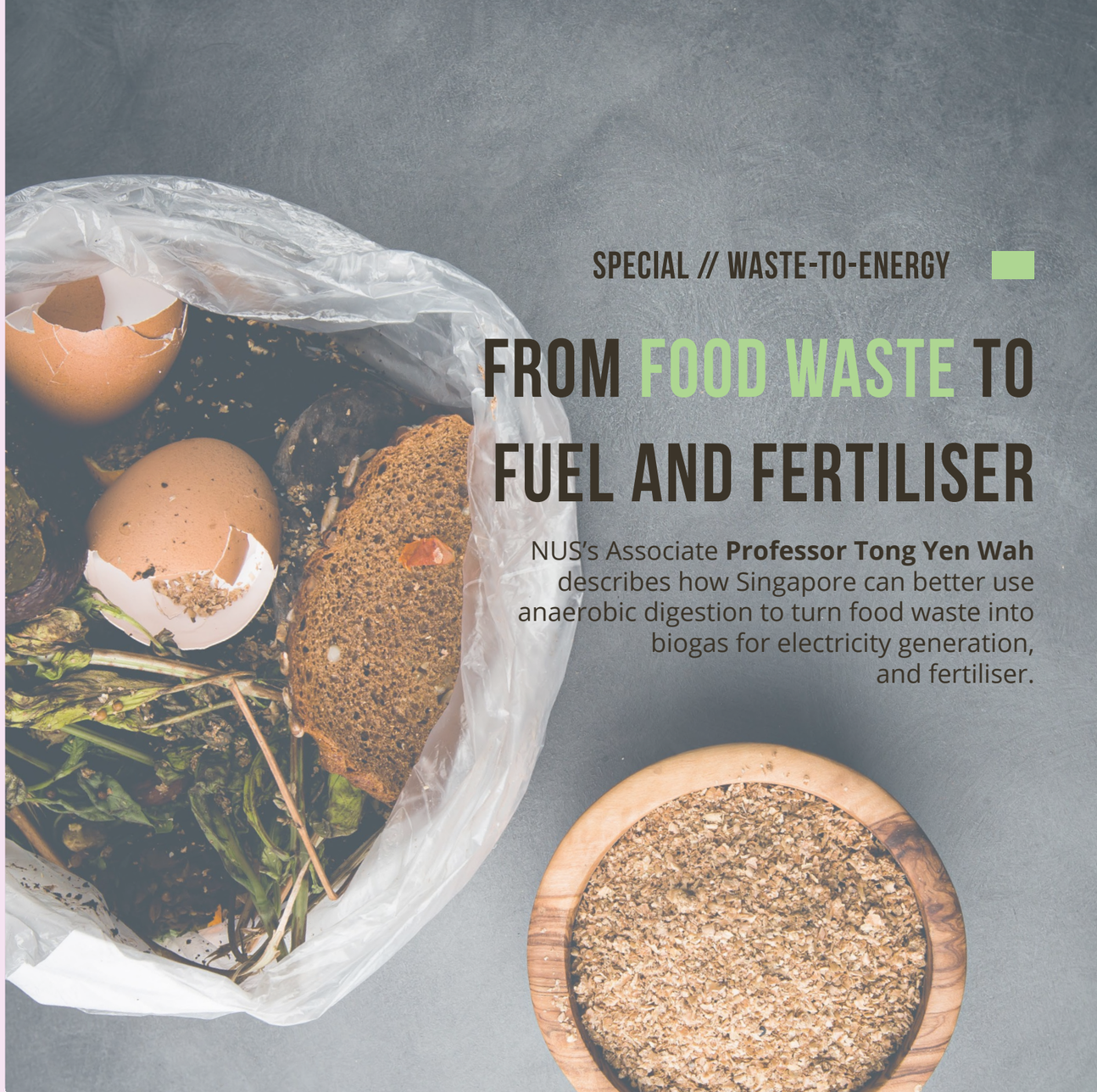
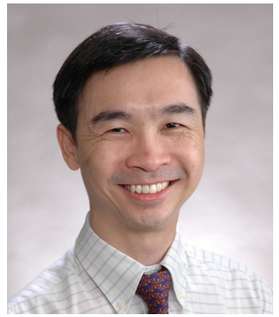


Image: NTU Singapore

SPECIAL // WASTE-TO-ENERGY

FROM FOOD WASTE TO FUEL AND FERTILISER

NUS's Associate **Professor Tong Yen Wah** describes how Singapore can better use anaerobic digestion to turn food waste into biogas for electricity generation, and fertiliser.



NUS Associate Professor Tong Yen Wah's research team research team has established a position at the frontiers of developing anaerobic digestion solutions that sustainably closes the loop for biological wastes like food waste and horticultural wastes.

As Singapore continues to take aim at its growing amount of food waste, a pioneering project by NUS has delivered crucial insights into the potential ways forward.

Two years from October 2020, Associate Professor Tong Yen Wah from NUS' Department of Chemical and Biomolecular Engineering led a project that installed an anaerobic digester at the East Coast Lagoon Food Village hawker centre, for the first time.

