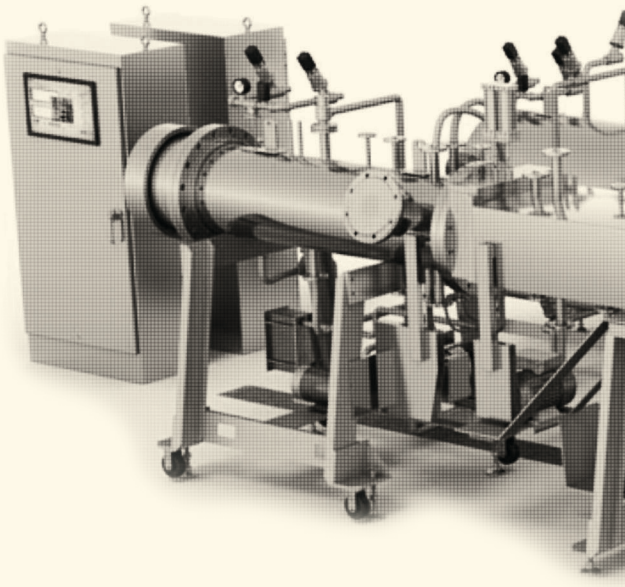
Feeling the heat



For over two decades, **Professor Juming Tang** has been conducting research using microwave and radio frequency energy for food safety applications. Here, he discusses the transformative technology that he has created, and the difficulties in maintaining a steady funding stream

Microwave pasteurised products with shelf-life of 9 weeks at 4°C.

How did you become interested in researching microwave heating?

Microwave heating is very unique compared with other heating methods. My interest started when I was teaching an undergraduate introductory food technology course in Canada in 1993. I started the research programme on microwave heating after joining Washington State University (WSU) in 1995 as a faculty member.

Specifically, what makes food safety an interesting and dynamic area to work in?

Research into food safety affects the industry as a whole, as well as having an impact on the lives of the general public. Such research will always be necessary, and this allows me to consistently secure funding from different agencies in order to sustain and expand my research programme.

It typically takes about 15 to 20 years to bring novel transformative technologies from concept to commercialisation, and sustainable funding is required to bridge knowledge gaps and overcome technical and regulatory hurdles.

Can you outline the core aims of your research?

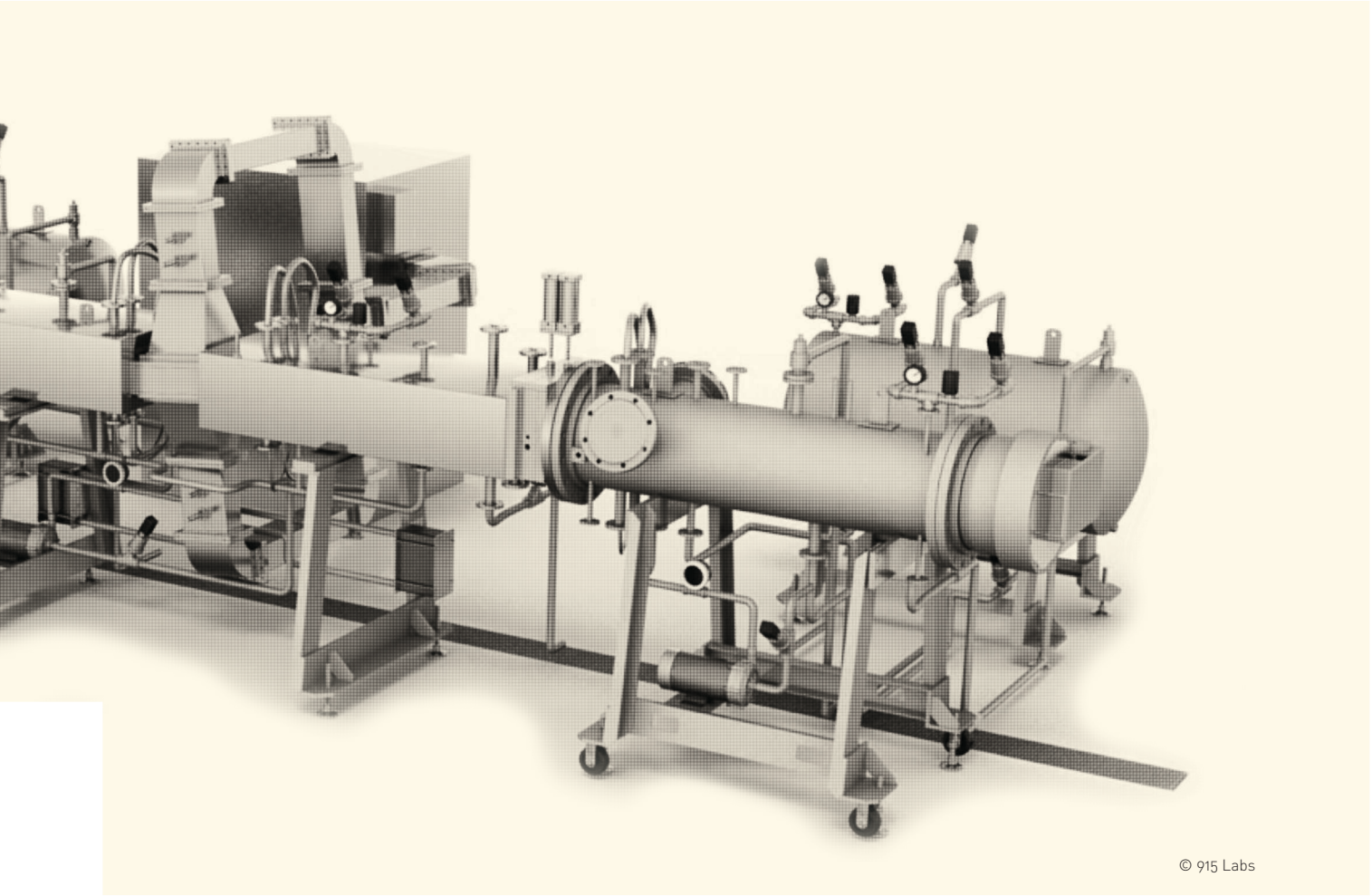
First of all, we aim to develop engineering design concepts that apply the unique advantages of volumetric microwave heating to inactivate bacterial and viral pathogens in pre-packaged foods. The designs can be scaled up for industrial applications. Following this, we aim to build pilot-scale systems so that we can prove the concepts and demonstrate to industry the advantages of these new technologies compared with conventional technologies, and the feasibility for commercial implementation.

