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Recent media coverage of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services report (p4) has escalated public engagement and awareness of the consequences of carbon dioxide accumulation in the atmosphere and climate change. There is an increased understanding that the time for remedial action is now very short. The agri-food sector has a key role to play in promoting actions to mitigate climate change through increased energy efficiency, use of cleaner energy sources, reducing waste and adopting measures to preserve soils, water and other ecosystem services for future food production. Progress has been made in many of these areas, but there is still much more to do.

Tackling food waste is a key area in which savings can reduce greenhouse gas emissions throughout the food chain. New programmes and tools targeted at monitoring and reusing surplus food in the foodservice sector have considerable potential to reduce food wastage (p6, p45). Providing technological solutions for more energy efficient cold chains in hot climates will also help to cut food loss (p5).

Our theme for June is aquaculture, a sector that offers great potential for expansion to feed a growing population. However, there are sustainability issues within the sector, such as habitat destruction, which need to be addressed. Offshore bivalve farming has considerable growth potential and can enhance biodiversity, increasing the catch of local fisheries while having lower negative impacts than other methods of marine food production (p18). The identification of species of fish that can be produced more efficiently than other seafoods, offers further potential to expand aquaculture in different regions (p22).

International collaboration is essential to ensure that fisheries in developing countries can improve production efficiency using sustainable strategies and technologies. Research programmes are supporting fish farmers in Asia by providing management tools and expertise to combat fish diseases (p28). Studies on adaptation of shellfish to changing environmental conditions will also be important in understanding the effects of climate change on aquaculture (p28).

**EDITORIAL**

**Melanie Brown**

*Editor*

Letters to the editor about any of the articles published in Food Science and Technology are welcomed.

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**Dangerous decline in biodiversity**

A recent report from the UN’s Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) concludes that nature is declining globally at rates unprecedented in human history and the rate of species extinctions is accelerating, with grave impacts on people around the world now likely.

The report concludes that it is not too late to make a difference, but only if we start now at every level from local to global. Transformative change – a fundamental, system-wide reorganisation across technological, economic and social factors – is needed to conserve nature.

Compiled by 145 expert authors from 50 countries over the past three years, with inputs from another 310 contributing authors, the report assesses changes over the past five decades, providing a comprehensive picture of the relationship between economic development pathways and their impacts on nature. It also offers a range of possible scenarios for the coming decades.

The report also presents a wide range of illustrative actions for sustainability and pathways for achieving them across and between sectors, such as agriculture, forestry, marine systems, freshwater systems, urban areas, energy, finance etc. It highlights the importance of adopting integrated management and cross-sectoral approaches that take into account the trade-offs of food and energy production, infrastructure, freshwater and coastal management as well as biodiversity conservation.

The pace of agricultural expansion into intact ecosystems has varied from country to country. Losses of intact ecosystems have occurred primarily in the tropics, home to the highest levels of biodiversity on the planet. For example, 100 million hectares of tropical forest were lost from 1980 to 2000, mainly due to cattle ranching in Latin America (about 42 million hectares) and plantations in South-East Asia (about 7.5 million hectares, of which 80% is for palm oil, used mostly in food, cosmetics, cleaning products and fuel).

In agriculture, the report emphasises promoting good agricultural and agroecological practices, multifunctional landscape planning (which simultaneously provides food security, livelihood opportunities, maintenance of species and ecological functions) and cross-sectoral integrated management. It also points to the need for deeper engagement of all actors throughout the food system (including producers, the public sector, civil society and consumers) and adoption of approaches that empower consumers and producers through market transparency, improved distribution and localisation (that revitalises local economies) as well as reformed supply chains and reduced food waste.

In marine systems, the report recommends an ecosystem-based approach to fisheries management is required in conjunction with spatial planning, effective quotas and marine protected areas. Freshwater systems need more inclusive water governance, better integration of water resource management and landscape planning and improved practices to reduce soil erosion, sedimentation and pollution.
Cold chain choices

A new study, Promoting Clean and Energy Efficient Cold-Chains in India, suggests that smartphone technology can help Indian farmers to tackle the sustainable cooling challenge[3]. Experts at the University of Birmingham, working with the Shakti Sustainable Energy Foundation and MP Ensystems, have produced a four-point ‘roadmap’ to address the cooling needs of farmers in the Indian states of Haryana, Punjab, Maharashtra and Karnataka.

The authors recommend four key actions:

• Promoting new business models that involve the communities taking charge of their own cooling needs;
• Establishing ‘Living Labs’ in rural communities where new technology can be tested;
• Providing training to enable people in the food industry to use new technology; and
• Creating a new framework for delivering IT-based cold chain solutions, particularly IT-based services to manage harvesting and logistics, and selling surplus cooling capacity.

Effective refrigeration is essential to preserve food, underpinning industries and economic growth. In India up to 50% of food is lost post-harvest because of lack of cold chain. Only 4% of produce that would benefit from a cold-chain actually does so, compared with around 70% in the UK.

Using mobile apps and data analysis to manage harvesting and logistics could help to reduce the amount of food wasted between farm gate and supermarket shelf, whilst boosting farmers’ incomes and reducing the environmental impact of much-needed food cooling.

Cold chains are expected to grow rapidly in the next couple of years. Under a business-as-usual scenario, most cold chains will run on diesel and adopt carbon intensive cooling and refrigeration technologies. The study suggests that the way forward for India is to transition to cleaner and more efficient cold chains, in order to tackle climate change and to achieve wider socioeconomic benefits.

Cold-chain infrastructure and business models need to be grounded within the communities – providing them with solutions to enhance their livelihood while catering to a country’s nutritional requirements. Enhanced IoT and Blockchain techniques proposed by the research team are designed to bring substantial benefits to farmers and other cold chain operators.

With populations and urbanisation growing and climate change causing rising temperatures, the world will need to provide far more cooling. How the world meets this challenge and provides cooling services to a growing middle class and to the vulnerable poor in the coming decades will have important ramifications for the climate: without innovations and targeted interventions the energy demand for cooling could increase more than five times by 2050. Growing GHG emissions associated with cooling equipment could easily outpace efforts to reach the goals of the Paris Agreement to halt global warming.

Circular economy

AMT Fruit, part of the Munoz Group, reduced its overall operational waste – the majority of which (81%) is citrus fruit waste – by 30% from 2015 to 2018[3]. The company works with over 250 growers to supply Tesco with 11 million boxes of citrus each year – approximately 140 million nets of citrus.

This waste reduction has been achieved in a number of ways including: revising and broadening product specifications, expanding sourcing countries, introducing new product lines and developing partnerships with food charities, which have received one million portions of fruit.

AMT conducted consumer research to gauge attitudes and as a result was able to work with Tesco to accept an increased amount of ‘scruffy’ fruit and to introduce a new giant line of over-sized fruit. This resulted in Spanish growers supplying an extra 10% of their crop to Tesco. Further improvements to the delivery strategies have extended the shelf life of citrus fruits by 40 million days.

However, despite this increased use of irregular fruit, the company still had in excess of 2,000 tonnes of waste each year from the UK operation. Citrus waste is wet and acidic and full of rots and moulds, making it unpalatable for animal feed, so all the remaining waste was being sent to AD plants.

At the start of 2018, AMT began a collaboration with AgriGrub, a company that feeds waste vegetables and fruit to the larvae of black soldier flies. When the larvae are an optimum size they are sold – branded as Calci worms – to pet food distributors and retailers as a form of live feed for reptiles.

Their virtuous by-product, frass, is a sustainable source of nutrients for plants and a novel bio-repellent for crop protection.

There is already a significant body of evidence on the efficacy of chitosan (the active component in frass) as a biopesticide. However for many years the cost of extracting the chitosan was considered too great, as the process involved boiling crustacean shells in sulphuric acid. Frass from insects, however, needs little processing and represents an economically viable source of chitosan for agriculture.

The company is focusing on higher margin crops which have few treatment options for pests and diseases as this is likely to give the best return in the least time. However longer term it hopes to find wider application of frass, especially where neonicotinoids are being phased out.

The first frass trials, on brassicas, showed a 94% reduction in aphid numbers on frass treated plants versus controls.
Printing food

Campden BRI has begun a research project to assess and evaluate how 3D-printing applications could benefit the food industry.[4]

3D-printing of food is a rapidly growing technology and new printers are now becoming available that can be used for various types of food materials. These are typically paste-type materials which include chocolate, vegetable and meat purees, pancake batter, cream, cakes and biscuits. The technology is capable of manufacturing product structures which cannot be achieved, or are difficult to achieve, using conventional technology. The project aims to provide an objective and independent evaluation of the capabilities and limitations of 3D-printing technology through practical trials on a wide range of food materials.

The team is working on a range of products and areas, including the potential of the technology for personalised nutrition based on the dietary requirements of different consumer groups, such as fortification with vitamin D, calcium and protein for the elderly population. Food could potentially be personalised further for specific deficiencies including anaemia, lack of essential fatty acids and dietary fibre. The project will also use an X-ray micro-CT scanner to scan simple and complex designs and to explore the scope of the possible structures and shapes that could be replicated by printing food. The modification of rheological properties to improve printing quality will also be examined.

Applying this technology to the food sector is not straightforward. There are many factors to consider, such as shelf-life, microbiological contamination, printing temperature, textures, rheology and ultimately whether different foodstuffs lend themselves to being printed. 3D-printing may have benefits for reducing process development and NPD times. Food waste could also be reduced as perishable products, which would otherwise decline in quality, could be printed on demand.

‘Guardians of Grub’

A new industry campaign, known as ‘Guardians of Grub’, was launched by WRAP in May 2019 to tackle nearly £3bn worth of food that is wasted every year across the entire hospitality and food service sector, of which 75% could have been eaten[3].

The campaign is aimed at empowering professionals from across the hospitality and food service sector to reduce the amount of food thrown away in their establishments. It is about making simple, low-cost changes to the way food is bought, prepared and served that have waste reduction in mind. A suite of free materials has been produced for the campaign, using the latest behavioural change strategies to inform best practice that can easily be incorporated into any business. These include information posters and how-to guides, and a free calculator to record the changes being made.

A video addresses the many environmental impacts of food, including the enormous amount of resources, water, land, energy and time required to produce food, as well as methane gas produced through decomposing food waste disposed of in landfill. This gas is thirty-times more harmful to the environment than carbon dioxide, with the United Nation Food and Agriculture Organization (FAO) estimating that global food waste represents more greenhouse gas emissions than any country in the world, except for China and the United States.

Many of the UK’s largest hospitality and food service representatives have pledged their support to the initiative, including the BBPA (British Beer and Pub Association), the FWD (Federation of Wholesale Distributors), the SRA (Sustainable Restaurant Association) and UKHospitality.

The sector is responsible for 10% (one million tonnes) of the total 10.2m tonnes of food wasted in the UK each year, with the cost of avoidable food waste varying between 38p and £1 for every meal it serves. On average 21% of food waste arises from spoilage, with 45% occurring in food preparation and 34% from consumer plates.

Recycling paper cups

Environmental charity, Hubbub, has launched The Cup Fund, to kickstart paper cup recycling programmes in locations across the UK[6]. The Fund will support at least 10 large-scale recycling programmes, offering grants of between £50,000 and £100,000 based on the specific needs of each application to develop long term infrastructure and ensure cups are collected and sent for recycling.

The ability to recycle paper cups has increased over the last two years and there is now enough capacity in the UK to recycle all paper cups used. However, because cups have a plastic lining that stops hot drinks from leaking, they need to be collected separately from other paper goods. As a result, specific cup recycling points are needed as well as clear communication to help the public recycle easily.

The aim is to collect cups in significant volumes in areas where there may not have been any drop off points before.

