NUS National University of Singapore | Faculty of Science

Advances in Science

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A special issue on Agri-food sciences: From the farm to the plate

FEATURES

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Advances in Science

The Faculty of Science conducts basic and applied experimental, theoretical and simulation research over a broad spectrum of science, mathematics and technology domains. We cover most of the key fields in biological sciences, chemistry, physics, pharmacy, mathematics and statistics.

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On the cover: Agri food innovation will increasingly become important in building an efficient, resilient and sustainable supply chain to provide fresh and nutritious food for consumers.

OPINION

The future of food and agriculture

The quest to feed another two billion people by 2050 in a sustainable way

Introduction

The last century has seen remarkable progress in science and technological innovation in the agri-food industry. As the global human population is expected to grow to 9.6 billion by 2050, we will need to produce 69% more food for additional two billion mouths. Though hunger and extreme poverty have been reduced since the 1990s, there still remains close to one billion people who are chronically hungry, and more than two billion people who are deficient in micronutrients.

Uncertainties such as climate change and political instability are expected to adversely impact food production. In the coming decades, we will have to transform our way of producing food while maintaining the overall sustainability of food and agricultural systems. In this article, we share our perspectives on agri-food science research and share trends pertinent to the industry.

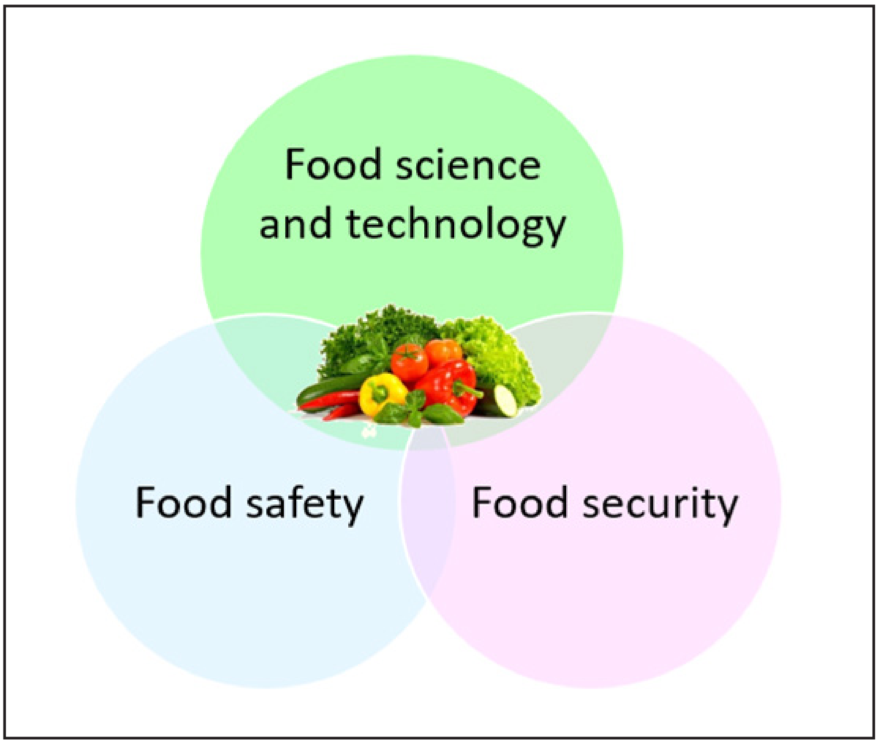

Figure 1: The future of food and agriculture relies on a combination of food science and technology, food safety and food security.

The future of food and agriculture relies on a combination of food science and technology, food safety and food security.

Food science and technology

Since the beginning of farming practices, humans have been selecting more desirable traits, such as higher yields, faster growth and better disease resistance. Scientific and technological advancements have been the main driver in increasing the agricultural productivity. The discovery of Mendelian genetics (1866), the Green Revolution (1940-1970) and the advent of biotechnology (1981) have changed the way humans grow and produce food. Currently, the agriculture industry is undergoing the next revolution, where more food can be produced using less manpower and resources.

There is a growing need to generate more and better quality food through a combination of physical, chemical and biological methods. Increasingly, the traditionally labour-intensive outdoor nature of agriculture is shifting to a more automated and mechanised indoor approach to reduce the impacts of climate change. With rising consumer expectations driving greater demand for natural and organic food, food producers will have to adapt accordingly in how they apply fertilisers and control the pest population.

With new biotechnological tools such as CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-associated protein 9), crop breeders can modify specific genes known to affect certain traits, so as to generate elite strains or varieties which are evident in some crop species including rice, wheat, corn, tomatoes, soybean, citrus fruits, leafy vegetables, etc. Plants generated from CRISPR-Cas9 technology are indistinguishable on both phenotypic and genomic level from those plants that acquired genetic mutations naturally through traditional selective breeding. In addition, CRISPR-Cas9 technology can develop plants with the desired traits many years faster than traditional selective breeding. Today, many research and development laboratories are leveraging this new technology to solve a range of food-related concerns for both farmers and consumers: a mushroom that does not turn brown when bruised, gluten-free wheat for people with gluten intolerance and drought tolerant waxy corn. We can therefore expect an increasing array of products with higher yields, better climate/environmental stress resistance and greater nutritional value in the market.