The anaerobic digestion system takes in source segregated digestible food waste, such as fruits and vegetable trimmings, preparation scraps from the stalls and leftover table waste. Microbes then feed on the blended food waste to produce methane-rich biogas and nutrient-rich digestate. Biogas is used to run a gas engine to generate electricity, while the digestate could be used as fertilisers for ornamental plants and landscaping applications.

Such digestors break down organic material, including those in food waste, in the absence of oxygen to produce biogas for power generation. The process also creates nutrient-rich liquid residues that can be used as fertiliser.

During the trial, where the digestor was placed from May 2021 to October 2022, Prof Tong and his collaborators tested a variety of measures to persuade its hawkers, cleaners and diners to separate food waste from other waste, so that it can be used in the digestor.

Associate Professor Tong Yen Wah, who leads the NUS team, is pictured next to the anaerobic digester at the East Coast Lagoon Food Village.

Images: NUS

The researchers provided covered bins to the participating stallholders and table cleaners for easier food waste segregation and collection.

They also placed five smart bins in the hawker centre, which record and store data on the amount of food waste contributed by each user, and offered small monetary incentives for such deposits in the trial's first three months.

Prof Tong said, "We wanted to encourage them to form the habit of setting aside their food waste and emptying it into the smart bins. We had other, more psychological interventions too. We explained to the hawkers and cleaners why tackling food waste is important, and tried to get the hold-outs to join the trial by pointing to others who were already on board."

Despite the researchers' efforts, only about half of the hawker centre's stallholders took part in the trial. The researchers also discovered other problems.

Vegetable scraps dominated the collected food waste, since the hawkers and diners threw away little meat, rice, noodles and other carbohydrates. The imbalance hurt the digestor's biogas production.

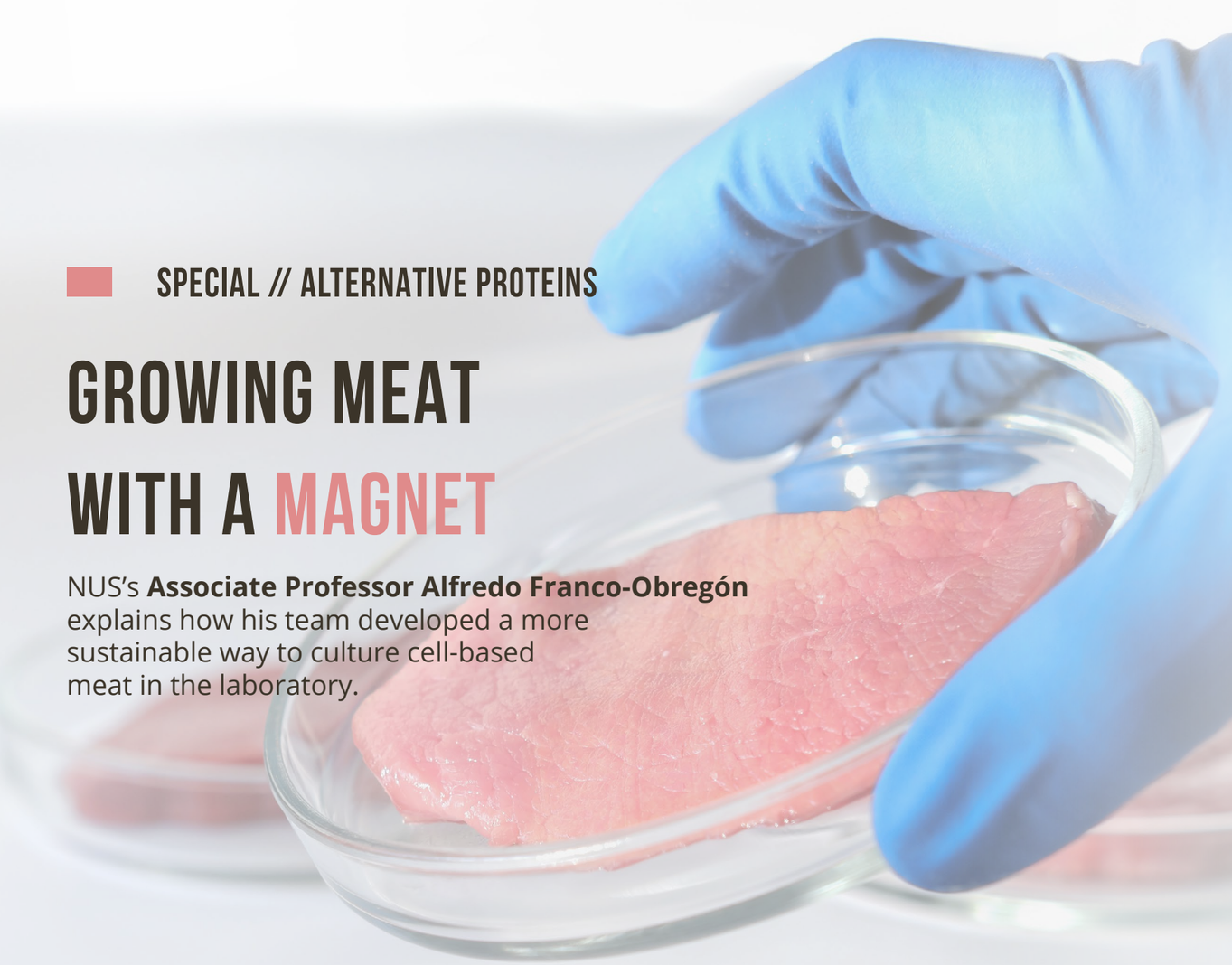
Prof Tong added, "Just like people, anaerobic digestors work best when they get a balanced diet. Our findings suggest that anaerobic digestion might be more suitable for places that sell or provide cooked food, such as canteens or residential halls where the food is catered from somewhere else, and thrown away if uneaten. You get a good mix of food waste then."