The Cup Fund is financed by Starbucks, which introduced a 5p charge on paper cups in 2018 to encourage customers to increase their use of reusable cups and avoid the charge. Proceeds are donated to Hubbub to carry out environmental projects that increase recycling as well as behaviour change studies to understand more about consumer behaviour, including the barriers that stop more people using a reusable cup. The instore charge has seen reusable cup use increase from 1.8% nationwide to over 5% of all hot drinks sold. Instore cup recycling is also offered in over 350 Starbucks stores across Britain, in a scheme that means any brand of cup can be brought back to be recycled.
Scientists from the Quadram Institute on the Norwich Research Park have developed a test that differentiates between buffalo and cow’s milk, and between the cheeses made from them.[3] Buffalo mozzarella commands a premium price, compared to cow’s milk mozzarella, and is thus a target for fraudsters, either through mislabelling of cow’s milk mozzarella, or by partial substitution of buffalo with cows’ milk during production.

A team at the Quadram Institute has developed a new method for testing the authenticity of buffalo mozzarella. This work was carried out as part of the FoodIntegrity project, funded by the EU’s 7th Framework Programme for research and technological development. The test is based upon detecting slight differences between the ‘same’ protein from different species. It uses mass spectrometry, which allows very accurate measurement of the mass of molecules. Both buffalo and cows’ milk and cheese contain a protein called αs1-Casein, which differs between species by just 10 (out of >200) amino acids.

During sample preparation, the protein is broken down by an enzyme into shorter sequences of amino acids. The analytical test homes in on several distinctive ‘marker’ peptides which, due to the amino acid sequence differences, are characteristic of either buffalo or cow. Using Multiple Reaction Monitoring Mass Spectrometry (MRM MS), the marker peptides are selected by their masses, fragmented further, and the individual fragments are also analysed. This provides a very high level of sensitivity and specificity. Relative quantities of each in a mixture can also be measured accurately.

Applying the test to commercial products, the researchers found that two thirds of restaurant meals and supermarket pizzas claiming to be buffalo mozzarella were mislabelled, and instead contained mozzarella made wholly or partially from cow’s milk.

For most products, buffalo mozzarella is added as discrete pieces, so if it contains milk from mixed animal sources, then the adulteration is likely to have happened earlier in the supply chain. This means that the restaurants or supermarkets are also victims and possibly even the cheese producers themselves, if they are being unwittingly supplied with pooled milk from undeclared sources.

Apprenticeship levy

The National Skills Academy for Food and Drink (NSAFD) has released a new report, looking at the health of the UK’s food and drink workforce and the impact of the Apprenticeship Levy on the food and supply chain.[6] The report surveyed trade organisations and representative organisations from across the food and drink supply chain, including representatives from organisations, such as National Farmers’ Union (NFU), Food and Drink Federation (FDF), British Hospitality Association, Lantra and Landex.

Although the report acknowledges that the Government’s reforms are broadly ‘working well’ across the food supply chain, it raises concerns that non-levy paying companies, principally SMEs, are missing out on opportunities. Government reforms have sought to put control of the system – including the means to pay for apprenticeships – in the hands of employers. However, SMEs that do not pay the levy are reliant on providers who have been successful in gaining contracts to work with them. Not all of these providers have the specialist capability to deliver an apprenticeship to food businesses and this can result in SMEs being unable to access suitable training opportunities.

An employer driven quality initiative to recognise high quality food and drink providers as ‘Industry Approved’ could go some way to providing the industry with reassurance about capability. Recent research identified that 96% of employers would prefer to work with these providers, as they have been through a rigorous approval process demonstrating their credentials.

The NSAFD, on behalf of the Skills Working Group, is convening a specialist group to look at how provision can better serve the needs of the food supply chain. Further research into the skills requirements of the wider food chain is already underway by the group, championed by FDF, with the aim of developing some tangible solutions to further improve the quality and availability of apprenticeships for all.

Authentication of cheeses

During sample preparation, the protein is broken down by an enzyme into shorter sequences of amino acids. The analytical test homes in on several distinctive ‘marker’ peptides which, due to the amino acid sequence differences, are characteristic of either buffalo or cow. Using Multiple Reaction Monitoring Mass Spectrometry (MRM MS), the marker peptides are selected by their masses, fragmented further, and the individual fragments are also analysed. This provides a very high level of sensitivity and specificity. Relative quantities of each in a mixture can also be measured accurately.

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In April, IFST held its annual conference in Birmingham. This year, the theme was nutritional science and those of you able to attend would have heard an incredibly thought provoking and challenging set of speakers bringing to life the challenges and opportunities we food professionals will face in forthcoming years.

This was my third and last conference as President of IFST and in each of the three conferences we have tried to focus on the challenges we will all face – either through emerging new technologies (2017) or redefining food risk management.

What is clear is that we are living in an ever-changing world where the boundaries of food science and technology are forever stretching into new topics. Increasingly areas, such as artificial intelligence, managing big data and the juxtaposition of food and medicine, are becoming part of our everyday working life.

To do justice to all the speakers at the conference would be impossible in this short article but two examples that demonstrate this come to mind.

The first was the very elegant solution Tesco has found to communicate to its customers not just which foods are gluten free variants of normal foods (several hundred products) but with the help of a customer idea and using artificial intelligence software they now can tell you which foods you can safely buy as part of a gluten free diet (over 20,000 products) thereby overcoming the essential issue – do consumers actually know which foods might contain gluten?

The second example is where opticians in Germany now assess their clients’ micronutrient status and provide supplements to mitigate challenges of macular degeneration and other eye health issues. How long before we see ranges of foods for eye health (and not just carrots)?

Finally, we held elections for the next President of IFST earlier this year and I am delighted that Helen Munday was the successful candidate. Helen will be well known to many of you at IFST and I look forward to working with her over the forthcoming years. I wish her all the best in her new role.

We are pleased to announce that Helen Munday is our new President Elect. Helen was invested during IFST’s Annual General Meeting on 12 March 2019.

Of her appointment Helen said: ‘It’s a huge privilege for me to take up this position. Both traditional and innovative food and drink products play an important role in our modern lives. All too often the skills and the science and technology behind them are taken for granted. During my tenure I will do my utmost to ensure our sector’s achievements, from academic research through to commercialisation, are widely recognised and valued.

I will strive to ensure that the food sector is as admired as others, such as aerospace, automotive and IT. I will look to balance the perception of our sector to fully recognise the positives in the food system including the role of technology and to make food and drink an aspirational career.’

Helen Munday is the Food and Drink Federation’s Chief Scientific Officer. Helen is accountable for the diverse food safety and science policy briefs, but also has responsibility for sustainability and contributes to health and wellbeing policy.

Helen has a wealth of experience of the food and drink sector. She started her career with Mars Petcare, where she spent 20 years in various roles including nutrition research, product development and innovation processes. A significant period of time was spent overseas, gaining invaluable international experience. Helen served as Head of Research at the Mars Petcare Global Research Centre for over five years.

Helen has also held the position of Director of Scientific and Regulatory Affairs for Coca-Cola and worked as Lead Technologist in AgriFood at InnovateUK.

Helen is a Fellow of Institute of Food Science & Technology and a Registered Nutritionist. With her qualifications in Agricultural Science and Meat Science, together with her vast business experience, she has a broad and deep knowledge across the entire agri-food chain.

On a daily basis, Helen is working with stakeholders at the most senior levels in Government, regulatory agencies, academia and NGOs to apply developments in the topics of food science and technology for the good of all.

Helen Munday announced as IFST President Elect

From the President

David Gregory
President, IFST

IFST Lecture 2019

IFST Lecture is always one of the highlights of our calendar. This year we are delighted that our guest speaker will be Professor Mike Gibney, University College Dublin. Professor Gibney is a former President of the Nutrition Society. He has served on several EU and UN committees on nutrition and health and published over 350 peer reviewed and scientific papers in Public Health Nutrition and Molecular Nutrition. He is a principal investigator on several national and international EU projects and author of two popular books Something to Chew on: Challenging Controversies in Food and Health and Ever Seen a Fat Fox? Human Obesity Explored.

The event will take place on 2 July in London. It will also be live streamed to various satellite receptions around the UK. This event is by invitation only.
New Scientific Policy Director appointed

We are pleased to announce that Rachel Ward has joined us as our new Scientific Policy Director.

In this role, Rachel will be focusing on developing the Institute’s outward facing activities - particularly aimed at growing the Institute’s increasing influence on matters of policy in relation to IFST’s areas of interest.

Of her appointment she said: ‘I am delighted to be appointed Scientific Policy Director for IFST. As an IFST Fellow I have supported various activities over recent years and I am looking forward to having more opportunities to work with our members and wider stakeholders.’

Rachel Ward has more than 25 years’ experience in international strategy, standards and risk management for the food chain. With a BSc (Hons) in Applied Biochemistry and a PhD on in vitro skin toxicology models, Rachel has worked in various roles across the food industry including analytical laboratory management, supply chain quality assurance, regulatory compliance, scientific affairs and risk management.

As an IFST Fellow, Rachel is actively involved in her local Midlands Branch and several IFST special interest groups.

Jon Poole, IFST Chief Executive commented: ‘We are delighted to have Rachel join IFST. Rachel brings a wealth of food industry experience but is also well-known and respected by many in the sector. This is a key role for the Institute given our increasing role in external affairs and influencing food science policy and I know Rachel will prove to be a real asset to us in driving these agendas forward.’

Julian Cooper, Chair of IFST Scientific Committee added: ‘On behalf of the Scientific Committee it is a great pleasure to welcome Rachel to the IFST Executive. She brings a wealth of experience to the role of Scientific Policy Director and the Committee and I look forward to working with Rachel to provide effective responses to consultations and increasing the impact of IFST.’

University College Birmingham brings home the Food Challenge bacon

The IFST student Group hosted its first ever IFST University Food Challenge at Coventry University on 27 February 2019.

The event saw teams from five universities – University College Birmingham, University of Nottingham, Cardiff Metropolitan University, Coventry University and Oxford Brookes University – compete against each other in a food science trivia contest which covered a wide variety of food-related topics including food safety, food regulation, food manufacture, nutrition and sensory science.

For over two years, James Huscroft (Past-Chair of IFST Student Group) has been working with IFST and the Institute of Food Technologists Student Association (IFTSA) in the United States to bring this event together. Alice Nield (current Chair of IFST Student Group) picked up the baton to bring it home in the final stages.

After five exhilarating preliminary rounds and a neck and neck final, the team from University College Birmingham was crowned the IFST University Food Challenge champion.


IFST responds to FSA on allergens

We have recently responded to FSAs consultation on amending allergen information provisions contained within UK domestic food information legislation for food packed for direct sale (PPDS).

We believe that policy and legislation must result in a step change in consumer protection, characterised by clarity, simplicity, consistency and enforceability. The definition of PPDS should include pre-packed foods that are only partially packed, and food prepared and packed on the sales premises at the consumer’s request. Since teenagers and young adults typically communicate and interact via modern technology, all aspects of allergen labelling and information transfer should be ‘future-proofed’ in line with innovation.

We responded that a combination of the proposed options would be preferable. These include additional activities to promote best practice, mandatory ‘ask the staff’ labels and clarification that the product is prepacked and not fully labelled and hence written supporting allergen information should be obtained from staff. The proposed requirement for PPDS foods to have a label on the packaging to tell the consumer which of the 14 allergenic ingredients (re FIC Annex II) they intentionally contain is also a possibility if it addresses last-minute ingredient substitutions and does not discourage dialogue about food allergies.

We responded that understanding the differences between fatal and non-fatal incidents is beneficial for the food industry, allergic consumers and the wider public, highlighting that consumer concerns should be captured, reviewed and actioned, as lessons should always be learned.
This year’s conference focused on the topic of nutrition and addressed the important interface between human nutrition and food science and technology. It highlighted the very latest scientific and technological solutions that are being developed and implemented to start to tackle our big nutritional challenges. The importance of this area was reflected in the record number of attendees at the conference. Nutrition has become a key element in the food science and technology zeitgeist.

The event was opened by our President, David Gregory, and chaired by Professor Judith Buttriss, Director General of the British Nutrition Foundation, who set the scene for the day. She emphasised the need for providing targeted advice on nutrition and the application of science to develop nutrition policy. She called for a balanced message on the challenges for public health nutrition and gave an insightful overview into the nation’s diet.