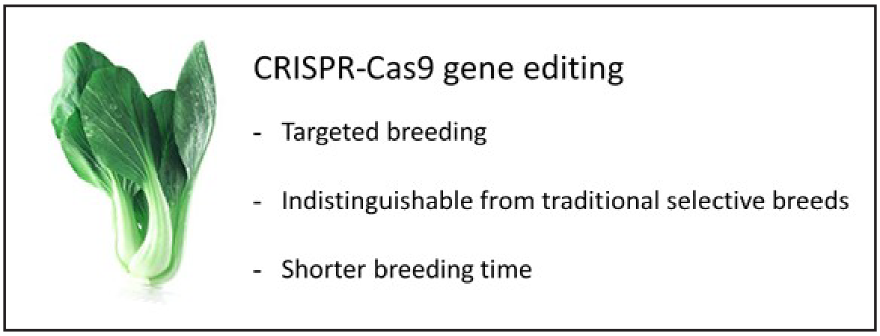

Figure 2: CRISPR-Cas9 gene editing technology is used in crop breeding to generate new crop varieties with desirable traits.

Food safety

Food safety refers to the handling, storing and preparing of food to ensure that it is safe for consumption. Since food hazards can occur at any stage in the food production and supply chain, it is important to have appropriate controls at each stage of production, beginning from the farm and ending at the dining table. Numerous food scandals, such as the horsemeat scandal in 2013 and the strawberry needle in 2018, underscore the importance of supply chain traceability. The implementation of food traceability can help to speed up the identification, isolation and recalling of contaminated products, hence reducing risks to consumers.

In the United States (US), all foods are regulated by either the Food and Drug Administration (FDA) or the United States Department of Agriculture (USDA). The FDA ensures that the foods consumed in the US are safe and properly labelled, while the USDA supports the agri-industry in providing safe and sufficient food supply. In Singapore, all food-related functions come under a new statutory board called the Singapore Food Agency (SFA) which was set up on 1 April 2019. Like the FDA and USDA, SFA will enhance food safety regulatory procedures and help the local agri-industry to adopt new solutions to raise productivity, apply research and development, strengthen climate resilience and overcome resource constraints.

Food security

The United Nations defines food security as "People having at all times, physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." This can be measured on different scales, from global to national to households and individuals. Singapore is at the top of the global index ranking for food security in 2018 and actively plans to ensure Singaporeans continue to have access to safe and quality food at affordable prices in both the short and longer term. However, as Singapore imports most of its food, climate change and other external factors that could influence food production and supply will adversely impact food security. Singapore has set a "30 by 30" goal to produce 30 per cent of Singapore's nutritional needs locally by 2030. With improved food production capabilities, strong talent base and reputation for food safety, Singapore can play a key role in boosting world food security.

Through a combination of food science and technology, food safety and food security, the global shift to a more sustainable food system can ensure a better future for all of us.

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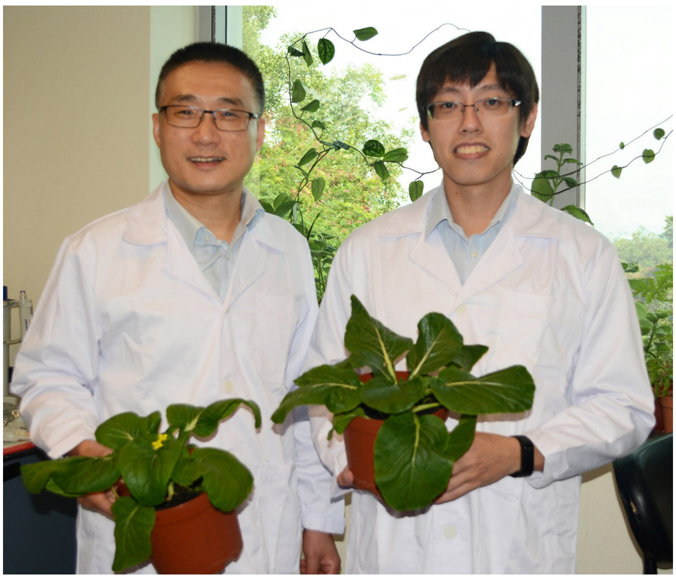
Norman Zhi Wei TEO (right) is a Research Fellow with the Department of Biological Sciences, NUS. He received his B.Sc. (Hons) and Ph.D. from NUS in 2010 and 2015, respectively. He has obtained his M.Sc. (Management of Technology) in 2018 from NUS. His research interests are in functional genomics, crop breeding and crop technology commercialisation.



Urban farming

Towards a leading role for Singapore in developing sustainable urban solutions

Introduction

The increasing global migration of people is creating challenges for existing ways of food production. Firstly, the rate of urbanisation is growing, giving rise to megacities. It is estimated that more than two-thirds of the world's population will gradually adopt urban lifestyles by 2050. Secondly, there is an associated phenomenon of "rural flight", where traditional centres of food production are going through rural de-population, in turn causing profound socio-economic changes. The abandonment of agricultural activities and the declining rural workforce will severely affect future food production capacity. Thirdly, the decrease in arable lands and the occurrence of weather extremes due to climate change pose imminent pressures on global agriculture.

