Smart foods for an aging population

The search for taste launched Japan as a food science pioneer. Now it leads a global drive to create functional foods, and opportunities abound for career-hungry researchers.

"As the wellbeing of Japan's rapidly ageing society becomes a public health imperative, functional foods — those shown to have specific physiological benefits — are under great scrutiny."

ALMOST A century ago, Japanese chemist Kikunae Ikeda could not have imagined that his appreciation of soup would lead to the launch of a multi-million-dollar industry. His quest to identify an elusive savoury taste led him to *kombu*, a type of kelp used as a fundamental ingredient for *dashi* — the quintessential Japanese soup stock. After simmering 38kg of dried *kombu* and examining its chemical components, he pinpointed glutamic acid as the secret behind the savoury taste.

Naming the taste umami, Japanese for "deliciousness," Ikeda continued to uncover umami-related compounds in other foods such as meat, fish and cheese. Shintaro Kodama, Ikeda's student at Tokyo Imperial University (now the University of Tokyo), in 1913 found further umami compounds in dried bonito. And in 1957, Akira Kuninaka identified the compound guanylate as the umami taste in shiitake mushrooms.

Ikeda went on to patent "a manufacturing method for seasoning with glutamic acid as the key component," which led to the founding of seasonings giant Ajinomoto Co, Inc. Now, widely known as the fifth taste after salty, sweet, sour and bitter, umami has revolutionised the global food industry.

Today, food science encompasses research across a vast range of fields including genomics, immunology and engineering. Multidisciplinary approaches are continuing to spur innovation and produce career opportunities in both basic and applied research. As the wellbeing of Japan's rapidly ageing society becomes a public health imperative, functional foods — those shown to have specific physiological benefits — are under great scrutiny.

"Japanese food scientists started a large-scale research project on functional foods in 1984," explains Makoto Shimizu, professor at the Tokyo University of Agriculture. "This project brought about the world's first policy in 1991 approving commercialisation of Foods for Specified Health Use (FoSHU)."

Among the first FoSHU to appear on the market were hypoallergenic rice and probiotic yoghurt. "The story behind FoSHU first appeared in *Nature* in 1993. Since then, functional foods have become internationally recognised," says Shimizu. "Today, functional foods are being developed around the world. The success of functional food development in Japan is dependent on a treasure trove of data accumulated by Japanese scientists over the past 30 years."

An appetite for innovation

As of March 2016, the total market value of FoSHU-certified products was ¥6.391 billion (approximately US$58.2 million), representing a nearly five-fold increase since 1997.

An array of FoSHU-approved products line supermarket shelves, including popular probiotics such as Yakult's eponymous dairy drink, Morinaga's Bifidus BB536 Yogurt and Meiji's Bulgaria Yogurt. Japanese beverage companies have also jumped on the wagon, launching FoSHU-certified non-alcoholic beer-flavoured drinks. Sapporo Breweries' Sapporo Plus and Asahi Breweries' Healthy Style both contain dextrin, which can help reduce blood sugar levels.

Now a science in its own right, functional food research has an effect on quality of life, longevity, and society. Careful evaluation of the efficacy of functional foods continues to play a critical role in advancing the field.

Yuko Takano-Ishikawa, head of the Functional Food Factor Laboratory at the National Food Research Institute (NFRI), highlights the importance of making sure a food is genuinely functional: "In my laboratory, we are developing new technologies to evaluate food functionality of agricultural products with regard to health-promoting functions, and to validate analytical technology."

"Our targets include antioxidant activities, which are thought to be involved in preventing various diseases and in having anti-allergic and anti-ageing effects," she says. "We have improved and validated analytical methods that enable us to

KAZUHIRO FUJITA

The Fukuoka Bio Cluster Project campus

The *neba-neba* boom

With one of the lowest rates of obesity in the world, Japan continues to fascinate healthy eating enthusiasts and nutritionists alike.

And while dieting and health fads come and go, one phenomenon that's sticking around is the national obsession with *neba-neb*a foods. Taking its name from the Japanese expression used to describe slimy or syrupy substances, a bowl of *neba-neba* toppings on rice might typically include ingredients such as *natto* (fermented soybeans), *nameko* mushrooms, okra, *mekabu* (kelp) and *yamaimo* (Japanese yam), all of which are culturally considered to be healthy foods.

Although frequently featured in television food programs, in the press and the blogosphere, the science behind *neba-neba* foods remains far from clear.

"What we do know for sure is that *natto*, *yamaimo*, and *mekabu* contain polysaccharides such as mucin and fucoidan, which give *neba-neba* foods their characteristically sticky texture," says Kimura. "These polysaccharides, which reach the colon without being digested and absorbed, are converted into short-chain fatty acids through microbial fermentation. It is known that short-chain fatty acids have a number of beneficial metabolic effects such as regulation of insulin secretion, regulation of appetite, and also blood pressure and fat accumulation. These are some of the effects that could go on to explain why *neba-neba* foods are thought to be beneficial."

IKUO KIMURA

Tokyo University of Agriculture and Technology

evaluate the antioxidant properties of polyphenols and carotenoids, in particular." These compounds can be found in a wide variety of fruit and vegetables, including wheat, onion and spinach.

Takano-Ishikawa's team is now building a database of antioxidant properties of agricultural and marine products and foods, which can be used as a basis for human clinical trials. "We believe that such databases will serve as a valuable contribution to respond to the needs of a super-ageing society, and to reduce the associated medical costs," she says.

The development of functional foods has been accompanied by a growing recognition that interdisciplinary research holds the key to future discovery. "Recent food science is transitioning from phenomenological to molecular approaches, which are helping to uncover the underlying biological mechanisms of functional foods," says Ikuo Kimura, associate professor at the Tokyo University of Agriculture and Technology.

"It is important to keep in mind that molecules produced in digestion and metabolism are not only energy sources but also signal transduction molecules," he says. "These are capable of exerting physiological actions via nutrient sensing receptors. Pathophysiological and pharmaceutical approaches in the medical sciences are essential to our understanding of food at the molecular level; it's an exciting time to be in these new fields of food pharmacology and pharmaconutrition."

Recipes for collaboration

Japan's competitiveness in food sciences has been boosted by the creation of bio clusters — large-scale R&D hubs facilitating academia–industry–government partnerships, and broadening the career opportunities within each. Some of the top clusters for food production and functional foods are located in Hokkaido, Kyushu, Kansai, Chubu and Shikoku.

Kazuhiro Fujita, director of the Fukuoka Bio Cluster Project in Kyushu, south-western Japan, says: "We have 24 bioventures currently developing functional foods. Our main targets are functional foods for the prevention of senile dementia, diabetes, and for anti-ageing."

Due to the growth of cross-border markets, "more international collaborations are needed to advance food science in the future," he says.

Over at the NFRI, where food scientists are engaged in research that spans the full breadth of food functionality, safety, supply and processing technologies, Takano-Ishikawa says "one limiting factor is the number of our researchers. To broaden our research scope and improve quality, we need more qualified scientists. We also need to work towards more collaboration with other research institutes as well as private companies internationally."

Future foods

An outward-looking, innovation-driven Japan continues to be at the forefront of mainstream and unconventional areas of food research.

In agriculture and bioengineering, scientists at NARO are using genomic approaches to develop high-yield, disease-resistant crops (rice, wheat, barley and soybean), as well as nanotechnology-enhanced methods to prevent damage to strawberries and other fresh produce during transportation. Packaging is both a science and an art in a country known for producing pyramidal watermelons and heart-shaped lemons.

In fisheries and aquaculture, there is an increasing focus on sustainability and environmental issues. Kinki University's Fisheries Laboratory has announced several world firsts in this area, including the first successful full-cycle breeding of bluefin tuna in captivity.

Long-lasting foods such as freeze-dried soups, energy bars and a variety of vacuum-sealed cooked meals have become standard items that can be stocked in case of emergencies at home and at work — a top priority in a country that remains constantly on alert for earthquakes and other natural disasters.

Further afield, the Japan Aerospace Exploration Agency (JAXA) has collaborated with Ajinomoto, Kewpie, Maruha Nichiro, Nissin and other manufacturers to develop space foods including *wakame* (seaweed) soup, *onigiri* (rice balls), seafood ramen and *yokan* (azuki bean jelly). Astronaut Koichi Wakata famously said that the foods familiar to him since childhood "always cheered me up in space," and gave valuable psychological support during his stay on the International Space Station.

Advances in food science are leading to a resurgence of interest in *washoku*, or traditional Japanese cuisine. "Scientists are learning that gut microbiota affect host homeostasis and can influence the development of disorders such as obesity and allergies," says Kimura. "As a consequence, there has been an increased level of interest in probiotics, which are often found in traditional Japanese fermented foods." (See **the *neba-neba* boom**.)

"Symbiotic foods consisting of a combination of prebiotics and probiotics will become more prominent in the future," he says. "Due to its emphasis on seasonal vegetables that contain large amounts of dietary fibres as well as fermented food, *washoku* is an exemplar of these symbiotic foods."

Shimizu highlights the need to tackle unsolved areas of food research. "Four prerequisites need to be met: nutrition, physiological function, palatability and safety," he says. "Many questions remain, such as how to improve the texture of food for the elderly, how to understand interactions between nutrients and drugs, and how to develop foods suitable for each generation or even for individuals based on genetic information."

This content was commissioned and edited by the Naturejobs editor

AJINOMOTO CO., INC.

Novel research enhances health and nutrition

Ajinomoto Co., Inc., is advancing health and nutrition by developing umami taste and amino-acid products developed based on innovative research and technology. As a world-leading food company, Ajinomoto offers high-quality, affordable umami seasonings and products to enable customers around the world enjoy both good taste and health.

Preparing and eating food together not only nourishes the body, but also enriches the heart. These activities enhance the happiness and health of people of all over the world by providing nutrition, imparting pleasant tastes, and strengthening bonds between people.