The first session of the day, Tackling the nutritional challenges, started with Dr Petra Klass-Wigger (Nestlé Research), who spoke on Emerging science and innovation: the impact on food consumption and dietary patterns. She highlighted the strategic evolution of Nestlé’s nutrient profile system, impact analysis and the socio-demographic trends influencing food demand.

Petra covered some of the megatrends in nutritional science, such as personal diets and food microbiota, and looked at how consumers are moving from basic nutrition to functional benefits, such as gut health, and how health and wellness has become an important driver for consumer food choice. This provides an opportunity to improve diet towards recommended intakes. She gave some excellent examples of the practicalities of reducing fat and sugar and the challenges of fortification.

Judith Robinson of Tesco gave a great insight into The challenges of making it easier for consumers to make healthier choices. She stressed that it is crucial to understand customers and the nudges that encourage them to move towards healthier choices. There have been positive moves towards healthy options within Tesco categories through reformulation and portion control.

Professor Jeff Brunstrom (University of Bristol) delivered a presentation entitled Mind over platter: what can psychology tell us about consumer behaviour and looked at how to encourage people to make healthier choices. He explained how self-control in decision making involves modulation of the vmPFC validation system and how we can use the science of psychology to help drive positive sustainable changes in dietary behaviour.

The second session moved onto Gut reaction and implications for future foods. Professor John Mathers (Newcastle University) addressed Genetic influence on weight loss – opportunities for personalisation. He reflected on the relationships between genotypes and weight,
concluding that genotype is not an impediment to losing weight. He suggested that genes relating to attention, memory and reward motivation behaviour could be relevant to weight loss, reiterating how sustained weight loss can lead to remission of type 2 diabetes.

Dr Maria Traka (Quadram Institute) spoke on Personalised nutrition and the gut microbiome: opportunities and challenges. She discussed the diverse and dynamic gut microbiota communities within individuals using taxonomic and functional information and addressed the molecular mechanisms of disease prevention by complex diets.

The final morning session, entitled Gene-edited food-making history or repeating it? moved on to GM and gene-editing. Professor Johnathan Napier (Rothamsted Research) eloquently explained the difference between the two and how the European Union has categorised gene-editing legally as a form of GM.

He explained his role in running the only GM field trials in the UK, evaluating the performance of oilseeds engineered to accumulate omega-3 fish oils. Johnathan also addressed the potential future opportunities for gene-editing and the possibility for removing the allergenic agent from peanuts. Professor John Dupré (University of Exeter) discussed the bioethics of working on genome-editing of farm animals and the challenging ethical issues that it raised.

The afternoon’s first session moved on to Tackling the challenges of specialist diets with Professor Lisa Methven (University of Reading) looking at Developing foods for an ageing population. She explained individual differences in sensory perception of foods by the elderly and the associations with food choices and dietary intake.

Lisa stressed the importance of improving the palatability of food designed to meet older people’s nutritional needs and highlighted the need for product reformulation and fortification. The loss of taste in the elderly could lead to poor nutrition due to loss of appetite.

Professor Helen Griffiths (University of Surrey) expanded on the theme by looking at Personalised nutrition for the silver economy. She analysed the changing European and UK age demographic and the challenges of mortality and health driven by diet. Helen made a powerful argument for personalised nutrition and dietary intervention to reduce mortality rates in older adults.

Lucinda Bruce-Gardyner (Genius Foods) presented a talk on A gluten free – nutritionally rich creative journey. Lucinda shared her personal and inspiring entrepreneurial story and her breakthrough when trying to help one of her sons who was diagnosed as gluten intolerant. She developed a gluten-free loaf equivalent to a wheat bread and explained how perseverance and consumer demand has driven the company’s success.

The final afternoon session looked at Nutritional science and technology solutions with Dr Rob Winwood (DSM Nutritional Products.) focusing on New technologies to improve the micronutrient status of targeted populations. Rob explained how it is increasingly recognised that the optimal intake of many micronutrients is not being achieved and how an individual’s micronutrient needs depend on their genotype. He described sophisticated, wearable, activity measurement devices that can provide detailed personal information for specific nutrient interventions.

Sandrine Pigat (Creme Global) gave the final informative presentation on Using data and predictive models for new product development to assess safety, shelf life and health benefits. Sandrine explained how big data and data modelling is used for making informed decisions in new product development, business strategy and consumer health and safety.

The Chair, Judith Buttriss, concluded the enjoyable and informative day by providing a useful roundup of the topics, reiterating the important need for our nutritional choices to be based on sound evidence-based science.
Meet our values

At IFST our mission is to act as the voice of the profession. Over the last few months we have been working hard to develop our values to reinforce what we stand for.

Evidence based
All that we do and deliver is based on evidence. This fundamental principle lies at the very core of IFST’s consciousness. We provide scientific evidence that the public, policy makers and our members can trust and use.

Independent
Our independent position and voice is critical and is what we and the combined experience of our membership enables us to provide reliable and authoritative information.

Professional
We aim to be a repository of information. We provide reliable and authoritative information. Our independent position and voice is critical and is what we and the combined experience of our membership enables us to provide reliable and authoritative information.

Food Science Community
We value our members as a community of food scientists and technologists. We respect the diversity of our membership, seek to learn from each other and always encourage a friendly, approachable and supportive spirit from all who work for and with us.

Innovative
Food science and technology is by nature dynamic and innovative. Whilst a serious subject and with serious implications, it is exciting and fun. We will seek to reflect this dynamism in the way we work and communicate with others. We will therefore be responsive to the constantly changing environment in which we work and to the needs of our members and stakeholders.

Recent highlights from IJFST

Reducing sodium content of roasted peanuts
The effects of ten treatment combinations of two salts (NaCl, KCl) and glycine were evaluated on low-sodium roasted peanuts. Consumers’ (N = 330, recruited from college campus) liking, emotions, perceived saltiness and bitterness intensity, satisfaction and purchase intent (PI) of peanuts were measured.

Emotions and PI were evaluated before and after presenting a low-sodium health benefit message. Sodium content of peanuts was reduced from 140mg Na/50g peanuts to 41.67mg Na/50g without significantly affecting liking scores and with positive PI over 60%.

In general, high bitterness and low saltiness intensity ratings negatively affected liking and satisfaction. Consumers expressed less satisfaction when perceived saltiness intensity was ‘Not Enough’ than when ‘Too Much.’

Based on optimisation analysis, any formulation within the range of 59-100/0-40/0-12.5% NaCl/KCl/Gly representing a potential 37% sodium reduction past minimum ’low sodium’ requirements - will yield an acceptable product.

Detection of 5HMF in apple juice
5-HMF (5-hydroxymethyl-furfural) is a product of thermal treatment and is increasingly considered a food contaminant. Different concentrations of 5-HMF were measured in apple juice to evaluate the performance of the electronic nose (EN) and electronic tongue (ET) as rapid detection techniques for 5-HMF when coupled with chemometric analysis.

Principal component analysis (PCA) and linear discriminant analysis (LDA) evaluated the discrimination capacity of EN and ET for 5-HMF. Loading analysis examined the discrimination contribution of the EN sensors.

Partial least square (PLS) regression analysis established a quantitative prediction model for different concentrations of 5-HMF based on EN and ET data. The results demonstrated that EN and ET coupled with chemometric analysis are two promising approaches for the rapid and online detection of 5-HMF in apple juice.

Oral behaviour of food emulsions
This study investigated the assumption that α-amylase in human saliva will interact instantly with starch and will lead to different oral behaviour and enhanced flavour release.

Orange oil flavoured emulsion was prepared with whey protein isolates (WPI) and modified starch (MS). The stability and flavour release of emulsions were examined through in vitro and in vivo studies.

MS emulsion mixed with artificial saliva containing α-amylase resulted in increases in mean particle size from 0.185 to 2.35µm and a significant increase in viscosity. Morphology and turbidity revealed strong flocculation, coalescence and creaming. However, WPI emulsion exhibited very little change in stability and behaviour.

Similar results were observed during oral digestion (in vivo) for both emulsion systems. Moreover, a higher intensity of flavour release (37%) was observed in MS emulsion than in WPI.

This demonstrates that a starch-stabilised emulsion has a very different oral behaviour to that of a protein-stabilised emulsion.

Pujols et al., 2019, doi.org/10.1111/ijfs.14187

Li et al., 2019, doi.org/10.1111/ijfs.14178

Hu et al., 2019, doi.org/10.1111/ijfs.14152
Belfast set to host CHRO2019

We are pleased to announce that IFST Northern Ireland Branch is hosting CHRO19, the world’s leading international conference on Campylobacter, Helicobacter and related microorganisms between 8 and 11 September 2019 in Belfast.

This international workshop will feature presentations by international and local experts reporting their most recent scientific updates and will provide the opportunity to meet, listen to and interact with world-class experts in the areas of scientific and clinical research, public health and industry, including Nobel Prize winner, Robin Warren.

Members' and registrants' corner

Members
Joshua Edge MIFST, Technologist – Tesco Stores Ltd
Amy Walker MIFST, Technical Manager – Biscuits – Tesco Stores Ltd
George Merry MIFST, H&S, Hygiene & Quality Officer – Four Anjels Ltd
Miguel Costa MIFST, Technical Manager – Lamex Foods UK
Pu Yuen Adrian Cheung MIFST, Quality System Manager – Bakkavor Group
Emily Meredith MIFST, Fresh Specification Technologist, Grocery Technical Assistant – Sainsbury’s Supermarkets Ltd
Sian Flaxman MIFST
Jenny Curtis MIFST, Director – Fine Food Consultancy
Mitali Patel MIFST, NDP Manager – TATA Global Beverages
Andrea Parodi MIFST, Supply Chain Technologist – AGT Poortman
Kieran Allen MIFST, Healthcare Scientist Specialist – Public Health England
Mathieu Colmant MIFST, Director – followfoodlaw.eu
Antony Bagshaw MIFST, Business Development Manager – Concept Life Sciences
Francine Hammond MIFST, Technical Manager – Tesco Stores Ltd
Dr Kirsty Poursahabidi MIFST, Research Fellow – Ulster University
Sonia Andre MIFST, Director – Ask Sonia Limited
Dr John Butcher MIFST, Lecturer in Food Bioscience & Microbiology – Glasgow-Caledonian University
Anis Patel MIFST, Food Safety Specialist
Joy Thomas MIFST, Business Manager – Cornelius Group Plc
Sean Sandison MIFST, Technical Manager – Tesco Stores Ltd
Sarah Ivens MIFST, Food Technologist – Food Centre Wales
Mary-Jane Hawkes MIFST, Assistant Lecturer – Coventry University
Noh Mataan MIFST – Halal Food Safety UK
Dr Silvan Somboonchan MIFST, Research and Development Scientist – Techno Food Ingredients

Fellows
Saiqa Aslam FIFST, Senior Group Technical Services – Cranwic PLC
Jamie Thornton FIFST, Managing Director – Food Safety Services Ltd
Sophie Christie FIFST, Technical Manager
Helen Maxwell FIFST, Technical Manager – Waitrose & Partners Ltd
Sameer Shah FIFST, Managing Director – MS Laboratories Ltd
Dr Elizabeth Krushinskie FIFST, Senior Technical Advisor – Firm Consulting LLC
Michael Hoffman FIFST, Technical Controller – The Silver Spoon Company
Dr Jane Parker FIFST, Associate Professor – University of Reading
Denis Treacy FIFST
Syed Nauman Gauhar FIFST, Technical Consultant – Shanz Services Ltd
Victor Medina FIFST, Managing Director – Integra Quality Ltd
Mollyanne Trumble FIFST, Interim Technical Consultant – FSQ Ltd
Breeda Cotter FIFST, Consultant & Freelance Contractor – Breeda Cotter Consultancy Ltd
Ben Dodridge FIFST, Category Technical Manager – Prepared Foods – Tesco Stores Ltd
Justine Norris FIFST, Director – Cotswold Project Management
James Ian Service FIFST, Director
Johanna Hill FIFS, Senior Team Leader (Paediatrics Product Development) – Nutricia (Danone)

Registered Scientists
Zoe Chick RSci, Quality Auditor Placement Student – University of Nottingham
Teresa Ennis RSci, Food Scientist – Mondelez International
Velimir Kirov RSci, Graduated Technologist Engineer – Millers Bespoke Bakery

Chartered Scientists
Rebecca Durrant CSci, Produce Technologist – Ocado
Roger Anderton CSci, Director/ Master Butcher – Anderton’s Ribble Valley Butchers

Registered Food Safety Principals
Chris Gilbert-Wood RFoodSP, Director – CGW Food Tech

Registered Food Safety Managers
Helen Maxwell RFoodSM, Technical Manager – Waitrose & Partners Ltd
Sian Flaxman RFoodSM
Barrie Trevena RFoodSM, Director – Kernow Enviro-Wise Ltd
Mollyanne Trumble RFoodSM, Interim Technical Consultant – FSQ Ltd

Registered Food Auditors and Mentors
Sian Flaxman
Barrie Trevena, Director – Kernow Enviro-Wise Ltd
Brexit-related uncertainties are now massively greater than almost everyone expected in the aftermath of the referendum. No-one knows what the impact of Brexit will be on the UK food system, but there are good reasons for thinking that the harder the Brexit, the more problematic will be the consequences for the UK and the Irish Republic. Food security requires a system that provides a sufficient, sustainable, safe, healthy and affordable supply – a hard Brexit could undermine food security in all five respects.