Aggregating food waste from different places, such as from food courts and hawker centres, or from a group of housing blocks, could provide the scale and diversity in food waste needed to make investing in anaerobic digestion systems worthwhile too. Such systems require more upfront capital than composting or aerobic digestion ones.

The NUS researchers also found through the trial that more hawkers would have taken part if they could contribute their food waste more easily. "If they had a sink that they could sweep the waste into, and which would automatically pump it to the collection bin, that would have been helpful," Prof Tong said.

Moreover, the trial confirmed anaerobic digestion's benefits. A life cycle assessment showed that it is greener, in areas such as reducing global warming and marine eutrophication, than composting and incineration. The NUS team also proved that the digestor's liquid residue can be safely used as fertiliser.

Moving forward, the team is partnering with a waste collection company that gets food waste from food factories and cruise ships, to use anaerobic digestion to convert it into biogas and fertiliser. Prof Tong said, "We are scaling up to demonstrate anaerobic digestion's potential."



SPECIAL // ALTERNATIVE PROTEINS

GROWING MEAT WITH A MAGNET

NUS's **Associate Professor Alfredo Franco-Obregón** explains how his team developed a more sustainable way to culture cell-based meat in the laboratory.

Images: NUS

Call it the next big thing in meat. Scientists at NUS have created a greener way to grow cell-based meat in the laboratory, so that people who want to eat meat can do so while shrinking their environmental footprint.

Firms have been producing such cultured meat as an alternative to carbon-intensive animal farming, but existing methods are rife with problems.

Most cultured meat involves encouraging animal muscle cells to grow by feeding them animal serum, usually foetal bovine serum, which is a mixture harvested from the blood of foetuses taken from pregnant cows killed in the meat and diary industries.

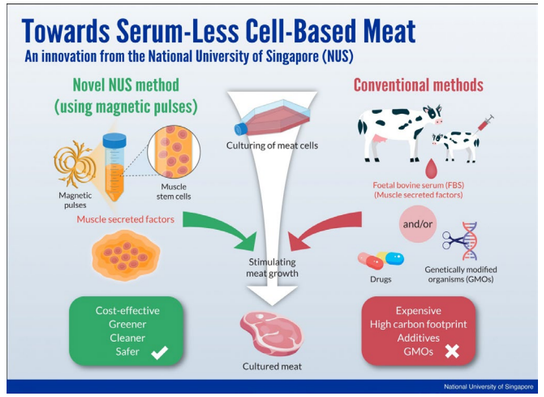
This process defeats the purpose of cell-based meat since it relies on animal products too.

Other firms have turned to drugs or genetic engineering to stimulate the cells' growth. These complex production methods increase costs, reduce cell-based meat's commercial viability and limit its potential manufacturing scale.

Associate Professor Alfredo Franco-Obregón from the NUS Institute of Health Innovation and Technology and NUS Yong Loo Lin School of Medicine led a multidisciplinary research team to develop a better solution.

The team found that using a pulsed magnetic field to 'zap' animal muscle cells, specifically myogenic stem cells from skeletal muscle, causes them to release molecules with regenerative, metabolic, anti-inflammatory and immune-boosting properties.

These molecules, called muscle secretomes because they are secreted by the muscles, can be used to help meat cells to grow into cultured meat, eliminating