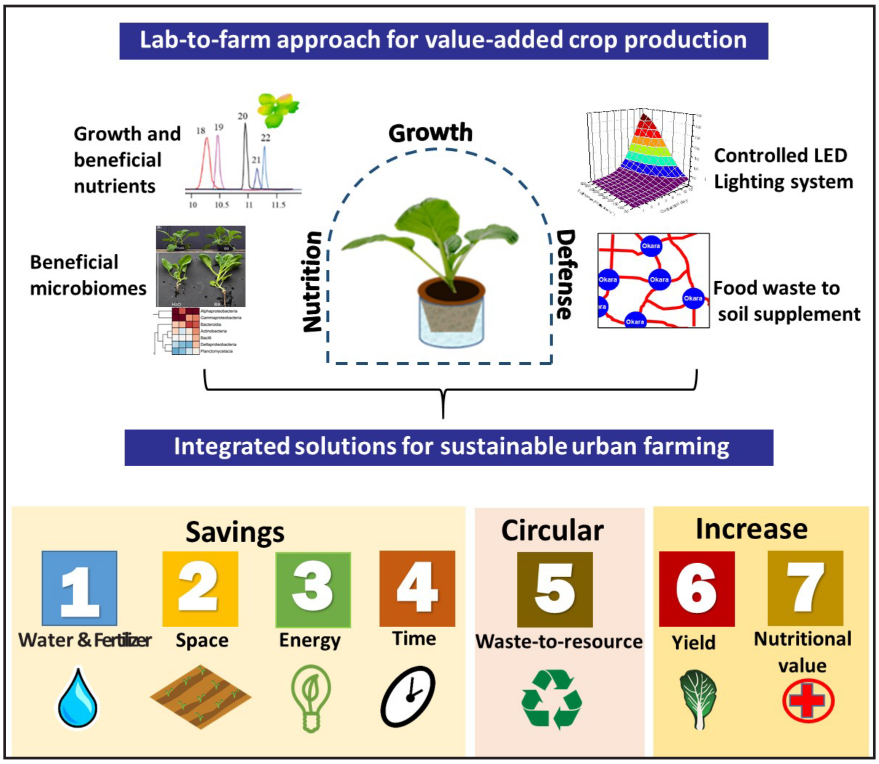


Figure 1: Integrated lab-to-farm approach for value-added crop production.

These trends are affecting the secure supply, availability and accessibility to safe, nutritious and healthy food. Conventional agricultural practices rely heavily on ample fertile land, and favourable environmental factors such as good weather, plentiful/clean water and abundant energy. The pressures resulting from these new trends pose a challenge to the sustainability of traditional agriculture. As the world continues to urbanise, sustainable and reliable measures will be required to address these challenges.

Feeding megacities: The rise of urban farming

Two options are available for supplying food to megacities: peri-urban agriculture; and city farming or urban farming. Peri-urban agriculture takes place at the fringes of urban areas or in the regions that lie in between cities and rural regions. In this article, we will focus on urban farming in greenhouses and indoor spaces. Urban farming is being advocated as a one-stop solution providing a sustainable means to grow food by innovatively using vacant urban spaces. Turning vacant spaces into urban vegetable gardens enhances food security by providing people with better access to fresh vegetables for a healthier food supply. This helps to promote the well-being of city dwellers and reduce pressure on rural agricultural land. Vacant or indoor spaces which can be used for urban agriculture include rooftops, yards and smaller areas like roadsides or private balconies, among others. Developing food production systems in the built environment reduces costs and dependency on long-range transport, in turn leading to energy savings and increasing the freshness and nutritional value of food produce. Urban farming also has socio-economic and ecological benefits, as described below.

Urban farming in Singapore

For a land- and resource-scarce nation like Singapore, urban farming is a necessity rather than a choice. We import most of our food, leaving the nation vulnerable to disruptions in the global food supply chain. To enhance food resilience and security for our growing population, Singapore is making concerted efforts to scale up commercial urban agriculture. In 2019, Minister for the Environment and Water Resources, Mr Masagos ZULKIFLI announced the "30 by 30" goal to produce 30% of Singapore's nutritional needs locally by 2030. This initiative requires harnessing innovative technologies to raise farm productivity, so as to move Singapore towards greater food self-sufficiency.

Currently, urban farming solutions in Singapore are based on commercial farming (indoor and greenhouses), landscape gardening and community gardens. Some of these approaches, such as community gardens, and greenhouses/nurseries located within residential blocks, are excellent avenues to bring together multi-generational families. Urban farming can also generate business and employment opportunities for Singaporeans. Specifically, it can encourage the development of research and development (R&D) and innovative solutions, using Singapore as a testbed for urban farming technologies that will be "exportable" to other regions.

Innovation: Research-centric and integrated

One such effort to develop innovative solutions in the urban farming space was started at the National University of Singapore (NUS) in 2016, with support from the National Research Foundation (NRF) and in partnership with the then Agri-Food and Veterinary Authority of Singapore (AVA), now known as the Singapore Food Agency (SFA), and a local farm. This project* aims to develop and integrate eco-friendly and cost-effective solutions specifically for value-added urban vegetable production by utilising the synergy between plant traits, their associated beneficial microbiomes and physico-chemical traits. Special emphasis is placed on innovations that convert local waste streams to novel agri-inputs, reducing input costs and avoiding transgenic technologies. To address these objectives, the project has four specific themes (Figure 1):

(i) evaluating plant traits and their nutritional/health benefits;

(ii) identifying beneficial microbes for plant growth, nutrition and plant defense;

(iii) developing cost-effective agrotechnologies; and

(iv) integrating the above three complementary parts at the laboratory to identify synergistic combinations.

Through this project, our research team developed Nutrigels, a novel soil supplement based on soya waste (okara) that is a platform for slow release of agri-inputs such as water or fertiliser, to provide savings. Nutrigel enhances plant growth, particularly when water availability is low. The nutrient profiles of vegetables show that specific nutrient subgroups accumulate at different growth stages and under different light wavelengths. By optimising the wavelength controlled LED lighting systems, we are improving plant growth, and the freshness of leafy vegetables. Together with biomass response models, this allows for the prediction of optimal harvesting times for growers to enhance their crop value proposition. When translated to farming, these outcomes can help advance the urban farming sector.