From taste to physiology

The first company to market monosodium glutamate (MSG), Ajinomoto was founded in 1909, a year after Kikunae Ikeda discovered that the amino acid glutamate was a key component of the Japanese soup stock *dashi*. He proposed that the taste of glutamate differed from the then established four basic tastes (sweet, salty, sour and bitter) and coined the term umami for this distinctive taste. But it took nearly a century of research in Ajinomoto and academia for umami to be recognized as the fifth basic taste. With the discovery of umami taste receptors on taste cells, as well as in other organs, research on the role of umami in both taste and physiology is expanding.

Ajinomoto's researchers discovered that umami is not just tasted by the tongue — it is also sensed in the stomach. This double detection prompts vagal nerves to send a signal to the brain to stimulate the digestion and absorption of proteins. "So in addition to enhancing the taste of food, umami also helps the body to digest and absorb foods," says Kazuya Onomichi (see photo on top right), corporate vice president and general manager of the Research and Development Planning Department at Ajinomoto. "Other cuisines besides Japanese have umami taste."

The science of deliciousness

Ajinomoto started using science to make food taste better by using its umami seasonings to improve the diets of customers all over the world. "People assess the deliciousness based on three factors: the food's taste, aroma and texture. When these three factors harmonize with each other, people tend to evaluate food as tasting good," says Chiaki Nosaka (see photo on bottom left), corporate vice president and general manager of the Institute of Food Sciences and Technologies at Ajinomoto. "We continue to research and develop original ingredients and compounds to realize each factor that contributes to the sensation of deliciousness. Anybody can prepare tasty food using our seasoning products."

The food company has identified substances that contribute to each of the

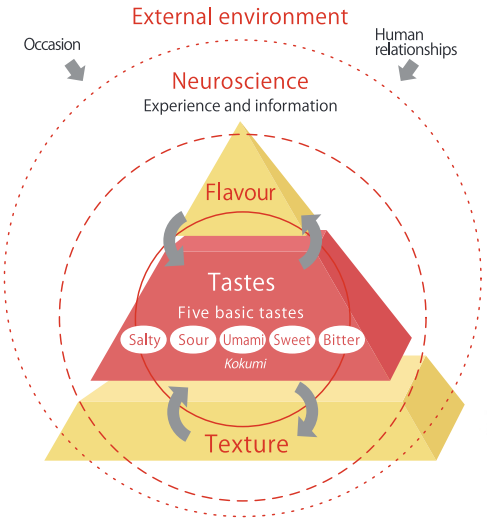
three factors and has done research to deepen taste, improve texture and analyse flavour to realize all three factors in one product. For example, Ajinomoto's Nabecube seasoning contains the rich taste, aroma and texture of soup. By just placing a Nabecube in a pot containing vegetables and meat in water, it is possible to instantly prepare a Japanese stew. Other foods such as ramen can be produced by using Nabecube in different ways. By using the science of deliciousness in this manner, Ajinomoto has produced seasonings and food tailored to the tastes of customers from around the world, which vary according to tradition, culture and eating habits.

A novel taste modifier ingredient

The company is also focusing on the functions of *kokumi*, a full-bodied taste that enhances and harmonizes with the five basic tastes. Although *kokumi* substances do not have strong flavours, people have *kokumi* receptors in the tongue and the body. *Kokumi* substances are produced during fermentation and brewing.

Ajinomoto discovered a potent *kokumi* substance — the tripeptide γ-glutamyl valyl glycine. It is found in foods such as scallops, fish sauce and beer.

Ajinomoto has developed a toolbox for enhancing the taste of foods that are low in certain components. For example, the taste of low-salt foods can be improved by adding umami components, low-sugar foods by using sweeteners and low-fat foods by adding *kokumi*. In particular, the company has developed a low-sodium product, Yasashio®, in which half the salt (sodium chloride) is replaced by potassium chloride. Polyglutamic acid (PGA) is added to compensate for the fact that potassium chloride is not as strong tasting as sodium chloride.



Glutamic acid and an AJI-NO-MOTO® bottle sold around 1910

Vital amino acids

About 20% of the human body is protein, which in turn is made up of 20 kinds of amino acids. Amino acids are thus essential substances for the human body. Based on amino acid research, Ajinomoto has developed the nutrition technology Amino L40 — a mixture of essential amino acids that contains a high proportion of leucine, at the optimal formulation to promote the synthesis of muscle protein.

Ajinomoto has developed two product series that exploit Amino L40 technology. One is a supplement for muscle protein designed for the elderly when they do activities such as walking. Sarcopenia, or reduced muscle mass, generally sets in around 45 years old and by the age of 80 it may cause muscle mass to drop by as much as 40% from its peak level. Amino L40 helps the elderly maintain and strengthen their muscles, preventing them from developing sarcopenia. Another product is the sports energy supplements of the AminoVital® series, which help athletes and sports enthusiasts recover from muscle injuries and conditions their muscles during and after sporting activities. The taste of both products has been improved by using technology that masks the bitterness of amino acids including leucine.

A novel technology to evaluate health

Ajinomoto has developed a novel technology known as the AminoIndex®. It measures amino acid concentrations in the blood from a single blood sample and can be used to assess health conditions and disease risks. For example, the technology is currently being applied to cancer and metabolic syndrome screening, and it can also reduce the occurrence of age-related illnesses. This technology allows people to assess their health condition before they exhibit signs of illness. As such, it is a valuable technology that can be utilized in *Me-BYO*, a new health concept, which instead of seeing health and sickness as two opposite and mutually exclusive states, views a person's health to continuously change, and applies to all conditions between being healthy and sick.

Using food technology to promote health

The company has been guided by the philosophy of "eat well, live well." To achieve its goals of becoming a top-ten global food company by 2020 and to help solve global issues, Ajinomoto is focusing on three main areas: global sustainability, food resources and healthy living. Ajinomoto has already succeeded in producing high-quality amino acids at affordable prices and demonstrating the importance of amino acids for people's lives. With 1,700 researchers globally, Ajinomoto is strongly committed to researching and developing amino-acid technologies and combining them with superior seasonings. Such a high commitment to research is rare among food-related companies. Its interests are very diverse, extending beyond food to include healthcare using diagnostic and cell culture media, cosmetics, and animal food and fertilizer.

"I believe healthy living is where we can make the greatest contribution," says Ajinomoto President and CEO Takaaki Nishii. "The Ajinomoto Group is a food company, but one of our main focuses is research and development, as well as technologies related to the development of amino acids." Summarizing the goal of the company, he adds "Our ability to harness the beneficial effects of amino acids to make nutritious foods tastier or to enable people to feel full with less food is closely linked to the very mission and raison d'etre of our group."

Ajinomoto will continue to pursue its vision of using technology to enhance food and nutrition. In particular, it will further explore the untapped possibilities of amino acids through using the latest technologies. In this way, Ajinomoto will seek to promote the health of people all around the world.

Eat Well, Live Well.
AJINOMOTO®

Contact

Website: **www.ajinomoto.com**

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AJINOMOTO CO., INC.

Food science: past, present and future

For over a century, Ajinomoto Co., Inc., has been researching and making food products and seasonings for taste buds around the globe. We spoke to Lord John Krebs of the University of Oxford and Takeshi Kimura of Ajinomoto about the history and future of food, taste and flavour, and Ajinomoto's role in human nutrition and sustainable food production.

Q: How did humans go from hunting and gathering to organized food production?

JK: The first big step in our relationship with food was the development of cooking. The earliest evidence of the systematic use of fire is between a quarter and half a million years ago, although some experts think it started earlier. That had a transformative effect because cooked food is easier to digest than raw food since cooking denatures proteins.

The next huge step was the development of agriculture roughly 10,000 years ago. The first agriculturalists were also the first geneticists — they took plants or animals and cultivated them systematically and selected the best varieties. Once we became agricultural food producers, we had periods of more food than we could consume immediately, and we had more time. One early application of technology was food preservation. For example, turning milk into cheese allows it to be stored longer.

Q: What are key trends in modern food production and consumption?

JK: We are shocked if we go to the supermarket and the 47th variety of olive oil we really want isn't there. That is the front end, but behind it are massive industrial-scale operations, such as production, transportation, chilling or freezing, and manufacturing.

Q: Japanese cuisine is popular worldwide. What are some of its defining features?

TK: A key component of Japanese cuisine is *dashi*, a soup stock made from dried seaweed called *kombu* and bonito fish flakes.

In the early twentieth century, Kikunae Ikeda, who became a professor at Tokyo Imperial University, went to study chemistry in Germany. He was so shocked by how different his physique was from Germans that, on returning to Japan, he worked on how to improve the impoverished Japanese diet. He was looking into the *dashi* soup stock and found that the amino acid glutamate is a key component of its flavour. He recognized that the taste of glutamate was different from the then established four basic tastes sweet, salty, sour and bitter, and named the taste of glutamate 'umami'. In 1908, he patented a method for producing glutamate as a new seasoning. We now know that there are receptors on the tongue for umami, which indicate that umami has been with us a long time. This gives cheese a lot of its taste and flavour, and also aged meats.

Another deep-bodied flavour described by Japanese chefs is called *kokumi*. For the last decade, we have been trying to isolate this component, and we came across glutathione. We found the receptor for this, cloned it, and tried to make a stronger version of the molecule. However, examination of its taste qualities revealed that it's not an independent taste; rather, it seems to enhance or modulate other basic tastes like sweet, salty and umami as well as some flavours and the mouthfeel.

Q: How can we use these taste compounds to boost health as well as taste?

JK: Western people generally eat too much refined sugar, salt and fat. So one could use *kokumi* to give something the same salty hit or sweetness but with less sugar or salt. *Kokumi* could also play a role in enhancing the mouthfeel of fat. In addition, there is a role for nanotechnology. If you make the fat particles extremely small and increase the surface area of fat that the mouth and tongue experience, you could create low-fat ice-cream with the same creamy feeling but which is lower in fat.

Q: 'Natural' and 'organic' foods are popular. Do you think these labels are useful?

JK: It's a masterpiece of marketing. All the food we eat is modified in some way. There's a belief that natural means more nutritious or safer. But what is it that is safer about natural food? Is it that there are no additives or pesticides? Natural foods — particularly plants — are full of toxins. Plants protect themselves against attack by insects or herbivores by filling themselves with poisons.