Ultimately, of course, we want to develop scientific bases and build effective tools for system design, production process development, regulatory acceptance and industrial application.

We also want to support technology transfer by licensing patents for commercialisation, providing educational programmes for the food industry, and educating new generations of scientists and engineers.

What are the unique challenges that your team has overcome in developing the technologies for commercialisation?

We had to address three main technical issues: 1) designing efficient microwave systems to provide stable and relative uniform heating patterns in foods; 2) visualising heating patterns and locating cold spots in foods and measuring cold spot temperatures in moving packages; 3) validating microbial safety of the processed foods for regulatory filing. We developed and patented a single-mode 915 MHz cavity design based on 3D computer simulation and mock-up testing. We developed an effective chemical marker method to determine and validate heating patterns, and developed a protocol for food safety validation using



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microbial surrogates for the targeted food pathogens.

How has your research contributed to the advancement of microwave-assisted thermal sterilisation (MATS) and pasteurisation (MAPS) systems?

Mine is the only laboratory in the world responsible for the development of MATS and MAPS from concepts to pilot-scale systems. We patented system design and temperature measurement methods, and WSU has licensed these to 915 Labs for commercialisation.

What value will your microwave technologies and processing methods bring to consumers?

We expect these technologies will provide consumers with a better standard of living through the delivery of a wide range of ready-to-eat chilled or shelf-stable meals that are safe, convenient, nutritious and available at affordable prices.

By incorporating shelf-life and nutritional information through smart phones in retail and at home, consumers will enjoy a better quality of life and also reduce their food waste.

Have you faced any obstacles while conducting your research? How have you addressed these issues?

As I mentioned, securing sustainable funding to support focused research programmes in food technology is very important – and it has been a challenge.

We have managed to maintain this research programme by obtaining competitive grants and conducting contract work with food companies. Since 2011, the US Department of Agriculture's National Institute of Food and Agriculture (NIFA) has increased funding opportunities to support breakthrough technology developments for food safety. We were able to secure two large grants from NIFA.

Our research requires high-quality space for installation and operation of pilot-scale systems, as well as infrastructures for hygiene food preparation, packaging processing, storage and tasting, and hands-on training of industrial personnel for technology transfer. Thankfully, the University worked hard to incrementally improve food processing pilot plants and support facilities in order to accommodate our expanded needs.

Where do you see your work heading in the future?