Future perspectives: The way forward

Future research and technological directives could be aimed at promoting a more balanced growth in different parts of the urban farming ecosystem. We can envisage a circular economy in urban farming that incorporates resilience/sustainability, which involves many stakeholders. These could include agri-input providers (seeds, plant nutrients, growth media and related inputs), automation developers and providers, solution integrators, supply chain logistics vendors, government and non-governmental organisations.

High-yield agriculture will be key to feeding the world's growing urban population and ensuring food security worldwide. Technological advancements fueled by outcome-based R&D initiatives are required to revolutionise next-generation agriculture. These should use fewer and more sustainable resources that can produce food more efficiently. In this view, innovations empowering urban farming that adopts a holistic, integrated and collaborative approach will be the key for feeding future megacities.

* For more details about the project, visit http://www.nus.edu.sg/neri/Research/food-energy-and-water-nexus.html

Sanjay SWARUP (right) is an Associate Professor with the Department of Biological Sciences, NUS. He is also the Deputy Director of NUS Environmental Research Institute and Deputy Research Director at the Singapore Centre for Environmental Life Sciences Engineering. He has a M.Sc. and Ph.D. in genetics from the Indian Agricultural Research Institute and a Ph.D. in plant pathology from the University of Florida. His research interest includes studying the ecology of highly complex microbial communities in the environment and in agriculture, from genes to ecosystems.

Shruti PAVAGADHI (left) is a Research Fellow with the Department of Biological Sciences, NUS. She obtained her Ph.D. in environmental chemistry and toxicology from NUS. Her research interest is in the development of innovative microbial solutions for increasing crop production. She is currently working on urban phtyobiomes associated with green leafy vegetables and evaluating plant-microbe interactions using molecular and metabolite approaches.

Food for the future

Engineering safe, healthy and nutritious food

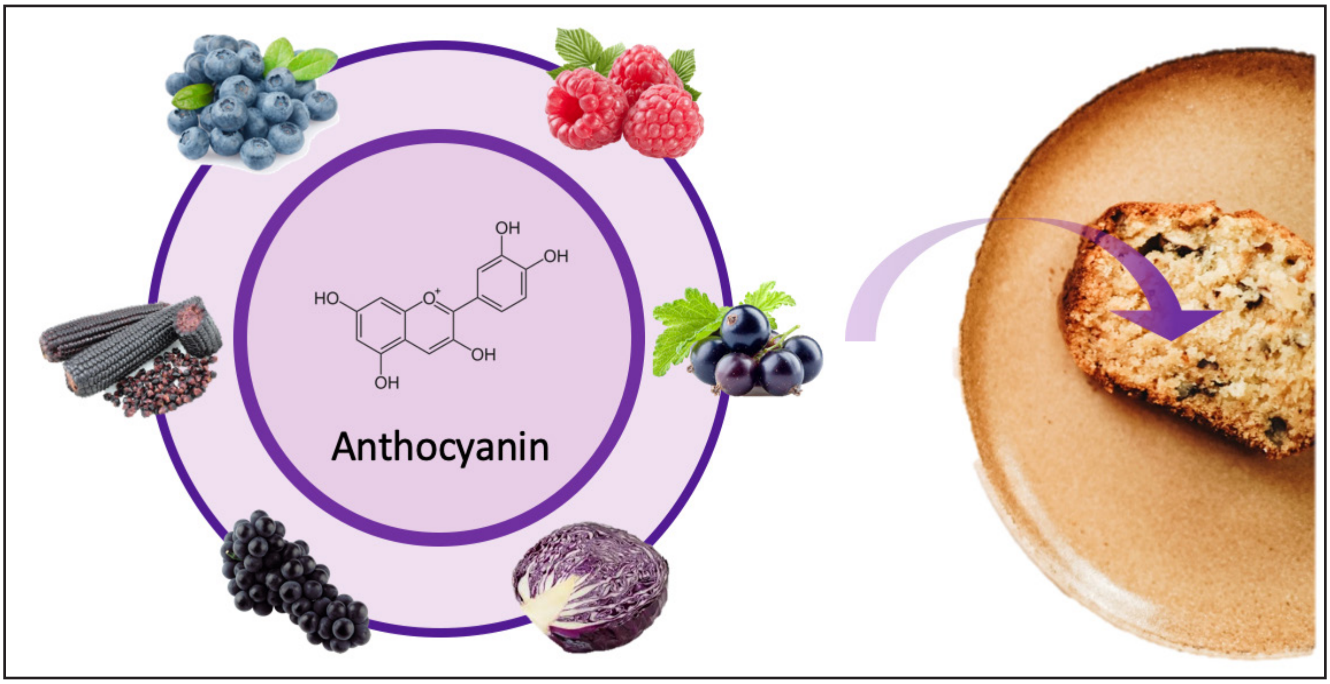


Figure 1: Anthocyanin-enriched functional bakery products can reduce the impact of sugar and improve blood glucose control. Food plants rich in anthocyanins include the blueberry, raspberry, blackberry, purple cabbage, grapes and purple corn.

Introduction

Food science and technology play an increasingly important role in enhancing the supply of food and the well-being of a growing population. In my laboratory, we design new ways to make our food safer, healthier and more nutritious. Recently, we have been involved in several interesting projects which focus on two challenging food-related problems facing the world today.

Functional food

Diabetes is a global public health issue that is reaching epidemic proportions. In Singapore, 400,000 people were diagnosed with diabetes in 2013. It has been predicted that by the year 2045, one in four people will be diagnosed with prediabetes and one in five with diabetes. There is hence a strong push to adopt more proactive measures to contain diabetes progression. In our laboratory, we have developed ways to make our staple foods healthier, so as to provide protection against diabetes.