The UK imports 30% of its food from other EU Member States[1]. 11% more comes from other countries (much via Rotterdam) under trade deals negotiated by the EU[2]. If Brexit leaves the UK outside the Customs Union and the Single Market, those supplies will become harder to obtain and more expensive.

Some Brexiteers, and the Trump administration, want the UK to import far more food from the USA, others favour Africa, others even further afield, but then it would be less safe or more expensive, or both. Senior supermarket executives have warned of empty shelves[3], and many companies have invested in stockpiling. Michael Gove, Secretary of State for Environment, Food and Rural Affairs, has said that to avoid delaying imports he would instruct Port Health Authorities not to inspect food consignments from the EU[4]. But that might result in numerous condemned loads from across continental EU being funnelled into the UK, undermining food safety. Many food companies have been stockpiling key ingredients, but perishable foods cannot be stockpiled, and stockpiling is an additional cost, for which additional income is unlikely to be forthcoming.

A No-Deal Brexit would mean trading with the EU, and the rest of the world, under the rules of the World Trade Organisation (WTO). WTO rules are designed to reward the most price-competitive suppliers, which provides suppliers with a strong incentive to externalise as many ecological and public health costs as possible. Consequently, public and environmental health is likely to be undermined by increased international price competition, especially if Brexit is used as an opportunity to reduce food Brexit dilemmas

Prof Erik Millstone, Professor Emeritus of Science Policy at the University of Sussex, assesses the likely impacts of a hard Brexit on the UK food system.
‘regulatory burdens’ on industry and commerce.

Senior US officials have insisted that the UK must accept any and all exports of US food products if it wants a free trade deal with the USA[5]. As a member of the EU, UK livestock producers have had to implement the policy of reducing the use of antibiotics in livestock. In the EU they can only be used therapeutically, not prophylactically, nor as growth promoters. Between 2009 and 2018 antibiotic sales to US livestock farmers rose by 27%[6], whereas UK farmers reported a 26% reduction[7]. SUSTAIN, the UK’s leading coalition of food and farming NGOs, reported in February 2018 figures indicating that the rate of microbial food poisoning in the USA is about ten times as high as in the UK[8]. US hygiene standards are poor and control technologies (like chlorine washing) are ineffective[9].

In September 2018, the UK’s International Trade Secretary, revealed that post-Brexit he wants to repeal EU food standards using controversial powers, which would bypass Parliamentary scrutiny[10]. Other ministers have contradicted Liam Fox’s plan[11], but that just compounds the uncertainties. ‘Taking back control’ is a good slogan but hard to achieve in a world food economy where supply chains are so interconnected. The claim that, on leaving the EU, the UK can cease to be a ‘rule taker’, and becoming instead a ‘rule-maker’, and trade freely with countries in all parts of the globe, is an illusion. If, as an independent country, the UK sets rules covering food safety and standards that do not meet the requirements of our trading partners, we may be able to import foods from anywhere, if their products conform to our rules. But UK producers will not be able to export to countries with tighter standards than the UK, unless they manufacture products for export that differ from those for domestic sale. If you want to export, your products must conform to the importers’ rules. The suggestion that the UK could substantially increase its exports while adopting a unique set of rules that will not be shared by our trading partners is a fantasy. In practice, the UK must decide which agricultural and food rules it will take: those of the EU, the USA or the WTO.

In summary, the implications of Brexit for the future of food in the UK are hotly contested and profoundly uncertain, but they could well be harmful to the UK and its citizens.

References and article available online at fstjournal.org/features/33-2/food-brexit-dilemmas

Prof Erik Millstone, Professor Emeritus of Science Policy, University of Sussex

email e.p.millstone@sussex.ac.uk
As anyone who has followed the Brexit negotiations can attest, the political process surrounding the UK’s departure from the European Union has been very challenging. There still remain many more questions than answers surrounding Brexit, and even at this late stage, uncertainty continues to complicate matters for our industry.

FoodDrinkEurope regrets but, of course, respects the decision of the UK to leave the European Union. What is of importance now is our future relationship. We must ensure a future trade relationship between the EU27 and the UK that allows for our strong trade links to continue and even to grow.

There is no industry more affected by Brexit than the food and drink industry. In 2018, frictionless trade between the EU27 and the UK resulted in food and drink exports to the UK worth €33bn, while exports from the UK to the EU27 amounted to €14.4bn. Many food and drink companies have established manufacturing sites across the entire EU28, including in the UK, and our supply chains have flourished thanks to free movement of raw materials and ingredients throughout the whole area. We have a lot to lose should the future trade relationship between the EU27 and the UK suffer and that is why we continue to advocate for the best interests of our industry – the largest manufacturing sector in the EU – and for the 4.57 million people it currently employs across the EU.

We firmly believe that the best way forward is to ensure no, or limited, regulatory divergence between the EU and the UK.

Mella Frewen, FoodDrinkEurope Director General, identifies the ingredients of a beneficial trading relationship between the UK and the EU post-Brexit.
Being a member of IFST provides you with a whole range of benefits to support your professional development. But, more than this, you’re part of a professional network which is working tirelessly to:

**SETTING AND RECOGNISING PROFESSIONAL STANDARDS**

The food and drink sector demands high levels of expertise and professionalism to ensure that our food is always of the highest possible standard. Our professional registers are widely recognised and valued throughout the sector as the benchmark for skills and expertise for food professionals.

**DELIVERING AN INDEPENDENT VOICE**

As a charity and professional body that is independent of government, industry and any other organisation, IFST is in a prime position to provide impartial, science-based information.

**PROVIDING AN ACCESSIBLE KNOWLEDGE BASE**

Scientific knowledge is fundamental to everything IFST delivers. We encourage the exchange of knowledge amongst food professionals. This knowledge needs to be evidence-based, yet understandable and accessible.

**SUPPORTING THE FUTURE OF FOOD**

The shortage of new talent to fill skilled roles in the food sector is a critical issue. A key focus for the Institute is therefore encouraging and supporting the future generation of food scientists and technologists. We have developed, often in collaboration with others, a wide range of activities and events.
there is also growing awareness of the potential wider ecosystem benefits of bivalve aquaculture, including regulating services such as nutrient remediation, carbon sequestration and coastal defence. In fact, non-food ecosystem services provided by bivalve aquaculture globally have been estimated to be worth between $2.95bn to $9.99bn USD per year.

The urgent need for sustainable food production systems capable of meeting a growing global demand for animal protein whilst removing the negative environmental impacts associated with wild bivalve harvesting and supporting a 'Blue Growth' agenda has boosted interest in bivalve aquaculture. Traditionally, bivalve aquaculture had largely been established in inshore areas either on the seabed or on structures fixed or floating in shallow sheltered waters. In this environment there have been notable negative environmental impacts. For example, farming bivalves in sheltered, poorly flushed inshore waters can result in the accumulation of waste products that pollute the seabed.
Recently, however, there has been a significant global offshore expansion of the industry with many large-scale aquaculture farms now operational in deeper and more exposed offshore waters in the UK, China, Canada, USA, New Zealand, France and Japan. In contrast to inshore waters, the offshore aquaculture industry is perceived as a more space-efficient and lower impact method to produce seafood\cite{7}. Offshore bivalve aquaculture has considerable growth potential especially in areas where planktonic food is plentiful, water conditions including depth are suitable and likelihood for conflicts over space use is low\cite{7}. The rise of offshore aquaculture has been driven in part by technological innovation and also a desire to increase sustainable food production. In 2018, a global seafood consumer survey highlighted that consumer demand patterns are changing, with 83% of seafood consumers agreeing that there is a need for sustainable seafood and 72% wanting independent evidence to support claims for sustainability\cite{8}. Offshore bivalve farming, such as cultivating rope-grown mussels, is a relatively new mode of bivalve aquaculture being promoted as one of the lowest environmental impact animal protein production methods available because the species feed naturally in the ocean and reduce local biodiversity\cite{6}.

**Figure 1 Global bivalve fishery production 2000-2016 (mussels, oysters and scallops)**

*Blue mussels, top right, on a rope in Lyme Bay*
can be harvested with relatively low fuel requirements. Mussel farms in general have also been highlighted as a climate-friendly method of food production with greater potential as a carbon sink for large-scale offshore farms. While mitigating climate change through bivalve aquaculture is currently not the primary driver for industry growth, it will become an increasingly important consideration in food production. A recent report by the Scottish Aquaculture Research Forum[11] showed that mussel farms have the lowest carbon footprint in animal food production with high carbon sequestration in the shells of the mussels estimated at 218,870 kg CO₂-eq per tonne of mussels harvested.

**Sustainable production**

Understanding the complex spectrum of ecological and social consequences of aquaculture is key to determining the sustainability of the industry[10,12] and to secure its role in global food production. International organisations, such as the Global Aquaculture Alliance, support sustainable growth of food production by providing guidance on best-practice for responsible and sustainable aquaculture and certification schemes for facilities that are managed in an environmentally, socially and economically responsible manner. The success of certification schemes hinges on robust and transparent evidence of sustainable practice. The future growth of offshore aquaculture as a sustainable low-impact production method will in part depend on addressing concerns over perceived environmental impacts, competition for ocean space and evaluation of benefits to inform policy in permitting and regulations.

Assessing sustainability for offshore aquaculture provides a wealth of new opportunities for scientists to collaborate with industry to help steer growth toward sustainable practice and support decision makers in managing ocean space for a balanced ‘blue growth’. Robust monitoring programmes capable of providing reliable evidence of the positive and negative impacts of offshore aquaculture to inform recommendations for best practice are crucially important to accomplish sustainable growth of marine bivalve production. To date, very limited research has been conducted on environmental change associated with offshore aquaculture, despite ‘blue growth’ strategies calling for greater offshore development. The UK is currently one of the largest producers of aquaculture products within the EU, with farming of mussels (inshore and offshore) being a major contributor to the UK shellfish aquaculture sector accounting for 95% of the total shellfish tonnage in 2012 and 80% of the total income[13]. UK aquaculture rope-grown mussels are included on the Marine Conservation Society ‘Best Choice Top 10’ list recognised with the highest rating for sustainability[14].