As the food industry starts to embrace and adopt the technologies we have been working on, we will need to research scientific and technological issues emerging from industrial production practices and consumer feedback.

An area of great interest that we have not been able to address is how we could take full advantage of the new technologies (short heating time and high sensory quality of the products) to directly bring health benefits to consumers. We are extremely interested in collaborating with leading laboratories in human nutritional sciences and related organisations. We hope to systematically study the influence of nutritional retention and reduced salt requirements in the prepared meals using MATS and MAPS, in order to address diabetic and obesity problems in school programmes.

A microwaveable future:
improving sterilisation and pasteurisation

Microwaves are far more than the white boxes found in most domestic kitchens. Researchers from **Washington State University** have developed an exciting new suite of microwave-based technologies that could change the way pre-packaged food is sterilised and pasteurised, meaning greater efficiency for the manufacturers and higher-quality outcomes for the consumers

SINCE THEIR FIRST appearance in 1946, microwave ovens have become a mainstay of the modern kitchen. When food is exposed to microwaves, polar molecules such as water that are found in the food begin to rotate, thereby producing thermal energy in a process known as dielectric heating.

Contrary to popular belief, heating of food using a microwave is more uniform than other heating methods; moreover, it is considerably faster and more efficient.

As with so many engineering breakthroughs, the technology has its origins in war – specifically the radar technology developed during World War II. American inventor Percy Spencer is generally credited with inventing the device, allegedly having observed a candy bar melt in his pocket while he was standing in front of an active radar set.

For decades, commercial microwave ovens produced by Spencer's employer Raytheon and others were too large and expensive for general home use. In their current incarnation, however, they represent the pinnacle of convenience and simplicity in the kitchen.

Of course, it would be wrong to think that innovation and progress in microwave technology has stopped. Despite their apparent simplicity, the processes underlying microwave ovens involve complex multi-physics phenomena, and there is much to be learned about the application of microwaves in food technology besides just heating up food – particularly when it comes to improving sterilisation and pasteurisation.

ENTER THE MICROWAVE

The food processing industry has benefited immensely from the incorporation of microwaves. Various specific applications from the tempering of frozen foods to the drying of pasta products have been made more efficient using microwave heating. This is because the same principles that make microwave ovens a useful addition to the domestic kitchen – primarily speed – are also very useful in industry.

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Heat treatment is a crucial step in the production of many pre-packaged foods. When meat is canned, for example, it must be heated enough to inactivate or kill even the most heat-resistant harmful microorganisms, such as the spores of Bacillus and Clostridium bacteria. This means that the products filled in sealed containers are exposed to temperatures above 100°C in pressure cookers, for different amounts of time depending on the product in question.

The canning process was invented way back in the early 1800s, when French chef Nicolas Appert found that if food was enclosed in a jar and boiled, it did not spoil. While there have clearly been massive advances in food technology since then, the physical principles for the production of canned and other pre-packaged food has remained roughly the same.

The advent of microwaves, however, presents an opportunity to revolutionise these traditional thermal processes. As the plastic packaging materials that are now so ubiquitous in pre-packaged foods are transparent to microwaves, they can be used to process the foods after being packed. Most importantly, microwave sterilisation offers a significant advantage because of the short heating times required and its associated ability to maintain food quality while ensuring sterilisation.

MATS AND MAPS

One man who understands this better than anyone is Dr Juming Tang, Regents Professor and Distinguished Chair of Food Engineering at Washington State University (WSU), who has dedicated the majority of his working life to understanding how microwaves can be used to improve both food safety and food quality. He is working on, as he puts it: "transformative food technologies to benefit the world".

In his time at WSU, Tang and his team in the Department of Biological Systems Engineering have developed two key technologies that incorporate 915 MHz microwaves into food packaging processes: microwave-assisted sterilisation (MATS) and pasteurisation (MAPS). MATS is designed to produce shelf-stable foods by inactivating heat resistance bacterial spores at above 120°C, while MAPS makes chilled meals free from bacterial and viral pathogens. Packages vary from single portions to institutional sizes, depending on applications.

These new systems use special cavity design involving microwave heat and a hot water

tunnel to rapidly heat packaged foods to the appropriate temperatures, holding them there for the minimum amount of time and then rapidly cooling them down. The benefits are obvious. First of all, heating time is cut to just a few minutes, meaning an over 80 per cent reduction compared with traditional methods. Further benefits of these systems include reduced amount of space needed to operate in and a better work environment.