As food scientists, we believe that making food healthier should not necessitate removing certain ingredients. Instead, we explore ways that allow consumed food to impart additional health benefits with minimal changes made. This helps to retain the flavour and sensory experience associated with its consumption.

One way to do this is through the development of functional foods. Functional foods are foods that provide health benefits beyond basic nutrition. For example, they may contain bioactive ingredients that can provide physiological health benefits for preventing and managing chronic diseases.

When food is digested too rapidly, the blood sugar level in diabetic patients may spike. My laboratory developed new functional food products, ranging from bread to cakes, which manage the blood glucose levels to prevent sudden spikes. These foods are suitable for health-conscious consumers and those with diabetes or prediabetes conditions. The functional bakery products that we have designed can be consumed as part of a daily diet (unlike medicines and health supplements). They can also deliver enhanced stability or bioavailability as part of the food matrix.

My team has found that a group of natural phytonutrient which give blueberry its purple colour, anthocyanins, are effective in slowing down the digestion of carbohydrates. Phytonutrients are natural pigments found in plants which can provide health benefits and help to prevent various diseases. By incorporating anthocyanins in bakery products using a suitable formulation, most of them can be transformed into diabetic-friendly products while retaining their optimal texture and good taste. The slow digestion profile of these products is beneficial for improving blood glucose control. This is not only important for diabetic patients but also for those who wish to prevent the development of diabetes due to a blood glucose surge. Moreover, anthocyanins in themselves are an effective natural antioxidant which can help to boost overall health. Through our novel products whose development is now led by Dr GAO Jing, a research fellow from my group, we offer consumers a greater choice of healthier foods, without compromising their eating experience.

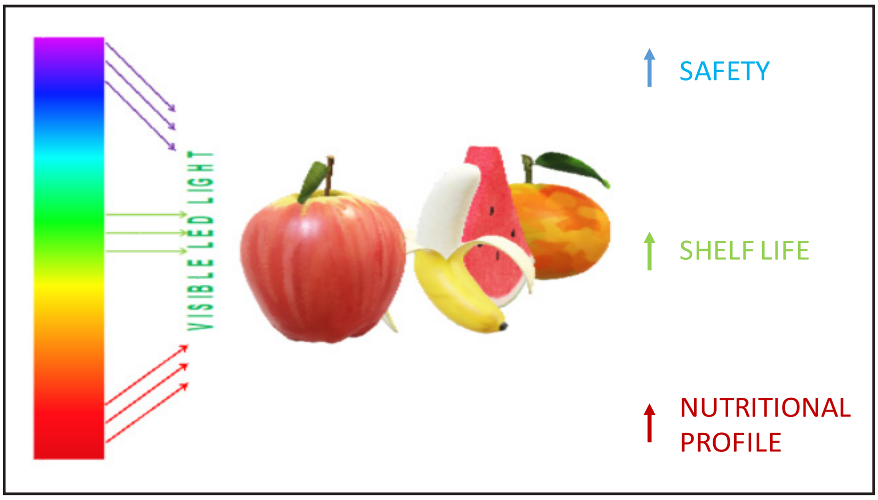


Figure 2: Specific LED wavelengths can enhance the safety, shelf life and nutritional profile of fruits.

Food safety

Apart from having the necessary nutrients for good health, food safety is an important aspect to reduce the risk of becoming sick from foodborne pathogens. We have been developing the use of light emitting diodes (LEDs) for potential application in the food industry.

In our laboratory, we have shown that LEDs are effective in killing certain bacteria strains that can cause foodborne illnesses. Building on this, we developed several applications that demonstrate the inactivation of dangerous foodborne pathogens such as *Listeria*, *Salmonella* and *E. coli*. These pathogens can cause food poisoning and in severe cases could also lead to death.

One of the applications involves keeping freshly cut fruits free of foodborne pathogens so that they remain safe for consumption. Freshly cut fruits are a popular food item locally, and can be found in food outlets across the island. Unfortunately, they are also susceptible to contamination by bacteria and other pathogens due to their high nutritional content. We demonstrated that LED lights can be used to kill harmful pathogens such as *Salmonella* on freshly cut pineapples and papayas. In a separate study, we have also shown that cells of *Listeria*, *Salmonella* and *E. coli* could be inactivated on freshly cut mangoes. These research outcomes show the potential of having LEDs on the shelves and display cabinets of food outlets to help keep freshly cut fruits safe for consumption. In other studies, my colleagues and I have also shown that LEDs can enhance the safety of other food items, including fruit juice, fresh seafood, ready-to-eat seafood and food contact surfaces.

In addition to food safety, our research has found LEDs to be able to enhance the nutrient profile of certain foods, such as bananas and green leafy vegetables. When we tested the effects of LED light with different wavelengths on bananas, we discovered that certain wavelengths increased the accumulation of nutrients such as ascorbic acid and polyphenols. The LED light also enhanced the ripening process of bananas. The increase in the ripening of bananas was greatest for blue, followed by red and green LED light.

These findings show that LED technology has potential for application in the cold chain, where it can complement refrigeration and food packaging to deliver safer and more nutritious food products. Further research and development are being conducted and led by Dr Vinayak GHATE, another research fellow from my group. Through our knowledge on the nature of food and the development of technological advances, our team aims to make food safer, healthier and more nutritious.

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Please visit http://www.fst.nus.edu.sg/OurPeople/ZhouW.html for more information about his research work.