(Right) Lord John Krebs, Department of Zoology, Oxford University; scientific advisor to Ajinomoto

(Left) Takeshi Kimura, member of the board and corporate vice president, Ajinomoto Co. Inc.

But the levels we consume are not dangerous. So I think the distinction between natural, which equals 'safe' and 'good', and artificial, which equals 'nasty' and 'dangerous', is completely inappropriate.

TK: As well as having a consumer retail business, we sell ingredients to major manufacturers, and many are looking for things that can be labelled 'natural'. But this is more image than science. We try to come up with natural solutions, but sometimes they cost more and are less effective. So to me, natural is not necessarily better, although from an image perspective it can't be ignored. Take umami, for instance. We were the first to market monosodium glutamate (MSG) as a food ingredient. Many 'natural' products contain glutamate, and regulatory authorities around the world have assessed the safety of monosodium glutamate, but people still hear the word MSG and think it must be bad. Some people love umami but avoid MSG. What's the difference? One has a chemical-sounding three-letter name.

Q: What kinds of issues exist around sustainability in food?

TK: We operate with a concept of 'Ajinomoto group creating shared value' — that your whole business should be centred on doing good for society and the environment. People tend to think companies are just in it for the profit, but we've been in existence for over 100 years, and if you think about the next 100 years, you can't act irresponsibly. With our business, we try to do positive things in terms of human nutrition, sustainability and environment.

We are doing a lot of research on taste, smell and texture of foods, as well as lot of work on nutrition, especially involving amino acids, to make products which benefit consumers. Globally, there is still a lot that can be done to improve nutrition, and one thing we're doing is nutritional education. We have several projects around the world. In conjunction with the Vietnamese government and the leadership of the Japanese government and academia, we helped create Vietnam's first chair of nutrition at Hanoi Medical University. We've been working to spread school nutrition programmes within Vietnam too.

We also have a project in Ghana. After mother's milk, children go on to corn porridge, which is low in the amino acid lysine, and hence there is a lot of stunted growth. So we have created a supplement, KOKO Plus, that you can add to the porridge. It contains lysine as well as vitamins, minerals, soy powder and some sugar. We're seeing some good results in preventing stunting and anaemia.

JK: In a broader context, the Food and Agriculture Organization estimates that the world will have to produce 70% more food by 2050. There are two patterns of health in relation to food — about one-third of people are obese, while 2 billion people get insufficient calories or essential nutrients.

Our present systems of agricultural production are largely unsustainable because of their environmental impact. A quarter of all greenhouse gas emissions are from agriculture and land use change. If we're to meet our Paris commitments, we're going to have to change the way we grow food. As well as emitting greenhouse gases, agriculture uses 70% of the world's fresh-water supply, and we've also been depleting soil, treating it as a resource we can 'use up'.

TK: There's a limited amount one company can do in terms of global issues like food supply, but for our part we're studying plant growth stimulators, and especially using our by-products for stimulating plant growth and immunity. We use a lot of raw materials for our food products and in fermentation, so by utilizing fermentation by-products to enhance plant growth we can reduce waste and at the same time increase productivity thus contributing to sustainability.

Q: How can food be more sustainable?

JK: On the production side, we need to be more technologically sophisticated. There's a lot of talk about precision agriculture. For example, farmers in some countries now use satellite technology to enable them to apply pesticides and fertilizers exactly in the doses needed in the parts of the field where they're needed.

Plant breeding, including genetic modification, will be hugely important in

improving yields and the nutritional profile of foods, especially where the staple crop — say, cassava, millet or sorghum — is deficient in certain amino acids.

Also important is conserving our natural capital, particularly water and soils. In terms of water, many countries use spray irrigation where most of the water goes straight up into the air. Israel uses almost entirely drip irrigation. Nearly 90% of the water goes into the growing plant.

On the consumption side, individual behaviour enters the equation. As people get richer, they switch from plant-based to meat-based diets, which have a bigger impact on the environment. There's a question of whether as individual consumers we can constrain our lust for more meat.

TK: We are interested in efficient food production and the reduction of food loss, but also in efficient utilization of nutrients. Each age group in each geographic and economic situation has different nutritional requirements. In Japan — the most aged society in the world — it is important to consider how to keep people with various backgrounds healthy. That requires discovering what state the body is in for each individual. To that end, we're really interested in metabolomics, which is affected by both genetics and the environmental history of the individual. We've been studying blood amino-acid profiles, and we find that certain diseases have specific signatures. We even offer a service in Japan for diagnosing cancer risk. We're working on the nutritional side now and hope to utilize this for optimizing nutrition for the various risk groups, including the elderly, so we can offer delicious tasting foods that fit the nutritional needs of individuals. If shelf lives could be doubled or tripled, we wouldn't need to waste so much food.

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Kraisid Tontisirin, senior advisor, Institute of Nutrition, Mahidol University, Thailand — Global leader in umami and amino acid research and production

The discovery of umami taste and the development of an industrial process for producing monosodium glutamate (MSG) in the last century were remarkable advances in the fields of food and nutrition. MSG is now used to improve the palatability of many food products all over the world. As a leading global company in the production of amino acids, Ajinomoto has found that in addition to seasoning food, MSG also imparts various health benefits. MSG can stimulate appetite in the elderly and those of various ages suffering from undernourishment because their sense of taste is impaired. MSG enables them to eat more food and thus meet their energy and nutrient needs.

Other amino acids are also essential components of medicinal food and provide functional components for food designed for sport and exercise. Essential amino acids, particularly lysine and threonine, can improve the quality of cereal protein for people as well as for chicken and pig feed. Ajinomoto Company has become the world leader in food, flavours and nutrition due to the advanced fermentation technology it uses to produce amino acids. It is committed to investing in continued research and development, which will support the global goals of the Food and Agricultural Organization/World Health Organization Second Conference on Nutrition held in Rome in November 2015 and the United Nations General Assembly Sustainable Development Goal 2.

Ajinomoto is improving people's health in South East Asia through nutritional education and school lunch programmes. In cooperation with Japanese academic, it established a dietetic system for Vietnam. In Thailand, Ajinomoto supports an educational unit that teaches the importance of good taste for better nutrition. Sensory Science for Better Nutrition is an example of an educational and research unit co-established by the company and the Institute of Nutrition, Mahidol University, in Thailand to transfer sensory science findings relating to nutrition and health (especially in the fields of physiology, psychology and nutrition) to food scientists and nutritionists in Thailand and other ASEAN countries. The unit also promotes collaborative research on sensory science and nutrition between scientists in Thailand and Japan.

The functions of amino acids and peptides are not limited to nutrition and palatability — their physiological functions as functional foods can also be explored by researchers. The use of available amino acids to improve nutrition must be appropriately adapted and designed to fit with a country's cultural context and problems. Ajinomoto anticipates that its amino-acid technologies will continue to achieve better nutrition for people and animals everywhere in the world.

Gary Beauchamp, distinguished member and emeritus director and president Monell Chemical Senses Center, USA

The Monell Chemical Senses Center was established in 1968 through a generous gift from the Ambrose Monell Foundation. It was the first basic and translational research institute in the world devoted to studying the chemical senses — taste, smell and chemesthesis (or chemical irritation). From its inception, Monell obtained research support from the government, foundations, individuals and industry; this strategy of having multiple sources of support has served the centre well (see *Nature* **491,** 510; 2012).

Monell receives industry support primarily through corporate sponsorship. Each sponsor provides the centre with an annual unrestricted gift and they alone are offered the opportunity to support basic research projects. Monell does not develop products or conduct proprietary research — all the results of sponsor projects are owned by Monell and Monell retains the right, as well as an obligation, to publish the results of sponsored work.

I joined Monell as a post-doctoral fellow in 1971, and, to my surprise, I find myself still here 45 years later. I subsequently joined the faculty and then served as director and president for 24 years. Ajinomoto became the first Japanese company to join Monell's sponsor programme in 1976. Since then, I have interacted extensively with Ajinomoto's scientific and administration staff. I have been most impressed by their strong focus on basic research, which contrasts with current trends in the food industry.

As a private company, Ajinomoto directs much of its internal and external research efforts towards its core interests, particularly amino acid chemistry and biology, and areas of broad and fundamental research. Internal Ajinomoto research as well as studies by external academic scientists from around the world have provided important insights into how the amino acid glutamate and related compounds act as flavour molecules to impart a unique taste and mouth feel referred to as umami. This sensation is now generally recognized as one of five basic taste qualities, along with sweet, salty, sour and bitter. Recent umami research has identified the oral receptors responsible for detecting and transducing umami taste, discovered similar receptors in the digestive tract and elsewhere in the body, implicated umami stimuli as satiety inducers, and demonstrated that these compounds can be used to reduce dietary salt.

Given the past success of Ajinomoto's basic research strategy and long-range view of the value of internal and external support of basic research, I am convinced that the company will continue to prosper. I personally look forward to working with my scientific colleagues at Ajinomoto to advance the science of taste, flavour, food and nutrition.

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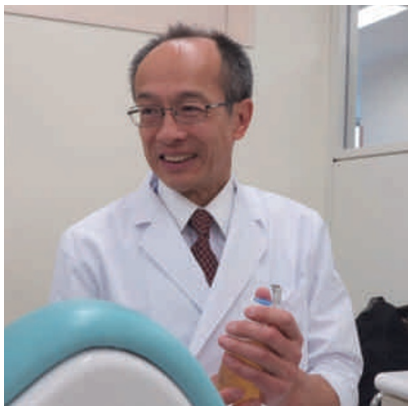
TOHOKU UNIVERSITY

Umami: Why is the fifth taste so important?

Tohoku University researchers have discovered that the ability to taste umami in food has health benefits, especially for the elderly. They found that a Japanese soup stock stimulates the ability to taste umami, promotes salivation, enhances appetite and improves overall health.