**Partnerships**

In the UK, unique partnerships between scientists from University of Plymouth and mussel farm entrepreneurs and scallop ranchers are exploring whether offshore bivalve aquaculture can not only be an efficient producer of seafood but also capable of delivering a ‘win-win’ outcome with gains for marine biodiversity and spill-over benefits to neighbouring capture fisheries. The research team, which specialises in marine assessment and monitoring, has developed robust monitoring methods and analyses designed to inform the offshore aquaculture industry and marine managers of both positive and negative impacts associated with aquaculture practice. Using a range of underwater survey vehicles and sampling techniques, the team has been measuring the ecosystem effects of an offshore mussel farm in Lyme Bay (South West England), since it was established in 2013, and a scallop farm in nearby Torbay since 2015. The mussel farm, founded by Offshore Shellfish Ltd, is located between three and six miles offshore. The farm has developed an innovative suspended rope technology to cultivate the native blue mussel, *Mytilus edulis*, the larvae of which live in the plankton and naturally settle and colonise the ropes. Once fully completed, the farm will be the largest of its type in European waters, covering a total area of 15.4 km² and growing 10,000 tonnes of mussels per year. The scallop farm, founded by Scallop Ranch Ltd, is an experimental project to determine whether a sustainable and commercially viable alternative to traditional scallop dredging can be created and replicated. The farm is 0.18 km² in size and the scallops are grown in lantern nets suspended from secure lines. The young scallops (known as ‘spat’) are bred in a nursery from local wild stock before being placed in the nets. Both the mussels and scallops then filter feed on the surrounding seawater requiring no additional food or chemicals.

**Biodiversity**

Early observations by the University of Plymouth team demonstrate that the mussel ropes, home to millions of blue mussels, also attract a high diversity of other animals and plants that settle on and
Vertically hanging ropes act as fish aggregation devices and large shoals of Atlantic horse mackerel (Trachurus trachurus) are frequently seen swimming around and feeding on the ropes.

lobsters and predatory fish utilise these sites for food and shelter, but these observations are still only brief snapshots in time relative to the daily activities of these animals. We know very little about how these predators move around the farm, how long they remain resident, or if they move off out into fishing grounds or to the nearby MPA (Marine Protected Area). By offering a refuge function, the farm may function as a de-facto MPA by replenishment of local fish populations (referred to as a ‘spill over’ benefit). To investigate these important questions a new project, ROPE (Response of Predators to Protection and Enhancement), funded by the European Maritime and Fisheries Fund via the UK Marine Management Organisation, applies innovative acoustic tracking technology to understanding how the UK’s largest offshore rope-cultured mussel farm influences the movements of commercially important fish and crustaceans. Working in collaboration with the local fishermen and the mussel farm owners, the project will tag and track the movements of seabbass, brown crab, lobsters and crawfish for up to two years. The tags attached to the animals emit a unique coded ‘ping’, which is recorded and monitored by static underwater listening devices, or acoustic receivers, placed around the farm, inside the nearby MPA and across fishing grounds in Lyme Bay. To supplement the acoustic tracking, we also use thin plastic coded tags that are reported back to the team when tagged crabs and lobsters are caught by fishermen. This unique project has received strong support from the seafood industry, marine conservation groups and government agencies with jurisdiction for effective marine planning and licencing of commercial aquaculture.

Conclusions
All sectors support the view that robust scientific evidence will improve our understanding of marine ecosystems and this information is vital to underpin policies and strategic decisions for sustainable and responsible use of our oceans. Our initial observations suggest that offshore bivalve aquaculture can potentially have a wide range of beneficial effects for the environment and may enhance the catch of local fisheries while having lower negative impacts than other methods of marine food production. The science-industry partnership in Lyme Bay is aiming to increase recognition of the potential for offshore aquaculture to play a significant role in achieving local conservation objectives, as well as demonstrating that offshore aquaculture can meet sustainable development goals. Early indications are that offshore bivalve aquaculture, particularly when strategically located over already degraded seabed or areas with low conservation value, has potential for achieving net environmental gains, supporting thriving oceans and achieving prosperous and healthy fisheries. As the blue economy continues to grow, more research will be needed to provide sound advice on the feasibility of co-locating offshore aquaculture with other interests, such as MPAs, offshore renewable energy installations and other fisheries. University of Plymouth is developing and applying survey tools and scientific techniques through collaborative work with food producers to support progress in sustainable aquaculture in the UK and beyond. The bivalve aquaculture industry clearly has an important role in the blue economy as a sustainable food production method, where a healthy ocean is essential to economic success. As Dr Sandra Shumway, Editor of the Journal of Shellfish Research, wrote ‘shelfish growers are committed to water quality – quality of their product and quality of the environment – from the day the molluscs spawn to the day the finished product is eaten by the consumer’.[21]
New species for EU aquaculture

Constantinos C Mylonas, Rocio Robles, Gemma Tacken, Marija Banovic, Athanasios Krystallis, Lluis Guerrero and Kriton Grigorakis, collaborators on the EU DIVERSIFY project, explore the biological and socio-economic potential of new-emerging candidate fish species for the expansion of the European aquaculture industry.

Introduction
The aim of the EU DIVERSIFY project was to expand the European aquaculture industry by diversifying its production and introducing new/emerging species with important advantages over those cultured currently, such as fast growth, large size or low requirement for fishmeal and oil. Another objective was to determine the drivers for market acceptance of the new food prototypes in order to position the EU aquaculture sector as a leader in aquatic food production.

The EU is the largest importer of fisheries and aquaculture products in the world. However, aquaculture accounts for only 20% of fish production in the EU, while the worldwide contribution of aquaculture towards seafood production is >50%[1]. An efficient, sustainable and market-orientated expansion of the EU aquaculture sector based on new fish species and products will reduce the dependence of the EU on imports, reduce the pressure on over-exploited fisheries and explore new segments and tailor-made products for the EU market.

DIVERSIFY has identified six new/emerging finfish species, with great potential for expanding EU aquaculture[2].
These fish species were chosen based on their biological and economic potential to stimulate aquaculture across the entire European geographic area. The fishes selected for study were meagre (Argyrosomus regius) and greater amberjack (Seriola dumerili) for warm-water marine cage culture, wreckfish (Polyprion americanus) for cool-water marine cage culture, Atlantic halibut (Hippoglossus hippoglossus) for marine cold-water culture, grey mullet (Mugil cephalus) a euryhaline omnivore for pond/extensive culture, and pikeperch (Sander lucioperca) for freshwater intensive culture using recirculating aquaculture systems (RAS). A wide range of factors, including reproduction, genetics, nutrition, larval and grow out husbandry, fish health, socioeconomics and final product quality were investigated for all these species.

Socioeconomic research
A science-based, applied market development approach was adopted to explore the perception of aquaculture products in general and of specific new fish products. The project addressed market potential and demand factors and motives, consumer and professional buyer preferences, and added value from new product development in relation to raw products.

An important barrier to the introduction of new fish species is that a large proportion of EU consumers is product-loyal in buying food. Market research identified the potential for new aquaculture fish products in cross-cultural consumer segments with increased-to-strong interest in new products in the main EU fish markets (France, Germany, Italy, Spain and the UK). DIVERSIFY has developed new processed
fish products and carried out sensory and conceptual testing by consumers in the five selected countries. This resulted in a sensory positioning in relation to other species in the market and identified opportunities for marketing. Market research indicated that buyers and consumers would welcome new species, if they are a) sustainably farmed, ideally in domestic or EU waters; b) fresh (especially southern-EU) or mildly processed (northern-EU); c) easy to prepare and/or ready to eat; and d) competitively priced.

In Europe, greater amberjack showed the most promising market opportunities, given its large size, processing potential and superior sensory characteristics. Grey mullet is a very interesting species requiring less fish meal and fish oils in its diet, which increases the sustainability of its production methods. No specific region with a preference for this species was identified. Wreckfish has very firm flesh that differentiates it readily from the other fish. The remaining species (Atlantic halibut, pikeperch and meagre) have certain advantages due to their biological and physical characteristics and are of interest in specific regions of Europe.

Research showed that the introduction of new species would have most impact if carried out on a country-by-country basis, because each market has different factors and motives that affect purchase behaviour. In some countries, the growth model shows that early adopters encourage the majority of consumers to try the new species, while in France, early adopters try the product readily, but encouraging the majority of consumers to try the fish needs extra marketing effort. In all countries, introduction of the new products in conjunction with a reference product that consumers already know improves acceptance and purchase by retail buyers and consumers. Changing the price to penetrate the market was only successful in Spain. In all other markets, price changes had a negative impact on market penetration.

The research has provided new insights in choice and buying behaviour of fish in the five main markets of the EU, identifying the most relevant segments of consumers in the five countries, how the product should be priced to have a good margin and where costs could be reduced to improve the margins.

**Product development**

The project aimed to develop new product concepts from the selected fish species based on consumer and expert input and to measure their technical and organoleptic characteristics.

In order to generate ideas for product concepts for further testing, focus group discussions were held with consumers and interviews were conducted with experts in the selected countries. In total, fifteen feasible ideas were generated from consumer focus groups. The experts interviewed agreed that the new products developed by the project were attractive and feasible with potential in the marketplace, provided that they are developed in close association with fish
yet as a farmed fish, it was not.

As a farmed fish, it was not available at all. As a farmed fish, it was not available at all.

Meagre was used to develop ‘frozen fish fillets with different recipes’, ‘fish burgers shaped as fish’ and ‘ready to eat meal: salad with fish’. Pikeperch was used for ‘fresh fish fillet with different ‘healthy’ seasoning and marinades’, ‘ready-made fish tartar with additional soy sauce’ and ‘fish spreads/pate’. Grey mullet was used for ‘thin smoked fillets’, ‘ready-made fish fillets in olive oil’ and ‘fresh fish fillet with different ‘healthy’ seasoning and marinades’.

Finally, greater amberjack was used for ‘frozen fish fillet that is seasoned or marinated’, ‘ready-made fish tartar with additional soy sauce’ and ‘fresh fish steak for grilling in the pan’. Guidelines, processing conditions, technical specifications and troubleshooting were established for these products as well as basic information on packaging, preservation, preliminary product shelf life and consumer handling/cooking specifications. These new product concepts had differing degrees of complexity, but in all cases it was possible to produce prototypes using the selected fish species. The results suggested that it was possible to produce these products at an industrial scale, which was corroborated by the presence of other similar products in the marketplace.

The technical characteristics and quality of the new products were assessed. The proximate composition of the products (protein, lipid, moisture, inorganic and carbohydrate content), the energy content, the quantitative nutritional value in terms of fatty acids and the sensory profiles were determined. As expected, processing had an effect on both the proximate composition and fatty acid quality of the products when compared to the raw fillet tissue. However, the effect depended on the processing method used, as well as the inclusion of additional materials (such as olive oil) during the product formulation. Processing generally had a negative impact on nutritional quality of the majority of products, reducing the proportion of essential fatty acids, i.e. EPA and DHA, when compared to the corresponding fish fillets. All processed products exhibited unique, more complex, sensory profiles, with more attributes than the unprocessed cooked fillet of the species. The characteristics of the processed products in the majority of cases were connected to the added materials and/or the processing method.

Finally, the correlation between the fish dietary history (e.g. dietary fat and protein levels, fat sources, etc.), other rearing parameters (e.g. rearing system, temperature, or density) and the end-product quality was evaluated. Results indicated that filleting yields and protein contents were not influenced significantly by rearing and dietary histories at grow out stage. Greater amberjack displayed the highest filleting yields and final contents of protein, fat and especially highly unsaturated fatty acids. Due to its vulnerability to fat oxidation, it was suggested that commercial sizes should be 1-2 kg with a relatively lower fillet fat content than bigger fish. Meagre filleting yield and protein content were quite attractive. This species has a characteristically low total fat content – an attractive feature for low fat dietary regimes – that is not influenced by the dietary or growing history of the fish. Grey mullet was confirmed as the best candidate for marine ingredient substitution of its diet either by terrestrial or marine origin vegetable sources. Diet had an important effect on the sensory characteristics of the grey mullet, especially in relation to the fillet fat content and its oxidative stability. Production at an industrial scale of the developed fish products was considered feasible. The technical yields achieved were good for all products, thus providing potential for high profit margins. The duration

"Processing generally had a negative effect on nutritional quality of the majority of products, reducing the proportion of essential fatty acids, i.e. EPA and DHA, when compared to the corresponding fish fillets."
There is a clear need for the aquaculture industry to persuade/engage consumers that new aquaculture products can constitute an excellent source of sustainable, high quality food.