RESEARCH FEATURE

Towards evidence-based functional foods

Uncovering the chemistry of health promoting constituents in edible plants by high throughput screening assays

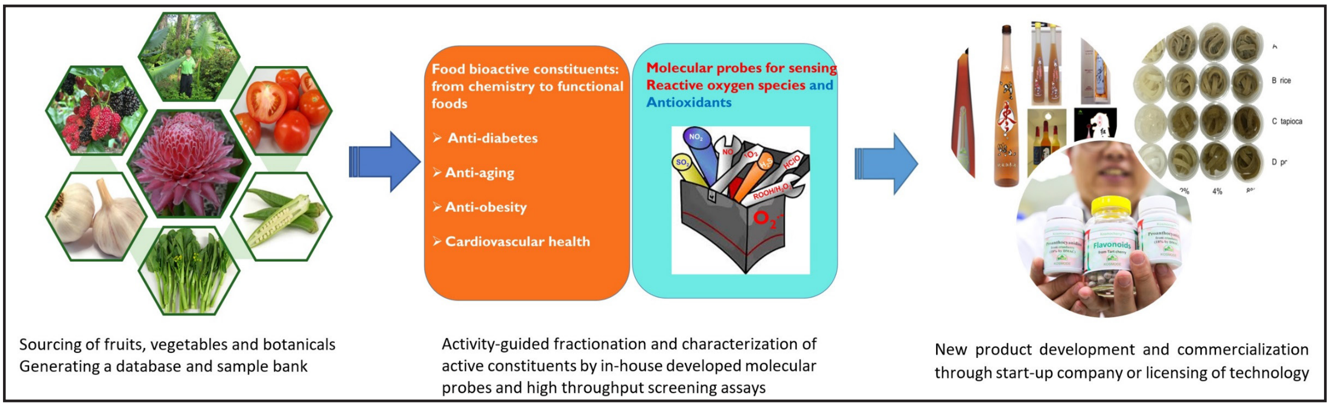

Figure 1: The roadmap towards evidence-based functional foods for health promotion from raw materials (left) to commercialisation (right) via fundamental research on the elucidation of bioactive principles and mechanisms (middle).

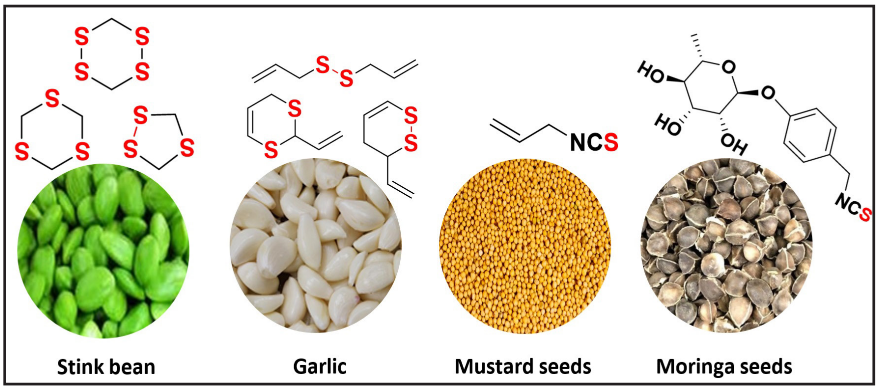

Figure 2: Dietary organosulfides are naturally occurring hydrogen sulfide donors: they are often smelly but good for health.

Introduction

Good health is an important factor contributing to well-being and a high quality of life. As such, the prevention of diseases is of pivotal importance. In the battle against diseases, we can learn from ancient wisdom, such as those stated in the *Yellow Emperor's Classic of Internal Medicine*:

*"To administer medicines to diseases which have already developed and to suppress revolts which have developed is comparable to those persons who begin to dig wells after they have become thirsty, and of those who begin to cast weapons after they have already engaged in battle. Would these actions not be too late?"**

A healthy lifestyle, regular exercise and healthy eating habits reduce the risk of contracting diseases. Fruits and vegetables are an important part of a healthy diet. We consume a wide variety of fruits and vegetables which contain diverse micronutrients and bioactive secondary metabolites which are believed to have health promoting effects. Yet, the scientific evidence of such causal relationships remains largely unknown and hampers the design and development of functional foods for specific health promotion purposes.

My laboratory seeks to uncover the chemistry related principles of fruits and vegetables for good health (Figure 1). By developing novel and effective high throughput screening assays, aided by molecular probes developed in-house, we are able to rapidly identify the potential health promoting effects of thousands of edible botanicals. The application of assay-guided separation allows us to characterise the chemical compounds and elucidate their action mechanisms. These results serve as the scientific basis for the development of functional foods that contain health promoting constituents. Specifically, I wish to highlight two aspects of our research achievements.

Dietary organosulfides as slow donors of hydrogen sulfide

Hydrogen sulfide (H_2S) is notorious for its rotten egg smell. Yet, recent studies suggest that it has a broad range of health promotion activities at low (sub micro-molar) levels in human blood. H_2S is one of three gaseous transmitters (nitric oxide and carbon monoxide being the other two) that are toxic at a high level but play critical roles at low concentration in reducing the risk of cardiovascular health, inflammation and ageing (for H_2S). Slow H_2S donors, particularly synthetic organosulfides, are highly sought after as therapeutic agents to help supplement H_2S and maintain its concentration in blood. There are plenty of naturally occurring organosulfides in fruits and vegetables.