Umami has been recognized as the 'fifth taste' after salty, sweet, sour and bitter. It can be detected in foods that contain high levels of the amino acid glutamate, such as soy sauce and green tea, and is essential in oriental cuisine.

Recognizing the importance of umami for health, Tohoku University researchers have developed a sensitivity test for umami tasting and have shown that umami is vital for maintaining health in the elderly. The team tested 44 patients with taste disorders using the umami substance monosodium glutamate (MSG) and found that 7 of them (16%) lacked an umami sensation, even while exhibiting an ability to detect the other four basic tastes. All the test subjects were over 65 years old and had lost their appetites. They had lost weight because they found their food was not palatable.



The results raise the question of why some elderly people exhibit umami-specific taste disorders. Takashi Sasano, a professor at Tohoku University Graduate School of Dentistry who led the study, explains that the issue is the ability to induce saliva. He found that boosting saliva flow in the mouths of his elderly test subjects helped stimulate their taste buds and improve their eating habits. "Umami increases the amount of saliva and enhances the umami sensation by its unique synergic effect with MSG in saliva. Consequently, reduced salivation causes umami specific disorders," he says.

Since available medication for relieving dry mouth symptoms produces serious side effects in the elderly, including sweating and dizziness, Dr Sasano and his team investigated a kelp-based stock, which is rich in MSG, as an alternative remedy. They instructed the test subjects to rinse their mouths with the stock at least ten times a day. More than 80% of the subjects reported an improvement in dry-mouth symptoms after a few months. "This is a safe and effective therapy without side effects," says Dr Sasano. While the other four basic tastes also stimulated saliva production, the results revealed that only umami induced a long-lasting increase in salivation.

Importantly, the researchers discovered that dry mouth is more closely related to reduced saliva production from minor salivary glands than from the three major glands. "We strongly believe that umami substances can enhance the secretion of saliva from the minor salivary glands," says Dr Sasano. "Minor salivary glands are scattered throughout the mouth, helping to moisturize and protect the lining of the mouth," he adds. Dr Sasano also points out that most of human saliva is protein and includes mucin. "Abundant mucin lubricates the mouth and helps keep the taste buds healthy," he says.

Tohoku University is promoting the need for correct diagnosis and taste disorder treatment by teaching the importance of taste and its relevance to health. "Taste dysfunction has negative implications for health, especially in the elderly, so we must take them more seriously," Dr Sasano stresses. Japanese food has become increasingly popular around the world, and Dr Sasano hopes that many more people will learn about the benefits of umami.

TOHOKU UNIVERSITY

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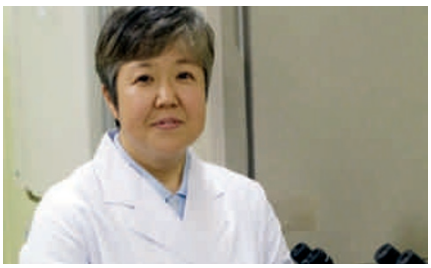

Kanagawa Prefectural Government

Promoting health through *ME-BYO*

By promoting the use of the innovative *ME-BYO* concept, Kanagawa Prefectural Government is opening up a new frontier in healthcare that will help tackle the rapid social changes accompanying a super-ageing population.

Located next to Tokyo, Kanagawa prefecture is home to 9 million people. It is one of the fastest greying prefectures in Japan, which in turn is the fastest ageing country in the world. In 1970, relatively few in the prefecture were aged 80 or over, but this age group is predicted to become the largest in Kanagawa by 2050.

As people age, they tend to alter their eating habits and become less active. Such changes raise the risk of lifestyle-related diseases, increase the burden on the nursing care system and curtail life expectancy.

"We won't be able to maintain the current social welfare system by the time this large cohort of older people become sick and need hospital treatment under the national health insurance system," warns prefectural governor, Yuji Kuroiwa. "To overcome such unprecedented changes in social structure, we have to seize the initiative now. The keyword is *ME-BYO*."

A new concept of health

By introducing the concept of *ME-BYO* — in which a person's health is viewed on a sliding scale between perfect health and sickness — to everyday life and encouraging its citizens to maintain their health, Kanagawa aims to promote healthy ageing as well as create new cutting-edge medical markets and innovative healthcare industries.

"Since everyone is somewhere on the *ME-BYO* scale, everybody needs to work on improving their health," says Kuroiwa. "For example, most people are not suddenly diagnosed as having full-blown dementia. In the *ME-BYO* concept, risk factors and symptoms of dementia are detected in the early stages. Thus, by discovering where you lie on the *ME-BYO* scale, the progress of disease can be delayed by eating healthy food, exercising and doing mental puzzles."

"The concept of improving *ME-BYO* is also effective for the sick," Kuroiwa adds, relating his own experience with his father who was diagnosed with liver cancer and informed he had two months to live. But after altering his lifestyle based on the advice of a Chinese medicine doctor, he lived for another few years.

"Some say the concept of *ME-BYO* is the same as disease prevention," Kuroiwa says. "But being either healthy or sick is a concept promoted by medical treatment providers. In reality, there's no clear-cut distinction between the two states. For the sick, the option of prevention no longer exists. And even if you are in good health, it doesn't mean you are completely healthy. In the *ME-BYO* concept, the *ME-BYO* level varies on a continuous scale between the two states."

ME-BYO innovations

It is already possible to gauge your *ME-BYO* state by using smartphones or wearable devices with built-in sensors that measure parameters such as heart rate, blood pressure and tone of voice. In the future, household furniture and appliances such as toilets and beds will be equipped with sensors that can collect data, analyse your *ME-BYO* state and dispense advice. Kanagawa is developing a system that will enable people to check where they are on the *ME-BYO* scale using cutting-edge technologies such as big data and artificial intelligence.

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Kanagawa runs healthcare programmes in cooperation with the municipal governments, local communities and companies. For example, the prefecture has designated its western regions, such as Odawara and Hakone, as ideal locations for improving *ME-BYO* since people can benefit from their natural environments, hot springs and agricultural and fishery products. Under the programme, Kanagawa has set up several points where people can perform daily *ME-BYO* check-ups using monitoring devices, create their own *ME-BYO* clinical records and do activities that improve their *ME-BYO*.

Also, new industries are emerging as companies enter the *ME-BYO* market. Kanagawa has been trying to create *ME-BYO* industries that optimize a person's mental and physical condition by providing products and services that improve *ME-BYO* and hence lead to a healthier life.

Kanagawa is encouraging research, development and marketing of companies in the prefecture by setting up three special industrial zones recognized by the national government — a life science industry zone, a robotics industry zone and a national strategic special zone. It also plans to establish a centre to educate healthcare and medical human resources to global standards. In addition, it has set up a research centre to promote the industrialization of regenerative medicine and cell therapy.

Moreover, Kanagawa has taken global initiatives to spread the *ME-BYO* concept, signing memoranda with overseas authorities, including the states of Maryland and Massachusetts and Stanford University.

To advance international cooperation, Kanagawa hosted an international conference, *ME-BYO* Summit Kanagawa 2015, in Hakone last October. At this conference, about 200 people from all over the world, including from the World Health Organization, the National Institute of Health (US) and the National University of Singapore, discussed the design of a new social system based on the *ME-BYO* concept. The prefecture plans to hold this summit once every two years.

The critical role of food

Kanagawa is looking for scientific evidence that shows food is a key factor for maintaining good health in *ME-BYO* projects. One project, which has been running since 2008, is seeking to develop methods to assess food functionality. This will assist people to maintain their health and delay the onset of lifestyle diseases associated with ageing. It will also provide fresh impetus to the food industry.

"We're building a public system for assessing food functionality and safety based on nutrigenomics," says Keiko Abe, a professor at the University of Tokyo and project leader. "The project adopts a scientific approach to the evidence-based analysis of the effect and efficacy of functional foods for health and anti-ageing. As Japan is greying, our mission is to find healthy ingredients, develop functional foods to maintain wellness and find ways to delay the onset of lifestyle diseases associated with ageing."

For example, Abe's team has shown that polyphenols in maple syrup are effective for fighting obesity and diabetes in mice, since they inhibited inflammatory reactions in the liver after the mice were fed a high-fat diet. The team is collaborating with major food companies to conduct case studies of functional analysis by nutrigenomics and to develop health products.

It is also important to ensure food safety. The safety of carcinogens in chemical substances such as food additives is checked by an analysis method developed by Kanagawa Prefectural Institute of Public Health that uses Bhas 42 cells. The institute established the method based on basic research conducted over the past 20 years.

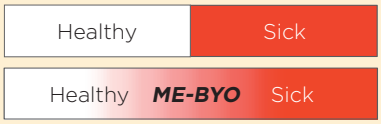
"Analysis methods for detecting genotoxicity of carcinogens in chemical substances during the tumour initiation phase already exist," explains Kiyomi Ohmori from Kanagawa Prefectural Institute of Public Health. "However, no officially recognized method existed to detect non-genotoxic carcinogens likely to be tumour promoters that do not use test animals to evaluate the promotion phase of carcinogenic substances. Thus, the development of a reliable and appropriate screening method to detect tumour promoters was a global need. Everyone is in the *ME-BYO* state for tumour initiation. Since tumours grow gradually with a promoter, it's vital to find out what compounds are promoters and what compounds prevent tumours from forming in the human body."

Bhas 42 cell transformation assay can detect tumour promoters and tumour initiators by varying the treatment conditions with test chemicals. The carcinogenic analysis method was officially recognized as an international standard method for predicting carcinogenicity by the Organisation for Economic Co-operation and Development (OECD) in 2016. This method will also benefit the development of *ME-BYO* industries, by helping to reduce animal testing during drug discovery and development. Ohmori's team is analysing the method's mechanism so that it can be added to the test guidelines of OECD regulations.

Through its *ME-BYO* projects, Kanagawa Prefectural Government aims to help solve the challenges caused by a super-aged society and build a new model to overcome the rapid social changes. "Everyone, including citizens, governments and medical organizations, will be happy under the new healthcare system. We want to obtain evidence to show that the *ME-BYO* approach can extend healthy life expectancy," Kuroiwa says.