The DIVERSIFY (EU FP7-GA603211) consortium consisted of 40 partners from 12 European countries, made up of research and academic institutions, as well as nine SMEs, three large enterprises, five professional associations and one consumer non-governmental organisation. DIVERSIFY had a total budget of €11.8m and lasted for five years (2013 – 2018).

DIVERSIFY investigated creating opportunities for new product concepts across Europe. European aquaculture could benefit from raising consumer awareness in the different segments about aquaculture products. The future of aquaculture seems less dependent on geography and more dependent on consumer lifestyles and their psychographic profiles.

Consumer sensory perceptions
Sensory profiles of six new products from the DIVERSIFY fish species (with low, medium and high processing levels) showed that products with a lower degree of processing generated higher overall consumer acceptability. However, products with a higher degree of processing were found to be more acceptable to consumers who do not like fish because of its taste, odour and the presence of bones. Differences in the overall acceptability and preferences across the different consumer segments were minimal.

Optimisation of intrinsic-extrinsic attributes
The optimal intrinsic-extrinsic quality profiles of the new products were determined using prototypes from the DIVERSIFY fish species[9]. The results indicated that it was possible to create new aquaculture products targeting similar consumer segments across all the big EU markets. A similar pattern in consumer choice-drivers was observed, with country of origin and price coming first, followed by quality certification (i.e. Aquaculture Stewardship Council (ASC) – label); nutrition/health claims appeared to have varying effects. In the aquaculture industry, the use of an ASC label signals to consumers that products come from a ‘controlled’, certified and responsible aquaculture source and increases the probability of consumers choosing and trusting a product.

Communication and behavioural change
The importance of communication in changing consumer attitudes and behaviour towards the newly developed product prototypes from DIVERSIFY fish species was demonstrated. There is a clear need for the aquaculture industry to persuade/engage consumers that new aquaculture products can constitute an excellent source of sustainable, high quality food. Results suggested that aquaculture products should not be promoted using generic messages, but should emphasise the traceability and health benefits as well as promoting the products as tasty alternatives for modern diets and responsible consumption.

Conclusions
The main impact of DIVERSIFY is expected to be the improvement of production technologies for the new/emerging fish species assessed in the project[10-12]. Furthermore, DIVERSIFY provides useful information on consumer perception and preferences that could help to increase the consumption of aquaculture products in the EU. An integrated approach combining biological, technological and socioeconomic activities will lead to a reduction in the dependence of the EU on imports from third countries, which do not always meet the desired standards for health, production methods and environmental quality.
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Sustainable Aquaculture Futures

Lisa Bichley and Nicola Rogers introduce the new Centre for Sustainable Aquaculture Futures (SAF), which is a collaboration between the University of Exeter and Cefas (the Centre for Environment, Aquaculture and Fisheries Science). It was launched in 2017 to facilitate wider collaborative opportunities in the aquaculture sector.

The growth of aquaculture

Aquaculture remains one of the fastest-growing food producing sectors in the world. The annual growth rate of fish consumption has now surpassed the growth rate of meat consumption (all terrestrial animals combined)[1]. As capture fishery production has been relatively static since the late 1980s, aquaculture has been responsible for the continued growth in the supply of fish for human consumption[1].

A significant milestone was reached in 2014 when the consumption of fish from aquaculture exceeded that from wild-caught fish for the first time[1]. However, with an increasing world population, for global fish availability to meet projected demand, it has been estimated that aquaculture production will need to more than double by 2050, rising to roughly 140m tonnes produced[1].

Aquaculture has the potential to play an important role in improving global food security. Increasing the proportion of farmed seafood in human diets could reduce agricultural land use (one of the largest pressures on the planet) compared to current food system trends[1]. However, aquaculture is not without its own challenges and any development must be conducted with high regard for sustainability of expansion and intensification.

Disease, or the achievement of high aquatic animal health status, is recognised as one of the major barriers to achieving enhanced sustainable production in aquaculture to 2050[4]. Mitigation of the negative impact of disease on yield is a central tenet in fulfilment of global production targets. Conservative estimates predict at least $6bn losses per annum from the global aquaculture industry due to disease[7]. Losses associated with disease caused by high-profile listed and emergent pathogens not only have the ability to inflate background losses, but also to implicate farmers from the most vulnerable producer communities in developing countries and to affect the globalised trading of foods.

Furthermore, disparity in the level of sectoral development and uneven production distribution remain significant[3]. Globally, aquaculture is dominated by Asia, which accounts for 89% of world aquaculture production[8]. Of this, China is by far the world’s top fish producer and the largest exporter of fish and fish products. Sixteen of the top 25 global producer countries, responsible for producing 94.4% of total aquaculture protein, are considered ODA (Official Development Assistance) eligible[2]. Therefore, solving problems in aquatic food security must take account of diverse scientific, commercial, sociological and political dimensions. In this respect, working in partnership and an increased focus on translation of scientific research to beneficiaries (farmers, their families, industry, and government) is key.

Centre for Sustainable Aquaculture Futures

Since its launch by Environment Secretary, Michael Gove, in October 2017, the Centre for Sustainable Aquaculture Futures (SAF) has established...
a strong presence within the UK and overseas via a range of programmes focused on aquatic animal health, diagnostics, host-pathogen interactions, AMR (anti-microbial resistance), human health and the social sciences. SAF has been developing collaborative partnerships with academia, governments and industry, and seeks to establish a network of world leaders in the fields of aquatic animal health, food safety and protection of the aquatic environment. To address the global challenges faced in aquatic food security and safety, sustainable intensification of aquaculture production will require innovative research and the translation of this research into practical solutions.

Key issues SAF is addressing include:

• providing scientific support to reduce global losses due to disease in aquaculture;
• providing evidence and tools to ensure that fish, shellfish, crustaceans and seaweeds produced in the global industry are safe to eat;
• understanding how cutting edge molecular diagnostics, pathology, animal breeding and nutrition can be applied to assist seafood farmers, particularly in more vulnerable societies;
• ensuring that aquaculture is developed sustainably, for the benefit of communities, economies and the environment.

Under the guidance of co-Directors Professor Charles Tyler (University of Exeter) and Professor Grant Stentiford (Cefas), scientists at the centre are working with experts across a variety of disciplines, spanning all scales of biological organisation from molecules to ecosystems, combining fundamental research with applied science, and working collaboratively with a wide range of partners locally, regionally and across the world to shape positive changes in practice, policy and innovation.

**A unique combination of capabilities**
At SAF the complementary expertise and capabilities of a cutting edge government laboratory and a leading university is supported by the combined offering of excellent research facilities and equipment. The University of Exeter is a UK top ten Russell Group University with a worldwide reputation for research excellence and award-winning impact in: investigating anthropogenic influences on marine biodiversity, chemical, particle and noise pollution, ocean acidification and offshore renewable energy. The Exeter team is also part of the group leading the RCUK’s Aquaculture Initiative Network – Aquaculture Research Collaboration Hub UK (ARCH UK®), which seeks to engage and expand UK expertise in aquaculture research and communication networks, and advise on funding for supporting the UK based aquaculture industry. The University of Exeter facilities include:

• Aquatic Resources Centre - a world class research and teaching facility that incorporates 14 aquaria rooms for both freshwater...
Assessing and Mitigating the risks of Harmful Algal Blooms (AMHABs)

Harmful Algal Blooms (HABs) or ‘red tides’ are a global issue and are increasing in frequency and impact, apparently in conjunction with climate change and nutrient enrichment. The production of biotoxins by HABs and/or the depletion of dissolved oxygen by decaying blooms, threaten shellfish and finfish aquaculture, including in UK coastal waters. In particular, HAB toxins can build up within marine species, such as shellfish, and become harmful to human health if ingested, even at relatively low toxin levels. In UK waters, HABs are currently estimated to cost marine industries over £20m per year, and their increasing frequency threatens to curb the growth of aquaculture.

The AMHABs project (led by Dr Ross Brown) is funded by the European Maritime and Fisheries Fund and aims to develop a regional model for predicting the HAB risks, both temporally and regionally (around the UK’s South West peninsula). Data for the model are collected based on environmental conditions known to promote blooms, including increasing solar radiation, sea surface temperature, rainfall, nutrient runoff and seasonal succession in plankton communities. Model predictions complement ‘real-time’ monitoring via in situ sampling and ‘remote’ satellite sensing of high biomass, surface-forming algal blooms. Predictions will allow existing aquaculture businesses to minimise the impact of HABs (e.g. by providing data to support the timing of shellfish harvesting, safeguarding food quality and human health) and will be used to guide the placement of new infrastructure in the UK’s forthcoming Marine Spatial Plan for SW England (e.g. locating new farms in areas that have a low risk of HABs).

Flexing your mussels: futureproofing shellfish aquaculture in the face of global climate change

This project is investigating the adaptive capacity of marine mussels across their global range when exposed to changing environmental conditions. Mussel aquaculture is worth $1.5bn globally, and is the primary aquaculture sector in Europe by weight. Cultivation of filter-feeders, such as mussels and oysters, has relatively lower environmental impact and arguably offers one of the main routes for sustainable expansion of aquaculture globally. However, mussels and oysters are also traditionally considered to be amongst the most vulnerable with respect to climate change. Consisting of three closely related species, which readily cross-breed (hybridise), marine mussels also offer a unique opportunity to investigate the impact of hybridisation on climate change tolerance.

NERC Industrial Innovation Fellow Dr Rob Ellis is employing novel genetic technology to develop an innovative, globally relevant tool (SNP array) to study hybridisation. Using a
multidisciplinary experimental approach, combining genetic techniques with traditional measures of mussel performance and physiology, and measuring these responses in multiple populations from across the global geographic range, Dr Ellis and his team are addressing the overarching question ‘does hybridisation confer an advantage to multi-stressor exposures in a commercially important bivalve species?’ This is a key knowledge gap that when addressed will enable the improved management of both natural and farmed mussel populations worldwide.

**Novel molecular tools for managing disease outbreaks in aquaculture for small-scale farmers**

Demand for fish in Asia and Africa is increasing and there is an associated expansion of aquaculture in these regions. In Bangladesh and India, shrimp and finfish culture sustains the livelihoods of hundreds of thousands of people. Disease is the biggest single factor limiting growth in aquaculture[7] and thus, combating disease is critical for both the protection of the livelihoods of farmers and for achieving national and global targets for aquaculture growth in support of poverty alleviation.

This Newton Fund project is led by Professor Charles Tyler and Dr David Bass and brings together an international consortium of biologists, social scientists, policy experts and NGOs from the UK, India, Bangladesh and Malawi. This multi-national team of scientists is seeking to develop and apply innovative and state-of-the-art methods in molecular biology, environmental DNA (eDNA) and histopathology for use as early warning tools to prevent disease outbreaks in aquaculture. Field-collected data is used to develop models for predicting the drivers of disease outbreaks. The ability to make these predictions will allow farmers to harvest their fish before disease onset, thus preventing major crop losses. This will increase crop productivity and, in turn, the health, well-being and profitability of small-scale farmers. The provision of training and knowledge exchange is also enhancing regional research capability. This is developing the skills of the next generation of local scientists, building future capacity to develop aquaculture in the region.

The project team has developed bespoke mobile phone apps to collect large data sets on farm management practices from hundreds of small-scale aquaculture farms in Bangladesh and Malawi. These data are used to identify trends in farm management practices that lead to the best production outcomes for farmers (e.g. pond size, location, water chemistry and hygiene). Through stakeholder engagement with farming communities and policy makers, scientists and aquatic health professionals are ensuring these advances are effectively communicated for the greatest benefit. Research in eDNA is an expanding field in ecology, evolution and systematics. The findings from this work will be directly relevant to industries developing field-based molecular biology tools and applications to monitor aquaculture production. The research will also be relevant in disease diagnosis and mitigation beyond the confines of aquaculture. Outcomes from the project will be of interest to scientists researching human and animal diseases and also to the medical profession.