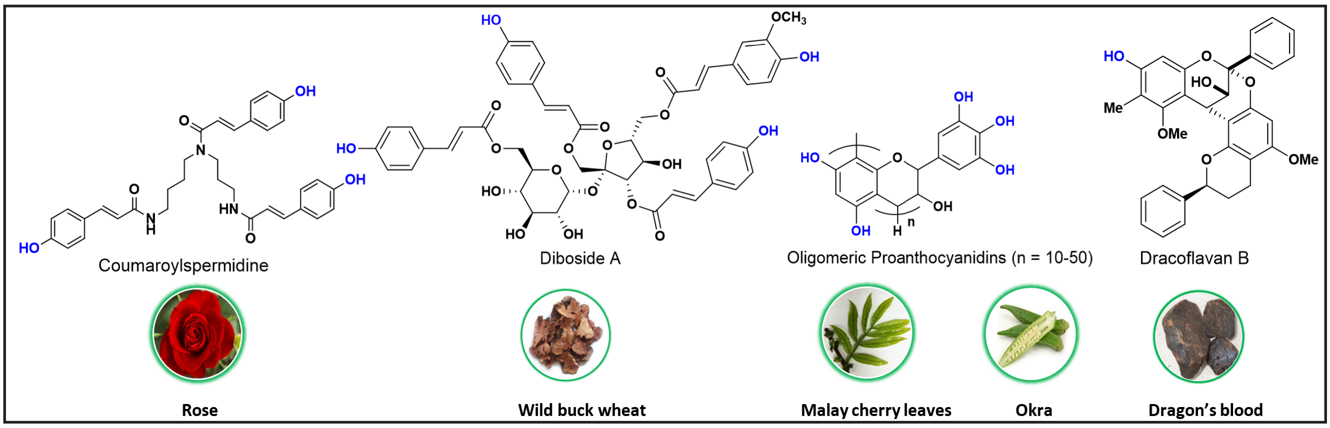

Figure 3: Polyphenolic compounds with potential use for combating diabetes through suppressing starch digestion.

Examples include durian, alliums (e.g. garlic and onion), cruciferous vegetables (e.g. kailan, caixin, and mustard) and Southeast Asia-specific *Parkia speciosa* (stink beans or petai). The flavours of these compounds are due to their unique organosulfides (Figure 2).

These vegetables have been suggested to be beneficial for heart health and for cancer prevention. However, the molecular mechanisms behind them are not clear. Taking advantage of our selective probe for H_2S detection, we could investigate how key organosulfides compounds in garlic and stink beans release H_2S upon reaction with gluthathione. We found that cyclic polysulfides found in stink beans and diallyl disulfides (DADS) in garlic are slow H_2S donors (i.e. lasting for a few hours). In contrast, diallyl trisulfide (DATS) found in processed garlic, particularly garlic oil, is a rapid H_2S donor (i.e. within minutes), which may not be ideal as too much H_2S is toxic. Our findings provide a guide for developing functional foods with dietary organosulfides that serve as slow H_2S donors. There are many fascinating aspects that remain to be studied. For example, will the organosulfides in durian, kailan and caixin also exhibit health promotion properties through H_2S generation?

Bioactive constituents from fruits and vegetables

Staple foods such as rice and noodles contain a high amount of starch. However, for diabetic patients, consuming these foods results in hyperglycaemia partially because they digest too fast due to their high glycaemic index. Vegetables which contain phytochemicals could reduce the digestibility of starch and the absorption of glucose, helping to reduce the rapid rise of blood glucose. If one were to eat vegetables first and starchy foods later, it may help mitigate the rapid increase of blood glucose levels. Yet, there are so many types of vegetables and we do not know which ones contain active compounds that can inhibit starch digestion enzymes (i.e. alpha-amylase and amyloglucosidase).

By developing a high throughput screening assay based on monitoring changes in starch turbidity during enzymatic digestion, we are able to screen the inhibition ability of starch digestion enzymes for many samples including common fruits, vegetables and edible plants obtained locally. This enabled the development of a database containing over one thousand samples, which we can leverage on to develop starchy foods with low glycaemic index. We have also elucidated the chemical structures that possess such inhibitory activity (Figure 3.) In particular, lady's finger (okra) is particularly interesting as a starch enzymes' inhibitor as it is a commonly consumed vegetable. Also, the Malay cherry leaves and Dragon's blood could have commercial potential because of their high starch inhibition activity, but little is known about their roles in controlling hyperglycaemia.

Our findings open up new avenues for tapping on edible plants, particularly fruits and vegetables, as effective weapons against diabetes. More studies are required before ascertaining if they directly contribute to health promotion.

*Ilza Veith, "The Yellow Emperor's Classic of Internal Medicine", University of California Press, page105, ISBN: 9780520288263.

HUANG Dejian is an Associate Professor with the Food Science and Technology Programme at the Department of Chemistry, NUS. He received his Ph.D. from Indiana University Bloomington in 1999 and did his postdoctoral research at the Massachusetts Institute of Technology. In 2004, he moved to NUS and established research activity on the chemistry of naturally occurring polyphenolic compounds, traditional Chinese medicine and functional foods.

Please visit https://sites.google.com/site/huangdjgroup/home for more information about his research work.

Medicinal plants research

Discovering the benefits of medicinal plants for improving health

Introduction

Nature provides many useful and life-saving drugs. Notable examples include the antibiotic penicillin from *Penicillium notatum*, the anti-cancer drug taxol from the Pacific Yew tree and the antimalarial drug artemisinin from the Chinese herb Qinghao. Greek physician, Hippocrates, also known as the Father of Medicine, once said, "let food be thy medicine, otherwise medicine will be thy food." In modern society, with allopathic medicine ("Western medicine") being the primary form of health care, is there a place in healthcare for fresh medicinal plants?

Our Medicinal Plant Research Group at the Department of Pharmacy, National University of Singapore (NUS) is exploring the potential roles of such natural resources, to harness their possible benefits safely and efficaciously.

Figure 1: Photograph of the flower and leaves of the leafy cactus Seven Star Needle (*Pereskia bleo*).