What is *ME-BYO*?

***ME-BYO* is the state between health and sickness**



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Kanagawa Prefectural Government
Kanagawa University of Human Services

Searching for a long, healthy life

As one initiative by Kanagawa Prefectural Government based on the new concept of *ME-BYO*, Kanagawa University of Human Services aims to enhance the quality of life through promoting functional foods and strengthening individual-based nutritional care.

The long life expectancy of Japanese people is due in no small part to their nutritionally balanced diets. So it might come as surprise that the Japanese diet has not always been as healthy as it is today. Throughout its history, Japan has tackled various dietary issues — ranging from nutritional deficiency to overeating — to improve the health profile of its population.

In recent years, however, the country has been confronting new dietary challenges. "Double burden malnutrition describes the situation where both excessive and low nutrition coexist within the same population," says President Teiji Nakamura of Kanagawa University of Human Services (KUHS). "For example, middle-aged men suffer from obesity, while female adolescents, the elderly and the sick are underweight."

He also points out that in ageing societies like Japan's, where medical care and welfare costs are increasing, it is vital to prevent people from developing lifestyle-related conditions that require care and impose a burden on the national budget.

To address these issues, researchers at KUHS are exploring so-called functional foods. These foods are generally agricultural produce rich in beneficial compounds. For example, oranges contain β-cryptoxanthin, which prevents osteoporosis, while tea contains methylated catechin, which staves off hay fever. "By adding functional foods to the existing diet, we aim to create a new Japanese diet that will improve health at an individual level," explains Nakamura.

As part of a project under the National Institute of Agriculture and Food Industry, the university is setting up nutrition care stations at local supermarkets and farm stalls, where dietitians provide individual consultations about daily meals and the appropriate use of functional foods based on scientific research.

The new concept of *ME-BYO*

KUHS is collaborating with Kanagawa Prefectural Government, which is aiming to become the prefecture with the longest healthy life expectancy (that is, the expected number of years for which people can live independently without care).

To achieve this goal, KUHS will draw on the concept of *ME-BYO*, which basically refers to the state of being in between perfect health and sickness. Thus, in this concept, the boundary between health and being illness is not well defined. This reflects the fact that the two states vary continuously throughout a person's life. Consequently, people should constantly strive to improve their well-being, regardless of their present state of health.

Kanagawa Prefectural Government proposes that food, along with exercise and social activity, is an important element for counteracting *ME-BYO*. And enhancing the safety and functionalities of crops will not only increase the health benefits of the food, but also vitalize the agricultural sector.

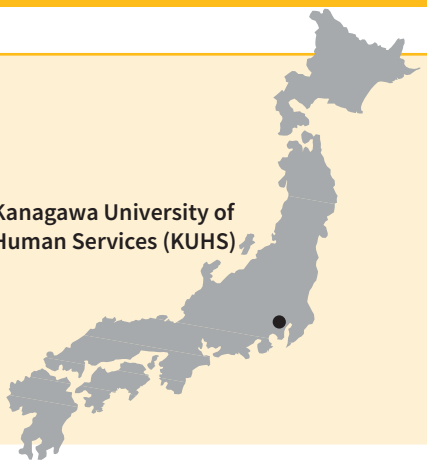
Based on this notion, KUHS works with local farmers to produce meals containing functional foods at local restaurants and canteens while collecting data on

the effectiveness and safety of functional foods. Other countermeasures to *ME-BYO* that KUHS is exploring include using technology to provide nutrition guidance and developing care robots in conjunction with the city council and local businesses.

"No other prefecture views preventing lifestyle-related diseases and the loss of independence of the elderly with such importance," says Nakamura. "In Kanagawa prefecture, we are harnessing the new concept of *ME-BYO* to tackle these problems."

Our location

Kanagawa University of Human Services is located on the western arm of Tokyo Bay. It is about half an hour by train from the lively metropolis of Yokohama and is not far from Kamakura, the shogunate capital during the Kamakura period (1185–1333). A bit further afield is Mount Fuji, which is 3,776 metres high.



Building a healthy diet

As noted above, the Japanese have not always eaten as well as they do today. Traditional Japanese cuisine relied heavily on rice and lacked sources of protein, fat, vitamins and minerals, leading to pandemics due to severe nutritional deficiencies.

The early stages of nutrition and dietetics research in Japan led to the discovery of vitamin B1 and the establishment of the country's first nutritional research institute and dietitian training school in the 1920s. But it was only after the Second World War that malnutrition was gradually overcome. Western foods such as wheat flour and skimmed milk were introduced at schools and hospitals, and dietitians played a vital role in educating the public on food and nutrition.

"It was not only good food distribution but also dietary education that improved the nutritional state of the Japanese people," Nakamura points out.

The westernization of Japanese meals, however, led to the emergence of obesity, diabetes and other chronic diseases. In response, the government shifted the focus of its nutritional policies from treating these conditions to preventing them.

"From 1990 onwards, nutritional education focused on preventing lifestyle-related conditions and addressing the general public, whereas it has been targeting individuals and specific groups from 2008," says Nakamura. "Therefore, a healthy Japanese diet was established by combating both low and excessive nutrition. These effective nutritional policies significantly contributed to Japan having the world's longest life expectancy."

Nurturing dietitians in Asia

The benefits of Japan's dietary resources are now overflowing its borders. In 2013, Hanoi Medical University opened Vietnam's first dietetics education and training course, supported by a collaboration between academia (Vietnam National Institute of Nutrition, Jumonji University, KUHS and Japan Dietetic Association), Japanese food industry (Ajinomoto Co., Inc.) and government (JICA and Kanagawa prefecture). KUHS is currently providing teachers for the course. In January 2016, it organized a training trip for teachers at Hanoi Medical University to visit KUHS, hospitals, care homes and schools in Kanagawa prefecture. The university will also provide various other forms of assistance, including training Vietnamese teachers in clinical nutrition, developing criteria for stationing dietitians and standardizing dietitians' work.

"If the partnership with Hanoi Medical University is successful, we are planning to expand it to other areas of Vietnam as well as neighbouring countries such as Cambodia, Myanmar and Laos," says Nakamura. "With a long history of improving nutrition, we have a duty to assist other Asian countries."

The future of nutrition and dietetics

From community-based work to supporting education and training in Asia, KUHS is leading modern advances in nutrition and dietetics at home and abroad.

Established in 2003, KUHS is a new public university and provides specialist programmes in nursing, nutrition and dietetics, social work, and rehabilitation, which are designed to nurture specialists who can assist in the fields of health, medical care and social welfare. This will enable them to become professionals who can provide holistic human services, reflecting the university's philosophy.

"In recent years, people around the world are gradually shifting from desiring a long life expectancy to wanting a long healthy life expectancy," says Nakamura. "How we respond to this shift is a question for future dietetics and nutrition studies. We are exploring how to optimize nutrients and food by researching nutrients and developing a new diet. And we want to communicate the results globally."

Kanagawa University of Human Services

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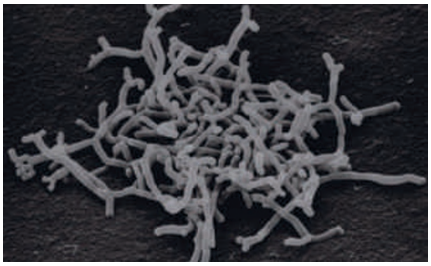


MORINAGA MILK INDUSTRY CO., LTD

The next frontier in probiotics

Founded almost 100 years ago, Morinaga Milk has been leading the development of advanced infant formulas, milk products and probiotic functional foods. Recent discoveries by Morinaga Milk scientists about the health benefits of human gut bacteria and their stabilization in foods is opening up a new era in probiotics.

Established in 1917, Morinaga Milk has a remarkable history of research on the nutritional properties of breast milk and its functional ingredients. This research has spawned a vast range of milk-based products, and Morinaga Milk now boasts hundreds of product lines. To better understand intestinal microbiota and their role in human health, Morinaga scientists are looking at how particular bacterial strains in the gut contribute to the health of infants and adults.

The role of the intestinal microbial community, the 'microbiome', in human health has emerged as a major area of research worldwide. All indications suggest that the microbiome is critical to human health and of particular importance in diseases ranging from intestinal disorders to brain health.

Morinaga scientists Fumiaki Abe and Jin-Zhong Xiao have been leading the company's research on the most important family of gut bacteria, bifidobacteria.

Not all probiotics are the same

"There are several hundred different species of bacteria in our gut," explains Xiao, general manager of Morinaga Milk's Next Generation Science Institute. "This microbial community is composed of bacteria that are beneficial to our health, those that produce harmful substances called putrefactive products, and those with as-yet-unknown physiological functions. The evidence is now accumulating that keeping this intestinal flora in balance is key to leading a healthy life."

Bifidobacteria are the predominant gut species in the infant microbiome and one of the major components of the adult microbiome. *Lactobacilli* is also known to be a beneficial bacteria in the human microbiome, but as it is present in much lower numbers than bifidobacteria, its influence on the microbiota is assumed to be limited. Although more than 50 *Bifidobacterium* species and subspecies have been discovered, only a few of these are common inhabitants of the human gut. Morinaga scientists have recently shown that there are major differences in function between these human-residential bifidobacteria (HRB) and the many other non-HRB species found in other animals, such as rats and pigs.

A key finding is that only those HRB species commonly found in the infant microbiome can utilize the oligosaccharides found in human milk and are tolerant to the antibacterial factor called human milk lysozyme. These characteristics allow infant HRB to colonize the infant gut, contributing to the development and maturation of a healthy microbiome. This points to the role of human breast milk in the selective colonization of the infant gut by *Bifidobacterium* species.

Clinical advantages

Certain bifidobacteria strains have been found to play a particularly important role in human health. One of Morinaga's most famous probiotics, the *Bifidobacterium longum* strain BB536, was isolated from an infant by Morinaga scientists in 1969. This

rare strain has been preserved and is cultured industrially using in-house technology as the basis for a variety of probiotic functional foods include yogurt, modified milk, supplements and infant formula. The subject of over 120 published papers and a wealth of clinical study data, BB536 has been shown to improve the intestinal environment, increase bone strength, alleviate symptoms associated with constipation and diarrhoea, protect against infection by the toxic *Escherichia coli* O157, and modulate the immune system with potential anti-allergy and anti-influenza functionalities and a potential relationship with cancer risk.