In addition, Tang emphasises the fact that using microwaves instead of conventional sterilisation and pasteurisation methods will mean improved food quality. It is generally thought that the shorter the time a food is processed for, the higher the quality it is, and the WSU has confirmed this idea with investigations into microwave-processed seafood and pastas.

After a long period of domination by traditional thermal processes, such as canning, microwaves could be about to get their chance to shine, having previously been relegated to niche positions in the food processing industry.

INTO INDUSTRY

Tang's technologies received their first FDA acceptance in 2009 for the processing of packaged potatoes in trays. Since then, they have received further acceptance for salmon fillets in pouches and a non-objection letter from the US Department of Agriculture Food Safety and Inspection Service for meat and poultry products.

The next stage for Tang and his team is to get their work applied in industrial plants. "915 Labs [WSU's industry partner – to which MATS and MAPS are licensed for commercialisation] is still in the early stages," he explains. "Starting in 2015, we began to offer three five-day boot camps per year at WSU to provide hands-on exposures to the food industry worldwide."

The FDA Food Safety Modernization Act was signed into law at the beginning of 2011, and marks the most significant reform of food safety laws in over 70 years for the US. Its key aim, according to the FDA itself, is to "ensure the US food supply is safe by shifting the focus from responding to contamination to preventing it".

In practice, the Act provides the FDA with the legislative mandate to require science-based preventive controls across the food supply, which means the tightening of food production procedures. There is, Tang opines, a gap that can be exploited by his team's technologies, as they will help food companies to comply with this new Act. Since it came into force at the beginning of this year, the Act has already led to food withdrawals from frozen food lines, stores and fast food restaurants.

In situations that require large quantities of pre-packaged food that taste good, while also following these new, stricter guidelines, the MATS/MAPS technologies are the perfect tool. Examples of its potential application include military units (in which trials are already underway), airlines, schools, nursing homes and hospitals.

AIMING SMALL

While large institutions such as the US Army provide Tang and his colleagues with an excellent customer base, their real ambition is to target slightly smaller end-users. In the next few years, the Centre of Excellence for Food Safety Using Microwave Energy, with Tang at the helm, wants to make it easier for small- and medium-sized companies – particularly those in rural areas – to implement these technologies themselves.

With support from the US Department of Agriculture's National Institute of Food and Agriculture, Tang hopes to create a framework in which his microwave innovations can be used by these smaller players to create all sorts of products. Products that are nutritious, tasty and long lasting.

Word of these novel technologies is beginning to spread outside the US as well, with institutions and companies in Australia, Singapore and India having also purchased MATS/MAPS systems.

After traditional methods of sterilisation and pasteurisation have dominated for over two centuries, now is the time for change. Not only are his innovations more efficient, they are resulting in tastier food – which is something that everyone can get behind. Once regulatory and technical hurdles have been overcome with the help of WSU and a steady funding stream, these ideas could end up changing the face of food technology for another 200 years.

FEEDING THE MILITARY

"Defence investment in next-generation technologies, such as microwave-assisted sterilisation (MATS), will have spill-over effects into other areas of the economy and help create local jobs."

Marise Payne, Australian Minister of Defence

For some time, the US military has understood the critical role that Tang's research could play in keeping future soldiers fed, and has accordingly been on hand to provide support.

Now, this has been further validated by the Australian Government, which has made a US $7.2 million investment in order to incorporate MATS technology into its own military.

Australia intends to establish an R&D plant at the Defence Food and Nutrition Centre in Tasmania, as well as a production facility.

CENTRE OF EXCELLENCE

Earlier this year, the US Department of Agriculture's National Institute of Food and Agriculture awarded Washington State University a US $4 million grant to establish a Center of Excellence. The goal of such a centre is to accelerate the transfer of technology like microwave-assisted sterilisation and pasteurisation to mainstream commercial markets.

UNLOCKING POTENTIALS OF MICROWAVES FOR FOOD SAFETY AND QUALITY

OBJECTIVE

To develop transformative processing technologies that enable the food industry to produce high-quality, safe and affordable foods to a wide range of consumers, while minimising environmental footprints.

KEY COLLABORATORS

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PROFESSOR JUMING TANG has conducted over 20 years of research in areas of thermal processes using microwave and radio frequency energy for food safety and pest control applications, in close collaboration with equipment and processing companies, related regulatory agencies and US government research institutions. He has trained 28 PhD students and published over 280 scientific papers, 2 books and 24 book chapters.