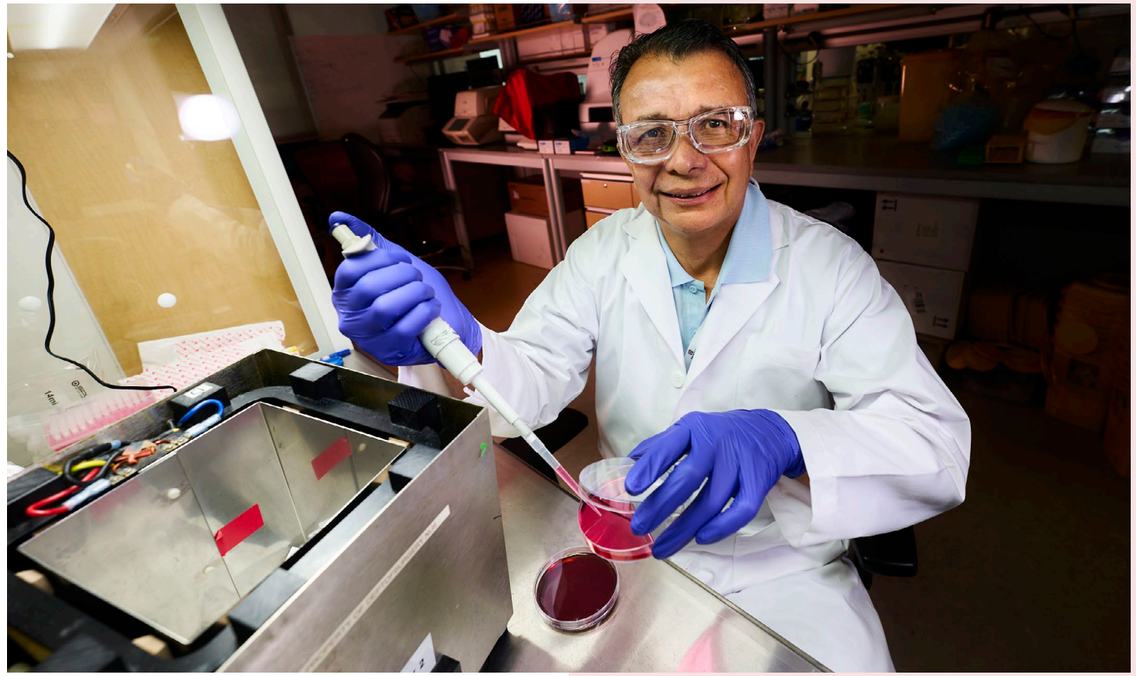
the need for animal serum, drugs and genetic engineering.

"By using myogenic stem cells as a sustainable and green bioreactor, we can harvest these secretomes in the laboratory safely, conveniently and at low cost, to grow cell-based meat at scale for consumption," said Prof Franco-Obregón.

He explained that in people and animals, muscles which are connected to bones, joints and ligaments produce energy during movement, which leads to the growth-inducing secretomes' release. This is why exercise increases strength.

In conventional cell-based meat growing processes, the muscle cells in tissue cultures do not move, and therefore produce little extra energy to release the secretomes.

This is why companies use the animal serum, which contains the secretomes, to coax the muscle cells to grow.



NUS Assoc Prof Alfredo Franco-Obregón and his team have found a novel way of growing cell-based meat by zapping animal cells with a magnet.

Since the NUS team's innovation simply harvests and uses the secretomes in place of animal serum, drugs or genetic engineering, it can be easily added to current cell-based meat growing systems.

The team has filed a patent for the technology and is in talks with potential industry partners to commercialise it.

The harvested secretomes could be used in regenerative medicine too. The team found that the secretomes of muscle and stem cells accelerate the recovery of unhealthy cells and their growth.

Prof Franco-Obregón shared, "The same secretomes that encourage muscle to develop within a petri dish also hosts agents that combat cancer, diabetes and immune deficiency.

"We are identifying agents that slow cancer growth, cause fat to 'brown' or metabolise itself, promote bone regeneration and more."

SPECIAL // UPCYCLING

A NEW LIFE FOR OLD SOLAR PANELS

With solar panel waste rising, A*STAR's **Dr Ady Suwardi** explains how an A*STAR-NTU team invented a method to turn old solar cells into heat-harvesting, electricity-producing materials.

With solar panel waste rising, A*STAR's Dr Ady Suwardi explains how an A*STAR-NTU team invented a method to turn old solar cells into heat-harvesting, electricity-producing materials.

The surge of solar power worldwide has a dark side. Research shows that with the increasing use of solar panels and the technology's lifespan of 30 years, the global waste generated from the panels' silicon is slated to hit eight million tonnes by 2030 and 80 million tonnes by 2050.

To turn this problem into an opportunity, scientists from the Agency for Science, Technology and Research's (A*STAR) Institute of Materials Research and Engineering (IMRE) and Institute of High Performance Computing (IHPC), and Nanyang Technological University (NTU), have invented a way to turn old solar panels into new high-performance thermoelectric material, which harvests heat and converts it into electricity.

Their method involves pulverising the solar cells that make up each panel into powder, adding phosphorus and germanium powder to alter the cells' original properties, then processing the combined powder under high pressure and heat using spark plasma sintering.

The team's sample material has a thermoelectric figure of merit – which is proportional to efficiency – of 0.45 at 873 K, the highest among elemental silicon thermoelectric materials.

This translates to power conversion efficiency of nearly 4% for heat source temperature of 873 K.

The upcycling method provides an alternative to current processes that separate solar cells' components to recycle them. These processes are

*The A*STAR-NTU research team invented a method to turn old solar cells into heat-harvesting, electricity-producing materials.*

costly and complicated, and mainly recover only the glass and metallic support structures.

It also gives new life to silicon, which makes up 90 per cent of solar cells but usually ends up in landfills, because it is too energy-intensive and expensive to chemically treat and re-melt it to remove its impurities and defects for re-use.