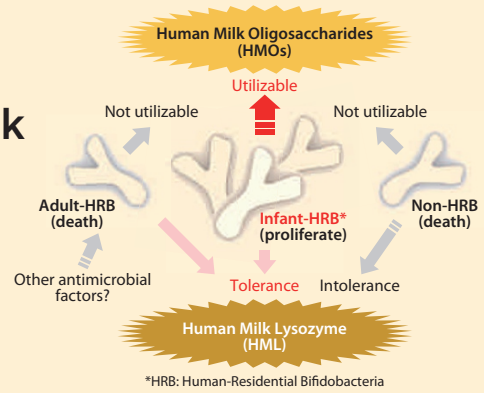
Another species of interest to Morinaga scientists is *Bifidobacterium breve* strain M-16V — a strain of bifidobacteria that is now widely used in Japan in neonatal intensive care units (NICUs) for newborns with very low birth weights. It has been shown to improve intestinal microbiota, promote healthy growth in infants, maintain intestinal tissue health and help with the ability to take milk.

Morinaga's study of bifidobacteria originates from research on infant microbiota, and it is in the field of infant health that it has perhaps had the most impact.

"Paediatricians in more than 100 NICUs in Japan are now using Morinaga *B. breve* M-16V probiotics to help promote healthy growth in very low birth weight infants," comments Abe, general manager of Morinaga's Food Ingredients and Technology Institute. "We have also published research studies indicating the potential effect of M-16V on infection, intestinal necrosis, atopic dermatitis and asthma. A hospital in Australia has even started using M-16V as part of a clinical investigation and a large-scale cohort study, and early results show that M-16V is very effective."

Compatibility of bifidobacteria in human breast milk

Only infant-type human-residential bifidobacteria both can assimilate human milk oligosaccharides (HMO) and are tolerant to human milk lysozyme (HML). This suggests that HMO and HML respectively behave like a 'carrot' and 'stick' in selecting *Bifidobacterium* species in the infant gut.



Premature newborns generally have poorly developed intestinal microbiota, and are deficient in bifidobacteria compared with healthy infants. "This may be one of the main reasons why infants are susceptible to serious infections and intestinal necrosis," Abe says. "Research to date suggests that M-16V is one of the most useful probiotics for infant health, and it is my hope that M-16V will make a meaningful contribution to improving the health of all infants and children, including low birth weight infants throughout the world."

"What is most important about BB536 and M-16V is that they are HRB," says Xiao. "Humans and animals have different native *Bifidobacterium* species, and we have found many genomic and functional differences between HRB and non-HRB species. When we consider infants, only HRB are compatible with human breast milk, so it is reasonable that HRB should be more suitable for infant use."

Delivery is key

"When a probiotic food is ingested, two things happen," says Xiao. "As the probiotics pass the stomach and enter the small intestine, the bacterial components interact directly with the intestinal immune system. If they are the right kind of bacteria, the probiotics can arrive alive and then proliferate in the large intestine."

Once the probiotics proliferate, they can produce metabolites such as vitamins, short-chain fatty acids and other biomolecules, with an accompanying impact on the metabolite profile, intestinal barrier function and immunological balance.

Abe is primarily concerned with how to keep human bifidobacteria alive until the point of user consumption. "Probiotics are living cells, so it is very important that they survive in the final product," says Abe. "We have developed various technologies for powdered supplements and infant formula to ensure our human bifidobacteria survive during the drying process and long-term storage. These technologies allow us to maintain high viable cell counts and good stability, which result in an excellent survival rate. The same is true of probiotics yogurt. Although there are many probiotic yogurts using bifidobacteria on the world market, most contain *Bifidobacterium animalis*, which is not a human species. One of the reasons for this is that it is difficult to ensure the survival of human bifidobacteria in yogurt. We have developed unique technologies including specific lactic acid bacteria that promote bifidobacteria survival in yogurt, as well as improved fermentation conditions, yogurt composition and package materials. Only with these new technologies have we been able to extend the shelf life of milk-based products containing BB536." With these unique technologies for maintaining stability in various applications and also the publication of large numbers of clinical studies on both infants and adults, we are confident that our bifidobacteria can contribute to the health of people of all ages."

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RYUKOKU UNIVERSITY

Exploring the boundaries of taste

Bringing together renowned chefs from Japan's culinary heartland and world-leading scientists in food palatability, Ryukoku University's new Center for Research on Food Palatability is unravelling the mystery of taste to establish the science of palatability and push the frontiers of Japanese cuisine.

One of Japan's oldest cities and the imperial residence for over a millennium, Kyoto boasts a remarkable depth of tradition and historical continuity that have defined Japanese culture since the eighth century. Back then, as today, cuisine and its mastery are integral to the culture and hallmarks of the Japanese approach to both food and life. Now, Ryukoku University, one of Japan's oldest educational institutions, is taking mastery of the sensory experience of cuisine even further with the country's first Center for Research on Food Palatability.

"Our new centre brings together chefs from renowned Kyoto restaurants and scientists at the forefront of taste research to further our knowledge of palatability and conduct innovative research on Japanese cuisine," says centre director Tohru Fushiki. "We also collaborate with product development researchers from the private sector to tackle problems and challenges specific to these partner corporations. With over 370 years of history in the renowned culinary centre of Kyoto, Ryukoku University is ideally placed to make a global impact in this new interdisciplinary and practical research field."

A food scientist and nutritionist, Fushiki has been studying the detailed mechanics of what makes food palatable for over a decade. From the isolation of taste bud receptors responsible for different tastes, to the olfactory and stimulatory mechanisms in the brain that reward us with feelings of satisfaction and joy in response to pleasing tastes, palatability is a complex and strongly interdisciplinary mystery that Fushiki and his colleagues are intent on deciphering.

Fats and palatability

Increasing the fat and oil content of food is known to make a product tastier and more satisfying, but the physiological and

neurological mechanisms responsible are only just beginning to be revealed. As ingested fats and oils are broken down and absorbed in the gastrointestinal tract, opioids are generated in neurons of the hypothalamus region of the brain — the brain's reward system. In this way, the ingestion of fat results in addictive, reward-seeking behaviour, but the mechanism linking the gut and brain remains unknown.

"Pure fats and oils cannot be discerned by the human senses of taste or smell, but when combined with other ingredients, high-fat foods are perceived as delicious," says Fushiki. "In other words,

highly concentrated fats and oils stimulate the brain's reward system, which in turn amplifies the flavours in food and significantly enhances palatability."

Interestingly, energy-free fat substitutes do not stimulate the same reward system via the gut in this way. Yet recent findings by Fushiki's team suggest that there may be other routes to achieve fat-driven palatability.

"Fatty acids and volatile compounds released by cooking and ageing have a distinctive aroma, which is a key component of the palatability of fats and oils since it signals their presence via olfaction," explains Fushiki. "Our olfactory memories are very stable over long periods and help us recognize food and assess its relative palatability. So by replacing fats and oils with small amounts of fatty acids, it is possible to create foods that have low calorie contents but are still highly palatable. It is discoveries such as these that will become increasingly important for the food industry as it strives to improve palatability while reducing fat and sugar content."

The umami effect

Sweetness, saltiness, acidity and bitterness have long been known as primary tastes for which humans have specific receptors. It was not until the 1980s that a fifth primary taste, known as umami, was named and generally recognized by the scientific community, although it was first scientifically identified in Japan almost a century earlier. Umami is discerned by taste receptors that are specifically stimulated by glutamate — an amino acid found in savoury meat broths and fermented products and the basis for the taste-enhancing effect of monosodium glutamate (MSG). Traditional Japanese cuisine relies heavily on umami in the form of broths prepared using cured bonito fish and *kombu* seaweed, from which MSG was originally isolated. In fact, this prominence of umami gives Japanese food its distinctive palatability and broad global appeal.

"We discovered that the same mechanism by which fats, oils and sugars stimulate the brain's reward system is also present for umami-rich Japanese broth," says Fushiki. "This means that there is a biological preference for the taste of umami, and that the traditional Japanese umami taste can provide the same sense of fullness and satisfaction that sweet and high-fat foods do in Western diets. This explains why traditional Japanese cuisine has relatively low calorie and fat content but remains highly palatable. Because of this, Japanese food can make a positive contribution to the health of people around the world."

Quantifying good taste

A major theme of research at the Center for Research on Food Palatability is the development of methods to quantify the subjective evaluation of taste. As taste preferences vary among individuals, it is difficult to achieve an objective understanding of palatability. The recognition that many aspects of 'deliciousness' reside not with the foodstuff but with the individual has made it possible to achieve some important advances in this area.

"We have demonstrated that palatability can be expressed in terms of four main factors: physiological palatability or the sensation of deliciousness; food culture as shaped by social customs; information on safety and desirability; and the brain's addictive reward system," says Fushiki.

While physiological and brain reward system factors are shared to a significant extent by all humans, cultural and information-related factors are strongly influenced by individual experience and background.

"Based on these factors, we have created a list of questions to assess the palatability evaluations that people consciously and subconsciously make when consuming food. The ability to even roughly measure such a subjective evaluation of the relative deliciousness of a food allows for further improvements in the development of new food products."

Exploring the frontiers of Japanese cuisine

Through the Center for Research on Food Palatability, a group of scientists and renowned chefs from well-established Japanese restaurants in Kyoto has been conducting experiments aimed at finding possibilities for innovation in traditional Japanese cuisine. Using a specially equipped meeting kitchen at Ryukoku University, these culinary experiments explore specific themes over the course of six months or more. The Boundaries of Kyoto Cuisine is a recent example of such a research project, which considered how to simultaneously protect Japanese food culture and engage with globalization.