Anti-cancer properties in plants

As part of a study on local medicinal plants for health promotion and treatment of diseases, a face-to-face survey of 200 users of fresh medicinal plants successfully documented 104 plant species used by the participants. The plants are used for general health purposes as well as to help treat various disease conditions (e.g. respiratory ailments and cancer). Some plants were boiled to make decoctions or herbal tea, some were blended and drunk, and some were washed and eaten like salad (taken raw), amongst others. It is clear that a segment of the population is using fresh medicinal plants to complement their healthcare needs. The herbal knowledge is usually handed down verbally from the older generations living in this region to their younger generations. Coupled with a comprehensive review of the traditional usage, seven plants were subsequently selected and screened against 12 cancer cell lines. The extracts of the leaves of six plants (which include the Seven Star Needle, the Simpleleaf Chastetree and the Black Face General, shown in Figures 1, 2 and 3 respectively) were found to be effective in reducing cancer cell

Figure 2: Photograph of the flowers, fruits and leaves of Simpleleaf Chastetree (*Vitex trifolia*).

Figure 3: Photograph of leaves of Black Face General (*Strobilanthes crispus*).

Figure 4: Photograph of mulberry (*Morus spp*) leaves and fruits. Mulberries are a good source of anthocyanins, a group of antioxidants which are known for their anti-inflammatory properties.

growth. These extracts are mixtures of naturally occurring compounds and the results support the traditional use of these plants in the treatment of cancer. Further work would be required to identify the active compounds and understand the mechanisms associated with the therapeutic effects.

While some fresh medicinal plants are well studied, e.g. *Aloe vera*, ginger and andrographis (Chuan Xin Lian), many others are not and they remain a wealth of knowledge to be explored, uncovered, and tapped into for new knowledge. These medicinal plants may have therapeutic properties which can complement allopathic medicine in the treatment of many diseases. They represent a large untapped resource for our healthcare needs and it is important to explore and have an improved understanding of the unique medicinal benefits which they can offer.

In an era characterised by evidence-based medicine, ageing populations, increasing prevalence of non-communicable diseases, constant threat from communicable diseases and rising healthcare costs, everyone should be empowered to take charge of their own health. One aspect could be through planting their own medicinal plants. This can take the form of a personal hobby or an activity in the company of like-minded people (in a community). Many medicinal plants are hardy and thrive well in our tropical climate. They can potentially be planted in a medicinal herb garden to provide a supply of fresh natural remedies throughout the year. Apart from our health, this may also contribute to our social and mental well-being.

KOH Hwee Ling is an Associate Professor with the Department of Pharmacy, NUS. She received her Ph.D. degree from the University of Cambridge. She is a registered Pharmacist with the Singapore Pharmacy Council. Her research areas include traditional Chinese medicine, quality control and safety of botanicals and drug discovery from medicinal plants. She has published three books on medicinal plants.

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Flavour compounds in natural food

The pleasantness of rich natural flavours, for example, the fruity and tropical notes of Ethiopian coffee, or grassy yet floral notes of Japanese Sencha, lies greatly in its complexity. Apart from containing a large number of different compounds, natural products also contain a spectrum of compound classes (e.g. aldehydes and lactones) with large variation in their concentrations. This prompts research interest in capturing and decoding the flavours of different foods.

Addressing this gap involves a fine blending of the science and art of flavours. Prof LIU Shao Quan from the Food Science and Technology Programme at the Department of Chemistry, NUS, in collaboration with Mane SEA Pte Ltd, a flavour and fragrance house founded in Grasse, France, is investigating and fine-tuning analytical techniques for flavour creation. This includes advanced sample preparation methods such as solvent assisted flavour evaporation (SAFE) and dynamic head space (DHS) technologies, as well as modern technologies such as quadrupole time-of-flight (Q-TOF) detectors and multidimensional chromatography. The collaboration leverages on NUS' research capabilities in food science and Mane's expertise in natural flavours.


Solvent assisted flavour evaporation (SAFE) utilises specialised glassware and is the gold standard for aroma extraction. It was applied on coffees of different origins (pictured) to profile their complex aromas. (Photograph by Aileen PUA, products courtesy of Mane SEA Pte Ltd.)

Many flavour compounds in food materials are present at very low concentrations that are detectable by human senses but not by analytical instruments. This has led to the development of analytical techniques and tools for projects focusing on coffee, tea, and citrus to gain molecular insights into the tantalising aromas and tastes of these natural products. Other than sample preparation to obtain representative extractions of odorants and tastants, the compound separation, identification and quantification aspects are equally important.

Some projects that the collaboration team has embarked on include the study of trace potent odorants using advanced analytical techniques to profile coffee aromas and the use of olfactometry (human nose as the detector) to differentiate among several Japanese green teas. This furthers the artistry of developing authentic flavours for increasingly discerning consumers, and allows for the development of analytical chemistry for complex natural food matrices.

Industry roundtable event

The Faculty of Science, NUS in collaboration with NUS Enterprise organised an industry roundtable event on 18 April 2019, focusing on healthcare, pharmaceuticals, nutrition and consumer products. The event brought together industry and academia to discuss the latest technological advancements in these sectors.

Prof Giorgia PASTORIN from the Department of Pharmacy, NUS highlighted industry-relevant programmes in the area of formulation technologies, disease management, and consumer care products. Prof ZHOU Weibiao from the Food Science and Technology Programme at the Department of Chemistry, NUS presented on research breakthroughs in areas such as novel functional food ingredients and diabetic-friendly functional food.

Prof Pastorin said, "The networking session during the event allowed participants to engage and explore potential opportunities for collaboration."

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