In fact, the A*STAR-NTU team found that the impurities and defects in silicon used for solar cells actually enhance the performance of thermoelectric materials made out of it.

"Our work shows that thermoelectrics is a fertile ground for upcycling defect- and impurity-sensitive semiconductors," highlighted Dr Ady Suwardi, Deputy Head of IMRE's Soft Materials research department, who led the scientists from A*STAR together with Dr Wu Jing.

While the NTU scientists, led by Associate Professor Nripan Mathews contributed their expertise in

> **" We can form many silicon-based compounds with the waste silicon from waste solar cells. Magnesium silicide, which is composed of magnesium and silicon, is expected to perform even better than just silicon with germanium and phosphorus.**
>
> Dr. Ady Suwardi, Deputy Head of IMRE's Soft Materials research department at A*STAR

extracting materials from solar panel waste, their IMRE and IHPC counterparts tapped on their command of material properties and computational modelling respectively to determine the optimal composition of materials for the thermoelectric material.

Dr. Suwardi explained that the team added phosphorus and germanium powder because the former adds high electrical conductivity while the latter confers low thermal conductivity.

In thermoelectric materials, the temperature difference between the hot and cold sides must be maintained as long as possible to maximise energy extraction.

He added, "We can form many silicon-based compounds with the waste silicon from waste solar cells. Magnesium silicide, which is composed of magnesium and silicon, is expected to perform even better than just silicon with germanium and phosphorus."

"The reason we started with silicon waste was to show that even by using it purely, rather than adding extensive amounts of magnesium, we can achieve high performance."

The scientists also aim to improve their process further. A priority is to determine how to use cold sintering, instead of the current sintering done at a few hundred degrees Celsius, to make the thermoelectric material. This would save energy and cut costs.

Dr Suwardi noted that the A*STAR-NTU partnership has been crucial in producing the results achieved thus far.

He said, "When the entire ecosystem, such as research institutions and funding agencies are involved, we can move towards greater sustainability."

SPECIAL // UPCYCLING

MAKING BETTER USE OF METAL WASTE

NUS's **Associate Professor Duong Hai-Minh** shares how his team is turning metal waste into lightweight, solid aerogels that can be used for many applications.

Images: NUS

The NUS team developed a sustainable technique that converts metal waste into lightweight aerogels which have wide range of uses in various industries.

Metals are already one of the most widely used materials on the planet, found in products from cookware to computers, appliances, jewellery and more.

The increasing use of metals, including for green technologies such as wind turbines, batteries and solar panels to combat climate change, however, has also led to a corresponding growth in metal waste.

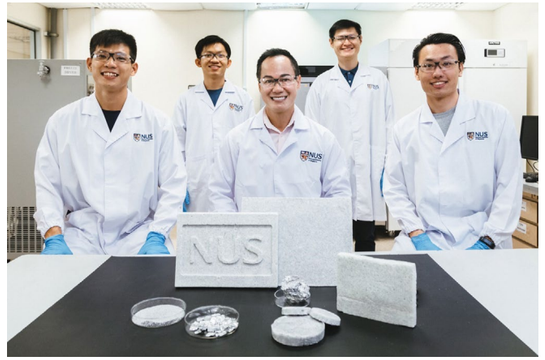
To improve the recycling of such waste, scientists from NUS have developed and demonstrated an eco-friendly method to convert aluminium and magnesium waste into high-value, multi-functional aerogels.

Aerogels are very light and solid materials used in many sectors. Currently, to recycle metal waste, the waste is sorted, compacted, shredded into tiny pieces, melted, purified and then cooled and solidified into metals to be used again. This process is energy-intensive and produces environmentally-harmful by-products, such as ammonia and methane during aluminium recycling.

Under the NUS team's new process, the shredded metal pieces are ground into powder. The powder is mixed with chemical crosslinkers that enable molecules to bond, and the mixture is heated in the oven, frozen and then freeze-dried to create the aerogel.

Associate Professor Duong Hai-Minh from the NUS Department of Mechanical Engineering, who led the team, said, "Our method is cheaper, doesn't produce hazardous waste, uses less energy and is more environmentally-friendly than conventional metal waste recycling."

While the scientists focused on aluminium and



NUS Prof Duong (pictured centre) and his team of researchers with the aerogels developed from metal waste.

magnesium due to the materials' high use and waste, among other reasons, their technique could be applied to any metal waste that can be ground into powder.

The scientists have identified applications for their aerogels too, including in construction. For example, their aluminium aerogel is 30 times lighter and 21 times better at insulating heat than conventional concrete.

Prof Duong added, "We can produce translucent aluminium aerogels by adding optical fibres during the mixing stage."

"These can be used as building materials to improve natural lighting and reduce energy use for artificial lighting, or to construct sidewalks and speed bumps that light up at night to boost safety for pedestrians and road traffic."