**Reducing global hunger and poverty**

WorldFish is an international, non-profit research organisation that harnessed the potential of fisheries and aquaculture to reduce hunger and poverty. Globally, more than one billion people obtain most of their animal protein from fish and approximately 800m depend on fisheries and aquaculture for their livelihoods. SAF scientists are partnering with WorldFish to help harness the potential of fisheries and aquaculture to reduce hunger and poverty. Collaborative research projects include: understanding the prevalence, spread and impact of key diseases in tilapia culture, and studying the impacts of antibiotic exposure on skin microbiomes and disease resilience in fish in aquaculture. Further work aims to highlight the importance of surveillance for antimicrobial use to identify the drivers and associated risks of Antimicrobial Resistance (AMR) emergence in aquaculture systems.

**The future role of fish in global food security**

The supply of sustainable food to a growing population is one of the critical challenges facing global society. It will require application of multi-disciplinary approaches, integrating data from different specialisms, and placing production in context with the environmental and human costs of meeting demand. Aquatic food is recognised as an extremely important part of world food security and nutrition. Importantly, we see aquaculture as a sector rather than a subject, where a broad range of stakeholders are brought together to consider how best to achieve a sustainable aquaculture future.

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**References and article available online at fstjournal.org/features/33-2-sustainable-aquaculture-futures**

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To find out more about the centre, or speaking to any of our researchers about collaboration, please visit the website at exeter.ac.uk/saf Pangasius: an important species for aquaculture in Bangladesh, contributing to annual fish production and the livelihood of rural people. Photo: Charles Tyler

Newton project: working with farming communities to develop the skills of the next generation, building future capacity to develop aquaculture for small scale farmers. This project engages and trains farmers in accurate disease diagnostics and establishes communication and training networks using bespoke apps and social media that will disseminate the outputs of the project as widely as possible.
Nutrition, epigenetics and health

John C. Mathers of Newcastle University explains how gene expression is regulated in the body and discusses how diet may induce heritable changes to the genome.

Epigenetics – the basics
Every nucleated cell in the human body contains approximately three billion base pairs (bp) of DNA and the DNA in each of these cells is exactly the same. The particular sequence of bases in the DNA for any individual was determined at conception and, except for monozygotic (identical) twins, each of us is genetically unique. From that fertilised egg onwards, at each cell division, our unique DNA sequence was copied faithfully to the next generation of cells. This means that each of our cells has the potential (the DNA blueprint) to make any of our proteins and to carry out any of our cellular functions. All cells express some genes in common i.e. the so-called ‘house-keeping’ genes that encode the proteins that are needed to maintain the basic functions of all cells e.g. transporting in oxygen and nutrients, generating ATP to fuel the work of the cell and exporting waste products. However, a liver cell is very different from a bone cell and since the work done by each cell type differs, there are characteristically different patterns of genes expressed in different cell types. In addition, during embryonic and fetal development, some genes are required for developmental functions that are not needed later in post-natal life. This means that some parts of the genetic code are ‘redundant’ in adult cells and there need to be mechanisms to control (or regulate) how the information in DNA is used to make the complement of proteins required by each particular cell in each particular circumstance. That regulation is provided, in part, by the cell’s epigenetic machinery. Epigenetics describes heritable changes to the genome without changes to the DNA sequence per se.\[1\]
In cancers and many other diseases, abnormal patterns of gene expression are associated with methylation of the promoter regions of specific genes leading to loss of function of the corresponding gene.

Epigenetic marks and molecules

The genetic code written in DNA is relatively simple. A unique linear sequence of adenine (A), guanine (G), thymine (T) and cytosine (C) bases provides the genetic blueprint for each individual. In contrast, regulation of the genome is necessarily complex to ensure fidelity of that unique DNA sequence and to ensure that the information in DNA is used in ways that are appropriate for the specific cell or tissue and any particular circumstance. For example, just after a meal, when we are absorbing nutrients that are required for immediate use, we need to switch on genes that are involved in nutrient storage e.g. for glycogen synthesis in liver and muscle. In addition, as noted above, specific cells, e.g. immune cells, neurones and muscle cells, carry out unique functions which mean that characteristically different patterns of genes are ‘switched on’ (expressed) in each cell whilst others are ‘switched off’ (silenced). The epigenetic machinery that contributes to this regulation includes a multi-layered system of chemical ‘marks’ and molecules together with a consortium of proteins described as ‘readers, writers and erasers’ that uses this epigenetic information[3].

i) Marks on DNA

Some cytosine (C) residues within DNA are modified by the addition of a methyl (CH₃) group to the 5’ position to generate 5-methylcytosine (5mC). This occurs normally when the C is followed by a guanine (G) in a so-called CpG dinucleotide. The pattern of methylation marks on DNA is dynamic with methyl groups being added by a family of DNA methyl transferase enzymes (DNMT, an epigenetic ‘writer’) and being removed by a series of reactions involving a group of enzymes known as ten-eleven translocation methylcytosine dioxygenases (TET, an epigenetic ‘eraser’). During the latter process, 5-hydroxymethylcytosine (5hmC) is produced as an intermediate (1). Recently, it has been discovered that in some body tissues, particularly the brain and embryonic stem cells, there is a considerable density of 5hmC as well as 5mC. Although the role of 5hmC is not yet well-understood, the role of 5mC in silencing genes has been established for many years. For example, about 40% of the human genome consists of repetitive elements, such as retrotransposons, which make up the large part of heterochromatin. Retrotransposons have been acquired after exposure to viruses over tens of millions of years and are potentially harmful. However, these areas of the genome are heavily methylated and ‘silenced’ so that the potentially damaging repetitive elements cannot be expressed. In addition, in cancers and many other diseases, abnormal patterns of gene expression are associated with methylation of the promoter regions of specific genes leading to loss of function of the corresponding gene[4].

ii) Marks on histones

Within the cell nucleus, DNA is wrapped around bundles of eight globular proteins called histones in a form of ‘smart packaging’, which regulates access to DNA for key cellular processes. Specific amino acid residues in the N-terminal tails of histones are ‘decorated’ by the addition of multiple small chemical groups including methyl, acetyl, phosphate and ubiquitin. These post-translational modifications appear to form a complex information system known as the ‘histone code’[5]. The histone code hypothesis suggests that the specific patterns of these histone modifications of distinct other proteins (epigenetic ‘readers’) which alter chromatin structure or enable gene transcription. Knowledge of the biological meaning of the various histone modifications is still rather sketchy although the role of a few of these marks has been elucidated. For example, chromosomal condensation that occurs in mitosis and meiosis is associated with phosphorylation of serine residues 10 and 28 on histone H3. Similarly, methylation of lysine residues at positions 4, 36 and 79 on histone H3 is associated with active transcription, whereas methylation marks on lysines at positions 9 and 27 on histone H3 and lysine 20 on histone H4 are associated with gene silencing. Importantly, it seems that DNA methylation and histone ‘decoration’ work together to regulate DNA[6].

iii) Non-coding RNAs

Less than 20 years ago, a new large family of RNA species was discovered that is now called non-coding RNAs (ncRNA) because these RNAs carry out their biological functions directly as RNA and do not need to be translated into proteins. From an epigenetic perspective, the best characterised ncRNA are the microRNA (miRNA) which are typically ~22bp long. The human genome encodes >1000 miRNA which regulate about 60% of all of our genes. Binding of particular miRNA in a sequence-specific manner to the 3’ untranslated region (UTR), to the coding sequence or to the 5’ UTR of the target messenger RNA (mRNA) inhibits translation or causes mRNA degradation. Again, there is coordination between types of epigenetic regulator and transcription of many miRNA is regulated by DNA methylation[7].

iv) The epitranscriptome

In the last few years, there has been an explosion of information about a constellation of post-transcriptional modifications e.g. addition of methyl groups,
on RNA species now known as the epitranscriptome[3]. This is an emerging field and much remains to be discovered but it appears that the chemically modified nucleosides in RNA play an important role in RNA homeostasis by regulating the amounts and activities of particular RNA species[4]. So far, little is known about whether, or how, environmental factors, such as diet, influence the epitranscriptomic landscape[1] but a potential link with obesity is discussed below.

Impact of dietary factors on the epigenome

The honey bee provides a striking example of the importance of diet in influencing the epigenome and subsequent effects on phenotype. Genetically identical female larvae are fed initially with ‘royal jelly’ but then those larvae destined to become worker bees are switched to a combination of pollen and nectar. In contrast, the tiny minority of bee larvae destined to become new queens continue to be fed royal jelly. This dietary difference results in two very different phenotypes – worker bees that do not reproduce and that have a short lifespan (a few weeks in summer) and the much larger queen bees, which can lay up to 2000 eggs per day and may live for three-four years (Figure 1). Several components in royal jelly are epigenetically active and it is becoming apparent that effects on a particular DNA methyl transferase (DNMT3) that is involved in ‘writing’ new methylation marks on DNA (de novo DNA methylation) may be central to the different reproductive potential of queen bees compared with worker bees that is induced by royal jelly[2].

Humans and other mammals do not exhibit the dramatic phenotypic plasticity that is evident in honey bees but there is growing evidence that a large number of components of human foods impact on epigenetic marks and molecules. For obvious reasons, most of the experimental work that provides evidence of causal relationships between food components and the epigenome has been carried out in mice or other model organisms. However, there is considerable empirical evidence that nutrients and other food-derived substances also influence the human epigenome. The molecular mechanisms underlying links between dietary factors and the epigenome are not yet well understood but include the role of dietary factors in i) providing substrates e.g. methyl and acetyl groups for marking DNA, RNA and histones and ii) affecting the activity of the epigenetic ‘readers, writers and erasers’ i.e. the proteins that are responsible for creating and using epigenetic information[5]. Folate, betaine and choline that contribute methyl groups for one-carbon metabolism influence cellular availability of S-adenosylmethionine (SAM), which is the universal donor used in methylating DNA, RNA and proteins, such as histones. The short-chain fatty acid butyrate, which is produced in large amounts in the large bowel from fermentation of fibre, was one of the earliest nutrients shown to have epigenetic effects. At physiological concentrations, butyrate is a potent inhibitor of histone deacetylase (HDAC) enzymes (which are epigenetic ‘erasers’) and, consequently, has widespread effects on gene expression. This action of butyrate is believed to be one of the mechanisms through which higher fibre intake protects against colorectal cancer and other large bowel diseases. Butyrate is also present in milk and milk products, including parmesan cheese[6].

Many plant secondary compounds (phytochemicals) that we value in foods because of their colours, flavours and health-promoting effects influence epigenetic marks and molecules. These effects occur largely through influences on the activities of epigenetic ‘readers, writers and erasers’ and some examples are given in Table 1.

Although the biological information in each individual’s genetic make-up (their genotype) sets boundaries for their individual phenotype, genetics is not destiny. Each person’s phenotype, at any particular time, is plastic and is a consequence of the cumulative effects of interactions between their genotype and environmental factors, including diet, over the life-course. The types of evidence discussed above supports the idea that epigenetics has a causal role in mediating the effects of interactions between diet and genetics in determining phenotype. This central role for the epigenome (illustrated in Figure 2) allows each individual (and, indeed, individual cells within each person) to respond to their nutritional environment and to ensure that an appropriate constellation of genes is switched on (and switched off) to help to main homeostasis and functional integrity[7].

Early life nutrition, epigenetics and health trajectories

Ground-breaking epidemiological studies by David Barker and his colleagues, supported by experimental studies in model organisms, have provided firm evidence for the idea that nutrition (and other environmental exposures) in early life has a lifelong ‘memory’ of early life events and exposures which persist across the life-course. These findings gave rise to the Developmental Origins of Health and Disease (DOHaD) hypothesis, which posits that the early life environment may alter ‘programming’ of the phenotype with potential to influence the risk of chronic diseases from childhood to old age. Whilst several potential mechanisms to explain this lifelong ‘memory’ of early life events and exposures have been proposed, including abnormal development of organs and tissues, epigenetic mechanisms appear to be particularly important because they provide a well-recognised pathway for embedding durable evidence of such exposures, which persists across the multiple cell generations. Indeed, epigenetic marks and molecules may be especially sensitive to environmental exposures during very early development since this is a life-stage in which genome-wide patterns of DNA methylation undergo radical change[8].