"We presented the results of our research at a recent public symposium," says Fushiki. "Our audience included professional chefs, people working in the corporate food industry and local government officials. Collaboration with product development researchers from the private sector is a particularly important aspect of our new centre."

Through this cross-disciplinary interaction, the centre has established a platform for developing innovative ideas for novel kinds of cuisine, as well as new culinary techniques for use in traditional cuisine. "We hope our research will help the Japanese food product industry better meet the needs of the elderly, hospital patients, school lunch programmes and people seeking to restrict their calorie intake by providing food options that are healthful and delicious," says Fushiki. "To enhance the quality of life of Japanese citizens, safeguard Japanese food culture and contribute to the development of food products that meet contemporary consumer needs, we need a sophisticated and precise understanding of palatability — that's the mission of the Center for Research on Food Palatability."

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RYUKOKU UNIVERSITY

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Hakutsuru Sake Brewing Co., Ltd.

Delivering the joy of Japanese sake to the world

By combining an ancient process with the latest technology, Hakutsuru is producing excellent quality sake and exporting it to the world.

With a history extending back more than 270 years, Japan's largest sake maker, Hakutsuru Sake Brewing Company, employs traditional methods for making sake (Japanese rice wine) while incorporating new technologies and equipment. Hakutsuru literally means white crane, and a logo of a crane features on all its products made in Japan, both those sold in Japan and overseas.

A history of sake making

The three essential elements for brewing sake are rice, water and rice koji (rice inoculated with a fermentation culture). Sake brewing is thought to date back to the second century when bowls of rice placed outdoors at shrines to offer to Shinto *kami*, or gods, naturally formed sake. This happened through mold growing on the rice, rain moistening the rice, and naturally occurring yeast and other microorganisms fermenting the rice to form sake.

Sake brewing was officially established in the Nara era (645–710), when a government department for making sake was created. Since then, the sake industry has been incorporated in Japan's system and is a vital source of funds for the national treasury.

"The technologies for sake brewing have been evolving for more than a millennium," notes Akira Nishimura, general manager of the International Business Division at Hakutsuru. "The basic method for making sake was developed more than 800 years ago. During its subsequent long history, technologies were developed to improve the quality of sake while simultaneously producing it in larger volumes. Japanese sake is a unique alcoholic beverage whose quality has been enhanced through the combination of refined sensibilities and new technologies."

Alcohol forms as a byproduct when yeast consumes sugar and water. Natural yeast can produce wine directly from grapes without any additives since grapes contain sugar and juice. However, rice lacks sugar; instead, it contains starch. So starch has to be converted into sugar

Dr. Akira Nishimura

by hydrolytic enzymes produced by koji. Yeast then converts this sugar into alcohol. Koji is made by sprinkling koji mold (*Aspergillus oryzae*) onto steamed rice, the mold is cultivated evenly on the rice and the rice mold is dried.

When brewing sake, both saccharification and alcohol fermentation progress simultaneously in the same container. This process is known as multiple parallel fermentation and is unique to sake brewing.

In the Heian era (794–1185), methods for cultivating yeast and koji were found. Koji mold was carefully selected and it has been proved to be a safe, edible

microorganism. However, brewers still cultivated microorganisms using rough rules of thumb, making it difficult to realize mass production at the time.

Hakutsuru's contribution to sake history

In 1743, Hakutsuru was founded in the Nada district of the city of Kobe. Master brewers known as *tamba toji* developed technologies for producing fine sake in large volumes during the cold winter in that district. Mass production also commenced at the time. Both the Nada district in Kobe and the Fushimi district in Kyoto became famous for their techniques for brewing fine sake, and sake from the two districts began to be shipped to the Tokyo area.

Sake brewing declined between 1868 and 1926 due to lower rice harvests and changes to methods for culturing yeast. Since 1926, some sake-making processes such as steaming rice, rice koji making and pressing sake have been mechanized, allowing sake to be produced in large volumes while maintaining quality.

Hakutsuru had started exporting its products overseas by 1937, when the Paris International Exposition was held. Since the 1950s, in parallel with the rapid growth of Japan's economy, Hakutsuru has been building new breweries and refurbishing existing ones so that they can make sake all year, not just in winter.

Sake is very delicate as it contains alcohol, sugar, organic acids, and lots of amino acids. It is thus vital to store sake at an appropriate temperature to preserve its quality. The taste of sake will deteriorate if sake is exposed to sunlight or its storage temperature changes drastically. On the other hand, because it contains lots of amino acids, sake can be served at various temperatures — from chilled (on the rocks or even frozen) to hot (up to 55 degrees Celsius). It goes well with Japanese food and with other cuisines all over the world. "The good thing about sake is it can be served at any temperature and with any food," says Nishimura.

The Nada district of Kobe is a highly suitable place for brewing sake because it has high-quality natural spring water — one of the essential elements for making fine sake. Nada is also home to a *tamba toji* guild. Superior skills are essential for brewing fine sake. It's vital to preserve traditional sake brewing methods while incorporating new technologies to produce sake that suits modern tastes.

The Nada district of Kobe is the largest producer of sake in Japan.

Illuminating research into sake making

Hakutsuru has conducted extensive biotechnology research into sake brewing. It has focused on koji mold, which produces hydrolytic enzymes that convert starch into sugar and protein into amino acids, such as glutamate, substance that imparts an umami taste in sake brewing. "The enzymes koji produces are very important and koji itself also contributes greatly to the taste of sake," says Takahiro Yamauchi, deputy section manager at the Research and Development Department. "If sake contains more glucose, it will be sweeter, whereas if it contains more amino acids, it will taste richer and more complex."

Each brewer has their own proprietary technique for preparing koji to produce sake with a certain flavour. By selecting different koji molds, a brewer can control the flavour of sake due to changes in the enzyme balance. There are many different koji molds, and Hakutsuru has developed its own to create its unique sake.

However, koji mold also produces an unfavourable oxidative enzyme that imparts an off-flavour, or *mureka*, to sake during brewing. Once this odour forms in sake, it persists and deteriorates the sake quality. Brewers usually prevent this smell by controlling the storage temperature and filtering sake to remove residual enzymes, including those that lead to *mureka*.

"The cause of this odour wasn't resolved for a long time," Yamauchi notes. "However, we identified that the smell was caused by an enzyme produced by koji mold, and we uncovered the reaction mechanism."

Researchers at Hakutsuru have conducted three influential studies on koji mold. In the first one, they purified the oxidative enzyme isoamyl alcohol oxidase to identify the effects its enzymatic properties have on the molecular biology of sake production.

In the second study, Hakutsuru developed a new pyrithiamine-resistant transformation system with a wild gene of a koji mold as a host vector DNA. "The koji mold is also used to produce material forms, such as enzymes for food and pharmaceutical products," says Yamauchi. "By using koji mold DNA, you can produce large quantities of exactly what you want." This transformation system is now widely marketed and used among molecular biology researchers.

In the third study, to demonstrate that a koji mold can be used for DNA transformation, researchers at Hakutsuru made a koji mold that does not produce the *mureka* taste by using the genetic information obtained in the first study and the transformation system developed in the second study.

In this way, Hakutsuru is using the latest technology to refine a millennium-old process to produce the finest quality sake.

HAKUTSURU SAKE SINCE 1743

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Web: **www.hakutsuru.co.jp/english**

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House Foods Group Inc.

Food innovation starts at home

One of the biggest names in home-cooked food mixes, spices and health foods in Japan, House Foods Group, has been a mainstay of the Japanese food industry for over 100 years and is renowned for its innovation, advanced food technologies and pioneering food science.

One of the most commonly eaten home-cooked dishes in Japan today, Japanese curry is an adaptation of the British–Indian curries that were typically found in Japan's international trading ports of Kobe and Yokohama at the turn of the twentieth century. In the early 1900s, this fare was exotic, being quite different from the traditional Japanese diet. Seizing on the potential of these milder-flavoured curries as a marketable home-style cuisine, Seisuke Urakami — an entrepreneur who had established a herbal medicine business in Osaka in 1913 — started producing curry mixes prepared using spices acquired from Indian importers in neighbouring Kobe.

"Urakami's first curry mix appeared in 1926," explains Yosuke Miyata, general manager of the Central Research and Development Institute at House Foods. "Some years later, his company introduced its own brand of House Curry, from which House Foods later took its name. In 1963, we began marketing the popular Vermont Curry, which has since become one of the long-selling products in the Japanese food market and the top brand of Japanese curry mix."

Since the 1970s, House Foods has built on its core curry and spice business to expand into retort pouch food, packaged noodles, snack foods, beverages, dressings and functional drinks, and has developed advanced product management, transportation and warehousing systems, manufacturing technologies and food analysis capabilities.

A healthy life through food

House Foods is currently pursuing a strategic plan to become a high-quality food company that helps its customers lead a 'healthy life through food'. This mission has spurred research and development on a range of new product lines, including high-quality, allergen-free foods and 'care' foods for nursing homes and specific dietary needs such as calorie or protein intake management.

"We are continually developing technologies related to culinary science, palatability and packaged food manufacturing, but we also conduct basic research on key ingredients, such as onion, turmeric, wasabi and other spices, as well as food analytical technologies, which are critical for quality assurance and maintaining food safety," says Miyata. "The development of advanced cultivation techniques and plant functionalities are also particularly important areas of research that support our overall business strategy of maximizing quality from field to plate."

House Foods' Central Research and Development Institute is dedicated to developing and improving all of the food technologies and supporting systems that underpin the company's success, from the point of cultivation right up to the shopper's basket. Much of this research is aimed at improving internal processes and factors such as taste, but some of it has wider implications. Two such examples are House Foods' development of a 'tearless' onion and

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pioneering research into the biochemistry and health benefits of turmeric.

The tearless onion

Although yet to hit the kitchen bench, the tearless onion is a reality and is one of the pioneering food technologies that put House Foods on the map of global food research. As with much of the company's research, the investigation that eventually led to the development of the tearless onion was triggered by a need to improve a food production process, as associate senior scientist Takahiro Kamoi explains.