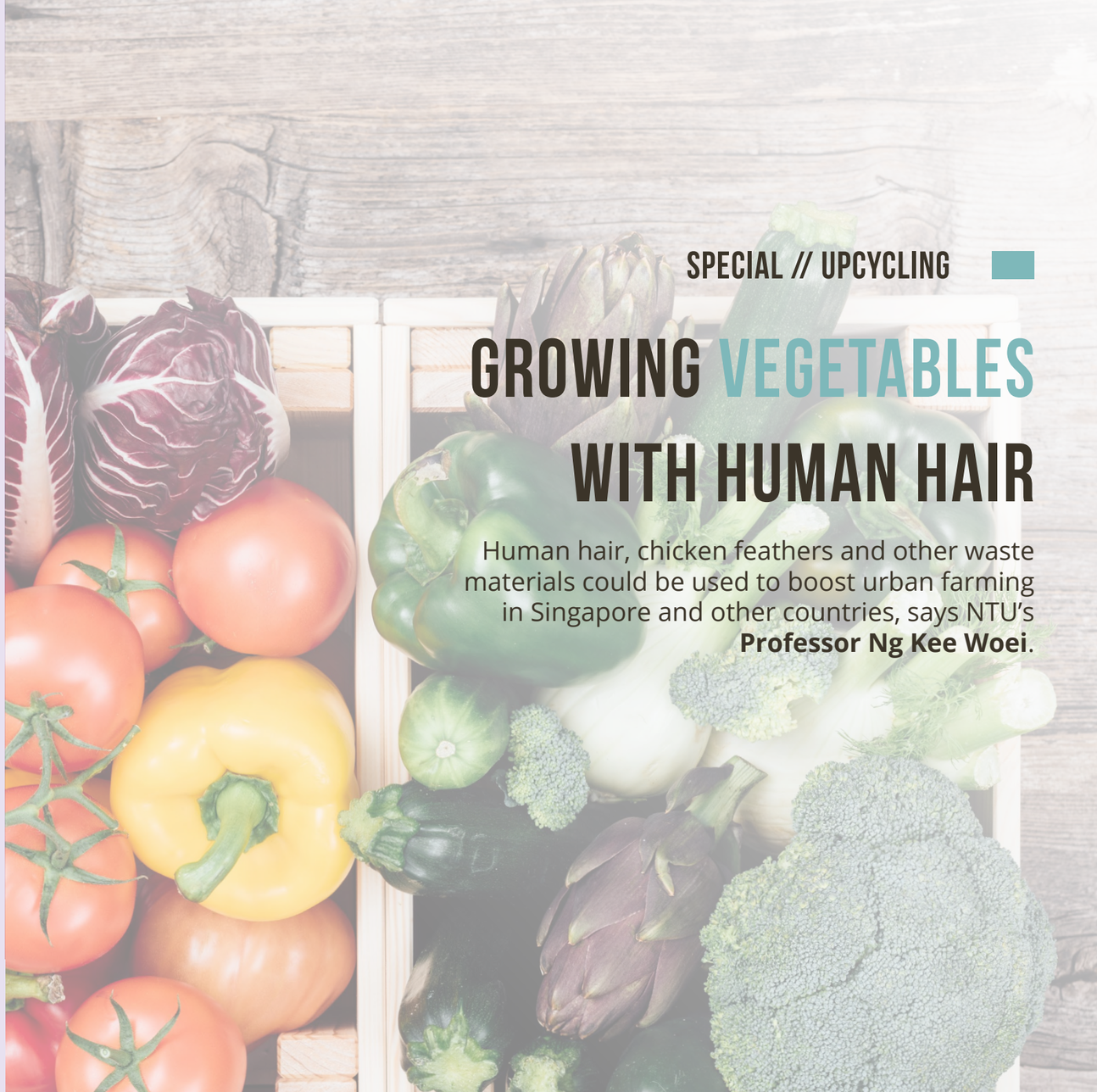
The scientists are also looking at potential biomedical applications.

Working with an industry partner, they have shown that their aluminium aerogel can be ground into micro-sized beads and used to cultivate cells for various purposes. Their work was the first to demonstrate that aerogels can be used to grow cells.

"This is an exciting development that could open doors to the wider use of aerogels for non-conventional applications, including drugs and cosmetics testing, vaccine development and tissue engineering," Prof Duong explained.

More recently, the scientists have developed metal-based hybrid aerogels that can withstand temperatures of over 1,200 degrees Celsius.

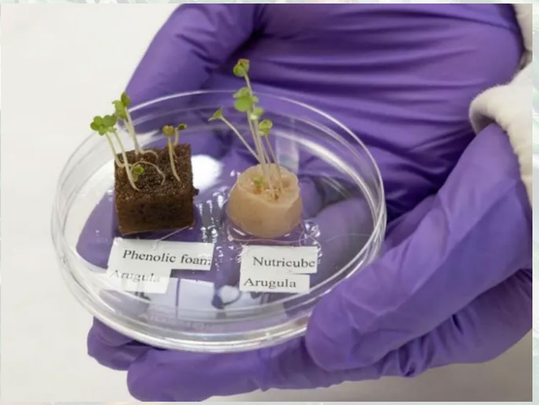
These can function as heat-resistant materials and as radiation shielding materials for defence applications.



SPECIAL // UPCYCLING

GROWING VEGETABLES WITH HUMAN HAIR

Human hair, chicken feathers and other waste materials could be used to boost urban farming in Singapore and other countries, says NTU's **Professor Ng Kee Woei**.



Keratin-based substrates being used to help plants grow. 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.

When you have a hair cut in the future, you could be helping Singapore farmers to grow leafy green vegetables. Scientists at NTU have developed a way to extract keratins from human hair to make sustainable hydroponics substrates.

Hydroponics is a method of growing plants without soil. In such systems, the plants' roots are submerged in channels with circulating water that contains nutrients, or grow down through mediums, also called substrates, that absorb the nutrient solution to nourish the plants.

The substrates on the market now are made of rockwool, polyurethane, phenolic foams and other synthetic materials that have several drawbacks.

Farmers have to dispose of them after each harvest as they do not degrade, and they can become infested with algae and bacteria.

Professor Ng Kee Woei, Associate Chair (Research) at NTU's School of Materials Science and Engineering, realised that he could use the keratins in human hair to make better alternatives.

He explained: "We had been working with keratin-based materials in my laboratory for some time. We knew that we could create keratin-based materials that would not only degrade in the farm environment, solving the disposal issue, but also release amino acids in the process, serving as a source of nitrogen for the plants themselves."

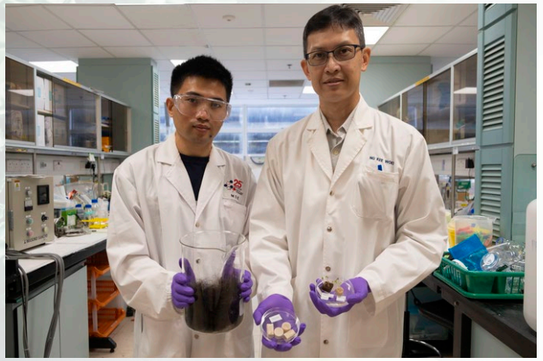
The NTU team collected human hair from hair salons, extracted keratins from it, mixed it with cellulose fibres to strengthen it, and dried the mixture into a spongy substrate. The cellulose was taken from softwood pulp, so the substrate is sustainable.

When the scientists used their innovative substrate in small-scale tests to grow crops such as microgreens and leafy vegetables, including the Chinese cabbage bok choy and arugula, also known as rocket, the plants' growth was either comparable or better than when they were grown in existing commercial substrates.

The NTU substrate has a highly interconnected pore structure that enables it to draw up the nutrient solution from hydroponics systems' channels efficiently. This means that it can easily feed water and nutrients to the plants' roots continuously. It can hold water up to 40 times its weight, on par with available substrates.

It has other advantages. Unlike existing substrates which are one-size-fits-all, it can be tailored to optimise different plants' growth in their specific farm environments.

Images: NTU Singapore



(from left to right) Dr Zhao Zhitong, Research Fellow, NTU School of Materials Science and Engineering, and Professor Ng Kee Woei, Associate Chair (Research), NTU School of Materials Science and Engineering.

Prof Ng elaborated: "We can add nutrients to help the plants grow better. We can customise the ratio of keratin to cellulose, and the cross-linking of these materials, so that the sponge degrades and releases nutrients at a rate that fits the specific plant's growth cycle.

"We can even take into account a farm's micro-environment when making the sponge for the farmer."

The NTU team is currently in talks with industry partners, including local urban farms, to test their substrate in large-scale field tests.

Prof Ng envisions it being used to grow leafy green vegetables and higher value crops, such as cherry tomatoes, both in Singapore and overseas.

He added, "We are looking at other keratin sources, such as poultry feathers. Singapore has slaughterhouses where the feathers are sent to incinerators at significant cost.

"That is one waste stream that I hope to upcycle in the near future."

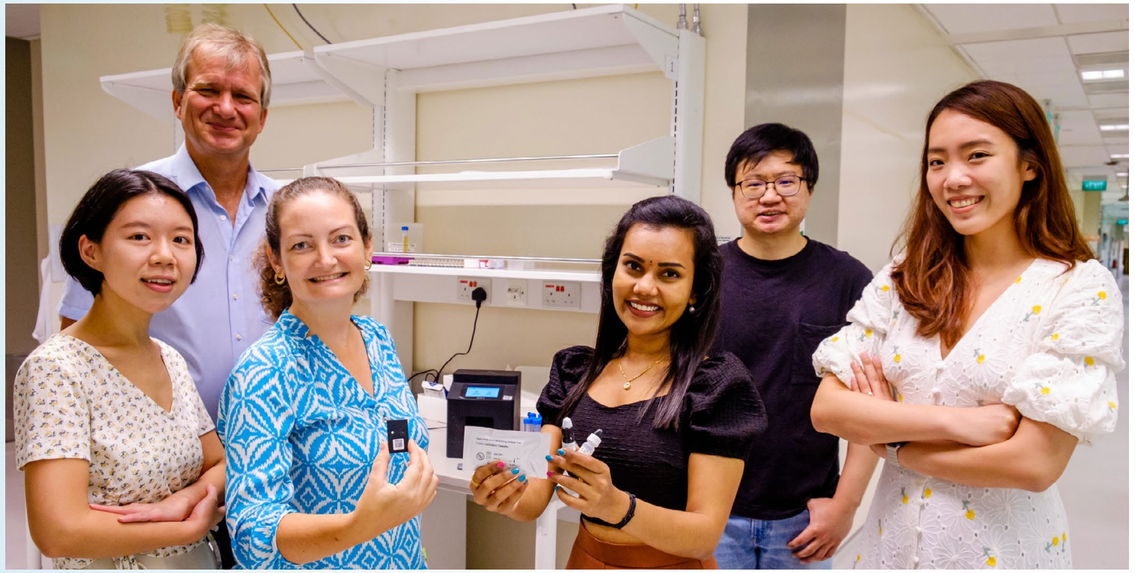
While some people have shared hygiene and safety concerns about eating vegetables grown in substrates made from waste hair and feathers, he said, "These vegetables will certainly have to pass safety and quality standards first.