"While investigating why a puree of onion and garlic sometimes turns green on mixing and heating, we discovered that the combination of amino acids from both vegetables with a compound called alliin from garlic, another called PRENSCO from onion, and an enzyme from both called alliinase, can result in a bright green pigment. Alliinase can break down both alliin and PRENSCO, and it was well known that cleavage of PRENSCO by alliinase produces the lachrymatory factor that stimulates the corneal sensory nerve and causes tears. However, in our tests we discovered that PRENSCO does not produce lachrymatory factor when attacked by garlic alliinase, so we began to look deeper."

Kamoi and his team discovered that a second enzyme found in onion but not in garlic, named lachrymatory factor synthase (LFS), acted on the sulfenic acid left after alliinase had broken down PRENSCO.

"Normally, in an intact onion, PRENSCO and alliinase are located in different compartments in the cell," says Kamoi. "When chopped, however, PRENSCO is exposed to both alliinase and LFS, resulting in rapid production of lachrymatory factor, which then volatilizes easily and induces tears."

Now Kamoi had a target — if the onion could be modified to lack either alliinase or LFS, the production of lachrymatory factor could be prevented. The researchers took their idea to one of Japan's state-of-the-art heavy-ion accelerators, and through ionizing mutation and successive screening combined with seed production by selfing, succeeded in obtaining a tearless onion strain deficient in alliinase.

"Lachrymatory factor is an irritant and antibacterial, so it has been suggested that it is needed by the onion plant to protect it from pests, but one of our strains grows well in open field trials and so we think there is more to it," suggests Kamoi. "Also, unlike genetically engineered plants, which have to go through a difficult approval process before they can be commercialized, the heavy-ion beam method we used is a non-genetically modified method, so there are no such hurdles. However, as expected the taste and aroma of the tearless onion are sweeter and milder than a standard onion due to the lack of pungent aromatics, and so our research continues." Research is also underway to obtain an LFS-deficient strain.

The universal tonic

The rhizome of turmeric, or *Curcuma longa*, is an important spice in Asian cooking and is also a widely used traditional medicine purported to have anti-inflammatory, antioxidant, antitumor and liver-protection properties. Scientific validation of these properties and identification of the biochemical compounds responsible are major themes of research at House Foods. For example, one of House Foods' key discoveries has been that the turmeric compound bisacurone can protect liver cells from alcohol-induced damage.

"We are investigating not only the wide-ranging health properties of turmeric compounds such as curcuminoid and bisacurone, but also their biosynthetic pathways so that we can develop a high-quality turmeric rhizome that is rich in these beneficial phytochemicals," Kamoi says.

Notably, although curcuminoids have potentially pharmaceutically important properties, very little is known about how they are produced in the turmeric rhizome, and no enzyme systems have been identified. Working with researchers at major universities such as the University of Tokyo, House Foods' scientists have succeeded in piecing the biosynthetic puzzle together.

"We have also developed a gene-based molecular method to discriminate *Curcuma* species," says Kamoi. "Various *Curcuma* species are cultivated, and the abundance of phytochemicals varies according to species, which can lead to quality problems in end products such as curry powders and beverages. By analysing genes related to certain enzymes involved in the biosynthesis of curcuminoids, we are now able to accurately classify the *Curcuma* species even when supplied in powdered form."

Looking forward

Research and innovation in food science are core drivers of House Foods' commercial success, but the importance of internal research and development is anticipated to increase manyfold in the future as the food industry faces a new suite of challenges. "Food safety, sustainability and depletion of food resources will be significant challenges for food science over the next 10 to 20 years," predicts Miyata, "but at the same time we will need to continue to promote the health and wellness of consumers by providing nutritionally balanced foods backed by research in emerging sciences such as 'nutrigenomics'. House Foods is committed to embracing these challenges and developing innovative solutions in food technology through research."

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Amino Up Chemical Co., Ltd

A unique culture for better health

Since 1984, Amino Up Chemical has been developing unique nutraceuticals and functional food ingredients with health and clinical benefits. Its flagship active hexose correlated compound — a mushroom extract — is attracting intense international interest as a preventative and complementary therapy for cancer, as well as a potential treatment for human papillomavirus.

"Our focus at Amino Up is to develop and manufacture unique ingredients with the potential for real health benefits," explains Kohei Homma, director and senior manager of research and development. "The ingredients we discover are new and unknown, and so we also carry out our own extensive research to accumulate the scientific evidence needed to satisfy users of our products and to demonstrate their clinical effectiveness. We call it evidence-based nutritional immunotherapy."

A long-established biotechnology company, Amino Up has assembled an impressive repertoire of physiologically active nutraceuticals, including a high-efficacy polyphenol antioxidant called Oligonol, a perilla extract with anti-allergy, anti-asthma, and anti-inflammatory activity, as well as a potentially potent anti-tumour ingredient derived from soy and mushroom culture called genistein combined polysaccharide (GCP), and an anti-stress ingredient extracted from asparagus, among a number of others. The health benefits of these products are supported by over 80 scientific publications including clinical data. But it is Amino Up's active hexose correlated compound (AHCC) product that has proved to be the most promising and of greatest interest to clinicians.

"We discovered AHCC more than 25 years ago after screening hundreds of different mushroom species to find those with the potential to stimulate the immune systems," says Homma. "We found one species stood out from all the others. We then found that we could enhance and isolate the beneficial component by culturing just the filamentous mycelia of the mushroom in liquid. It is a long process, taking about 2 months, but the final AHCC product has some unique properties, including a strongly stimulating effect on the immune system."

Although AHCC has many promising applications as an immunostimulant, its role as a complementary and preventative therapy for cancer has attracted the most interest. "AHCC has been used for many years now as a complementary nutraceutical to ease the side-effects of chemotherapy and radiation therapy for cancer patients," says Homma. "In these patients with suppressed immune function, AHCC lowers the risk of secondary infection and the generation of new cancers, as well as being an anti-inflammatory and having a beneficial effect on intestinal flora."

Amino Up has received preliminary results from the University of Ottawa showing that AHCC might suppress the proliferation of cancer stem cells — a root cause implicated in most cancers — by affecting the transcription of microRNA, which could have wide-reaching implications in cancer treatment. Recent pre-clinical studies have also indicated that AHCC might be an effective treatment for human papillomavirus (HPV), which is responsible for 99% of cervical cancers, achieving full eradication of HPV in 50% of a small group of chronically HPV-positive patients. These promising results have led to a much larger clinical study at the University of Texas, along with other trials in Italy, Bulgaria and Thailand.

"To maintain health and reduce the global costs of healthcare in the future, nutritional approaches like AHCC will become increasingly important," continues Homma. "We are beginning to accumulate a lot of scientific evidence that shows that AHCC can be tremendously effective in a clinical setting as well as being very useful for improving and maintaining health."

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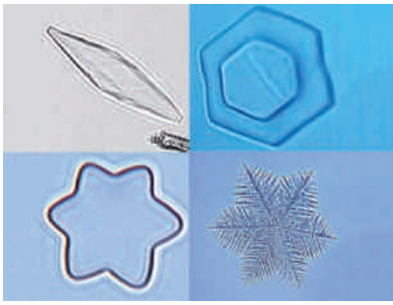

KANSAI UNIVERSITY

The next revolution in frozen food starts here

Kansai University has played a leading role in discovering, developing and commercializing natural antifreeze agents that promise to transform the frozen-food industry.

The flash freezing of fresh food makes it possible to distribute local produce around the world. Yet despite advances in flash-freezing technology, frozen foods still lack the flavour and texture of fresh produce. This degradation is caused by the enlargement of ice crystals in the critical temperature range of 0 to –5 degrees Celsius. The crystal expansion damages cell walls and causes a loss of cellular water — a process called drip loss, which has been a major obstacle for the frozen-food industry.

It has been recognized for many years that animals and plants in freezing climates have biomolecular mechanisms for preventing the freezing of cell tissue. However, isolating antifreeze proteins (AFPs) found in such organisms in sufficient quantities for commercial use remained an elusive goal until the early 2000s, when Kansai University's Hidehisa Kawahara discovered that the Japanese white radish (daikon) and its sprouts express AFP in abundance.

"In collaboration with a Japanese food company, we developed a process to extract AFP from radish sprouts in large quantities in 2009. This extract is now commercially available," Kawahara explains. "Since 2012, AFP has been used by the food industry to prepare frozen foods such as Japanese udon noodles. The amount of AFP needed is less than 0.3% by weight, so the cost of AFP is similar to that of existing food additives."

Contrary to what its name implies, AFP works not by lowering the freezing temperature but by latching neatly onto the edges of ice crystals to prevent crystal growth. Unfortunately, like many natural proteins, AFP is easily degraded by heat and acid, limiting its application in the food industry.

"This Japanese technology is world leading. Kansai University is the only institute for research and development in this field in Japan."

Searching for another solution, scientists discovered in an Arctic beetle a heat- and acid-resistant lipopolysaccharide called xylomannan with the same function as AFP. Although promising, xylomannan from this source could not be isolated efficiently, preventing its commercial development. In 2014, however, Kawahara and his colleagues identified high levels of xylomannan in the commonly eaten enokitake Japanese mushroom, and the team has already industrialized its extraction.

"Xylomannan from *enokitake* promises significant quality improvement for frozen deep-fried foods," says Kawahara. "We can now produce frozen omelettes and certain types of frozen processed seafood, which was not possible before."

Kansai University President Harushige Kusumi is justifiably proud of his researcher's achievements. "This Japanese technology is world leading. We can now produce both AFP and xylomannan in industrial quantities without genetic modification. Kansai University is the only institute for research and development in this field in Japan," he says. "Our success in this area stems from our tradition of industry–university cooperation as well as on our collaboration with industry and government in the industrialization of food science across diverse disciplines, including biochemistry, life science and biotechnology."

Recent achievements:

- **Confirmed control of ice crystals in the plane by applying xylomannan.**
- **Discovered a natural supercooling facilitating material.**
- **Studied the supercooling preservation of cells, tissues and organs.**

KANSAI UNIVERSITY

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