"If they do, we should be more open-minded. We should judge based on the science, not perceived issues, so that we can really make a concerted effort to go green."

FEATURE // COVID-19 DIAGNOSTICS

TESTING FOR COVID-19 IMMUNITY

With a new quick test kit by NTU and SMART scientists, people can easily find out if they need to get a booster shot against COVID-19, says NTU's **Professor Peter Preiser**.



(from left) Patrina Chua (SMART), Professor Peter Preiser (NTU), Dr Megan McBee (SMART), Abirami R. (SMART), Say Yong Ng (SMART), and Sharon Ling (SMART). Dr McBee and Abirami is holding the test kit cartridge and the reagents required for the rapid detection of COVID-19 neutralising antibodies.

Images: NTU Singapore, SMART

As Singapore and other countries transition to living with the COVID-19 coronavirus, scientists from NTU and the Singapore-Massachusetts Institute of Technology Alliance for Research and Technology (SMART) have created a quick test kit that can tell whether a person has immunity against the virus and its variants.

With the kit, which requires just blood from a finger prick and takes only 10 minutes to produce results, people can find out if they should go for vaccination or booster shots.

This can help firms and governments to personalise their vaccination approach, for example by offering shots to those who lack immunity and are at higher risk, such as healthcare workers and the elderly.

With such personalisation, governments can more effectively use limited vaccine resources, and better address vaccine hesitancy, where people are wary of taking the vaccine or booster shots due to fears of side effects.

The NTU-SMART team conducted a clinical study that found that the protection provided by vaccines on the market declines steadily over three months, with varying degrees of decline across individuals.

Professor Peter Preiser, NTU's Associate Vice President for Biomedical and Life Sciences, and Co-Lead Principal Investigator of SMART's Antimicrobial

COVID-19 antibodies test kits (right) and the digital reader device (left in black), which can detect levels of COVID-19 antibodies from a drop of blood in just ten minutes.

Resistance Interdisciplinary Research Group, who was one of the team's leaders, said: "Our study proves that our new test kit can be a powerful tool, allowing healthcare organisations to screen people and determine their vaccination needs, especially against current and upcoming variants.

"It will help allay some people's fears that they will be 'over-vaccinated with a booster', since the results will inform them accurately if they are well-protected against COVID-19 or not."

While the SMART scientists developed some of the kit's technologies, their NTU counterparts brought their expertise in reagents to the table.

The kit's reagents detect, in the blood, the levels of neutralising antibodies against SARS-COV-2, the virus which causes COVID-19, and its variants.

The team also relied on NTU's Protein Production Platform (PPP) to generate enough of the reagents quickly and at high purity. "This was not a trivial undertaking. Without the PPP, the kit would have been very difficult to achieve," said Prof Preiser.

To ensure that the kit is easy to use, the scientists reduced the number of steps needed to obtain results. Anyone can use the kit as it does not require medical training or specialised laboratory equipment. They also worked with firms to make the kit easier to manufacture. This included designing the kit's cassette so that they could make moulds for production, and optimising the type and number of layers of paper used in the kit.

The team is currently partnering with a local polyclinic on a follow-up study that uses the kit. "We aim to establish the levels of neutralising antibodies in the polyclinic staff, and are tracking who gets infected with COVID-19 over time," said Prof Preiser.

"We want to see if there are more infections in the group with lower levels of antibodies, or whether the infection rate is completely random. It relates to the question of how predictive the level of antibodies is in defining the risk of future infection."

He added that the kit can be easily adapted for new COVID-19 variants of concern and other diseases. "In the long term, it can be used in different situations to help people make decisions about vaccinations."

Image: NTU Singapore

SCANNING ELECTRONS

Scientists from NTU Singapore observe how electrons behave under a 'scanning tunnelling microscope'. This is done by bringing the edge of a special class of very thin electrically insulating material incredibly close to the extremely sharp metal tip of the microscope.

Pictured here is a close-up view of the microscope's tip and a test sample inside the ultra-high vacuum chamber. The distance between the two is just one nanometre or less, even smaller than a strand of DNA.

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