Much DOHaD-related research to date has addressed maternal nutrition during pregnancy and, to a more limited
Obesity

We are familiar with the ways in which excess body fat increases risk of multiple complex diseases through endothelial dysfunction, oxidative stress, insulin resistance, dyslipidaemia and systemic inflammation. In addition, there is now strong evidence that the epigenome is also disrupted in obese individuals. For example, an epigenome-wide association study has revealed multiple changes in DNA methylation associated with body mass index (BMI)[9]. Obesity is a risk factor for many age-related diseases and reduces lifespan and there is now evidence that obesity is associated with acceleration of the ‘epigenetic clock’, a panel of CpG sites at which methylation changes track with ageing[9]. Very recently, a comparison of DNA methylation in obese individuals and in those with bowel cancer has shown hypermethylated CpG islands (clusters of CpG sites which occur, often, in the promoter regions of genes), which may account for the epigenetic instability that drives cancer initiation in obesity[9].

In humans, the most common epitranscriptomic mark is N6-methyladenosine (m6A) in which a methyl group is attached to the nitrogen (N) at position 6 in the adenosine base within mRNA. This provides a potential link with nutrition because the fat mass and obesity associated protein (FTO) is a demethylase (an epigenetic ‘eraser’) that converts m6A back to adenosine. The FTO gene is polymorphic and people carrying the unusual variant of the FTO gene (those having an A rather than a T at rs9939609) are heavier and more likely to become obese. The mechanism linking FTO genotype with excess weight is poorly understood but may relate to perceived responses to food since the FTO genotype regulates expression of ghrelin, the hunger hormone[10]. This provides a potential link between m6A and behavioural responses to food that predispose to increased energy intake and obesity[10].

Future perspectives

Research on understanding the effects of diet, and its interactions with genotype, on the epigenome and the consequences for health and well-being is moving fast. Advances in the field are being accelerated by better tools for investigating epigenetic marks and molecules. For example, commercial epigenetic arrays make it possible to interrogate the methylation status of >800,000 individual CpG sites simultaneously using DNA extracted from small amounts of human blood or tissue. In addition, next generation sequencing provides in-depth analysis of patterns of miRNA expression and of DNA methylation whilst ultra-high performance liquid chromatography (UHPLC) coupled with tandem mass spectrometry (MS/MS) can provide quantitative profiles of RNA modifications (the epitranscriptome). However, the complexity of histone ‘decorations’ is more challenging so that an integrated analysis of all components of the epigenetic machinery is unlikely to be routine for some time. Nevertheless, this novel research promises to deliver new insights into links between diet and health and is an attractive area in which ambitious young researchers can build their careers.

## Table 1: Examples of epigenetically active compounds from plant foods

<table>
<thead>
<tr>
<th>Name of compound</th>
<th>Example food source</th>
<th>Class of compound</th>
<th>Epigenetic action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anacardic acid</td>
<td>Cashew nuts</td>
<td>Phenolic lipid</td>
<td>HAT inhibitor</td>
</tr>
<tr>
<td>Curcumin</td>
<td>Turmeric</td>
<td>Polyphenol</td>
<td>HDAC inhibitor</td>
</tr>
<tr>
<td>Dialyl sulphide</td>
<td>Garlic</td>
<td>Organosulphur compound</td>
<td>HDAC inhibitor</td>
</tr>
<tr>
<td>Epigallocatechin-3-gallate (EGCG)</td>
<td>Green tea</td>
<td>Polyphenol</td>
<td>DNMT inhibitor</td>
</tr>
<tr>
<td>Genistein</td>
<td>Soy beans</td>
<td>Phytoestrogen</td>
<td>DNMT inhibitor HAT activator</td>
</tr>
<tr>
<td>Caffeic acid</td>
<td>Coffee</td>
<td>Hydroxycinamic acid</td>
<td>HDAC inhibitor</td>
</tr>
<tr>
<td>Quercetin</td>
<td>Onions</td>
<td>Flavonol</td>
<td>HAT inhibitor</td>
</tr>
<tr>
<td>Sulphoraphane</td>
<td>Broccoli</td>
<td>Isothiocyanate</td>
<td>HDAC inhibitor</td>
</tr>
</tbody>
</table>

DNMT, DNA methyl transferase; HDAC, histone deacetylase; HAT, histone acetyl transferase. DNMT and HAT are epigenetic ‘writers’ whilst HDAC is an epigenetic ‘eraser’. From Mathers (2017).

Figure 2 The epigenome is central to interactions between diet and the genome in determining phenotype (Mathers, 2017)
Working on healthy choices

Employees consume about a third of their daily energy intake at work and this can have a significant influence on overall diet and long-term health. Natasha Maynard of research and training charity IGD explores the use of behavioural science in the form of simple ‘nudges’ to encourage healthier food choices at work.

Supporting health and wellness makes good business sense
Consumer interest in health is on the rise with 85% of British shoppers claiming they want to improve their diet in some way. Most food and drink companies would agree they have an important part to play in supporting people to achieve this aspiration. Many have demonstrated their commitment to consumer health by:

- providing more nutrition information on pack
- reformulating recipes to make products healthier
- promoting products more carefully
- introducing new, healthier options.

However, as well as supporting consumers, it is important that companies also consider their own employees. A company employing 1,000 people could risk more than £126,000 a year in lost productivity, solely due to obesity. Many organisations are placing greater emphasis on employee wellbeing, not least...
because of growing recognition that if you look after the wellbeing of your people, they will be healthier, happier, more productive and loyal[3].

**A unique opportunity to influence peoples’ food choices**

There is growing evidence from behavioural science that the shape of an environment can have a major impact on outcomes. Changing the physical environment is usually more powerful than trying to influence employees’ conscious thinking alone, given that we make most of our day to day decisions intuitively.

Small, sometimes unnoticed, changes in how options are presented (often called ‘nudges’) can encourage healthier choices. This was the thinking behind IGD’s recent programme of experiments with the Behaviour and Health Research Unit (BHRU) at the University of Cambridge.

This partnership tested various ways of helping people make healthier choices in workplace restaurants. The research took place between 2016 and 2018 at 19 workplace restaurants spread across regions in England. Involving around 17,000 people from a mixture of office, depot and manufacturing sites, it represents one of the largest experiments of its kind ever undertaken in a real working environment outside laboratory-type conditions.

Professor Dame Theresa Marteau, Director of the BHRU at the University of Cambridge, has described the project as one of the most ambitious studies to date for healthier eating in the workplace, helping to expand the evidence base and understand the practicalities involved in making changes in real world settings.

The **results**

The BHRU has published the results of this research in peer-reviewed scientific papers[4,5,6]. The findings proved that simple changes can make a substantial difference to food and drink decisions made at work. In general, people were happy with changes made in the offerings of their workplace restaurant to support their overall wellbeing, as long as the changes were well managed.

These changes can be delivered in a way that is also good for
How to inspire change in the workplace

Throughout the experiment, volunteer sites shared huge amounts of their data with the BHRU to allow evaluation of the results. An enormous amount was learned about the practicalities involved in introducing change to a catering environment and as a result IGD has developed some advice for running a healthy eating programme in workplace restaurants. Ideally, healthy eating should exist as part of a broader health and wellbeing programme, addressing both the physical and mental needs of employees. Addressing healthier eating at your workplace as part of a longer-term commitment will have the greatest impact.

Step 1 – Get the right people on board

Getting senior-level commitment will empower your people to suggest and make changes. If you do not have this already, ask one of the senior leaders in your business to sponsor and champion healthy eating in the workplace.

Step 2 – Assess your current offering and set some targets

Make these realistic at the start, as more ambitious targets can be set over time.

Step 3 – Make a series of changes

Take a series of steps in sequence rather than making lots of changes at once. This way, you can see what does and does not work in real time, and you can backtrack on some of the changes if necessary.

If you have more than one restaurant in your organisation, you do not need to adopt a ‘one size fits all’ rule. You can apply the same underlying principles but be guided by differences in customer demand at each site.

Step 4 – Measure impact

Consider how to measure the impact of your programme, for example through sales of healthier meals and colleague satisfaction. It will take a while for dietary changes to have an impact on overall health so give it enough time to see results.

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Methods overview (see references for full details)</th>
<th>Authors’ conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offering a balanced choice[4]</td>
<td>Restaurants adapted their range by increasing the proportion of healthier cooked meals, snacks and cold drinks to at least 50%, while keeping the total number of food options constant (replacing some of the highest energy foods and drinks with products containing less energy).</td>
<td>Overall, increasing the proportion of healthier options available in worksite cafeterias seems a promising intervention to reduce energy purchased, but contextual effects merit further study.</td>
</tr>
<tr>
<td>Reducing portion sizes[5]</td>
<td>The portion size of targeted food categories, including main meals, sides, desserts and cakes, were reduced.</td>
<td>Results suggest that reducing portion sizes could be effective in reducing energy purchased and consumed from targeted food categories, and merits investigation in a larger trial. Future studies will need to address factors that prevented optimal implementation, including site dropout and application across a limited range of products.</td>
</tr>
<tr>
<td>Calorie labelling[6]</td>
<td>The calorie content of food and drink was labelled prominently where customers were selecting what to purchase.</td>
<td>A calorie labelling intervention was acceptable to both cafeteria operators and customers. The predicted effect of labelling to reduce energy purchased was only evident at one out of six sites studied. Before progressing to a full trial, the calorie labelling intervention therefore needs to be optimised and a number of operational issues resolved.</td>
</tr>
</tbody>
</table>

Table 1: Conclusions for each intervention
Three ways to help people eat well at work

The IGD has published the conclusions of the study in a guide offering simple and practical tips for any employer providing food and drink at work. The advice offered is centred around the three areas tested in the experimental work:

1. **Offer a balanced choice**
   Altering the range of food available to tip the balance in favour of healthy choices is a proven route to encourage healthier eating. There is a strong commercial case for getting your offer right on health too. IGD’s ShopperVista research reveals that nearly one-third (31%) of consumers would eat out more often if healthier options were more available, and 34% claim to actively avoid some outlets because they do not offer enough healthy food.[7]

2. **Reduce portion sizes**
   During the experiment, volunteer restaurants were guided by the BHRU to increase the availability of food and drink containing fewer calories. This was drawn from Public Health England (PHE) guidance suggesting an approximate 400-600-600 kcal split over breakfast, lunch and dinner. For a complete meal, a 500-kcal limit was imposed to allow 100 kcal for additional fats for alternatives cooked without fat – limiting vegetable and carbohydrate sides cooked with added fat to one menu option per day;

3. **Provide calorie information**
   Nutrition information helps consumers make informed choices. However, too much information can be difficult to absorb in a restaurant setting, so displaying the energy information simply and clearly is the priority.

**Conclusions**

This study on healthy eating in the workplace proves how simple changes can encourage healthier food choices at work. Many of the companies involved in the study are now spreading best practice throughout their business, including internationally in some cases. IGD’s aim is to mobilise more employers to rethink their catering offer.
Reducing our waste size
Global food waste is one of the world’s most pressing sustainability challenges. One prominent report noted that between 30 and 50% of all food produced annually (between 1.2 and 2bn tonnes) is lost or wasted before reaching a human stomach[1]. In the US, up to 40% of food goes uneaten, an average of roughly 9kg per person per month[2]. Such extreme levels of food loss and waste are incomprehensible considering that more than 800 million global citizens are hungry.

In addition, food wastage has serious environmental consequences in the form of resource and soil depletion, biodiversity loss, water pollution and air pollution – mainly in the form of methane emissions contributing to climate change. A report by the Food and Agriculture Organization of the United Nations (UNFAO) notes that if ranked as a country, food waste would be the third largest emitter of greenhouse gases, behind only the US and China[3]. Wasted food means wasted water – the World Resources Institute (WRI) notes that food loss and waste accounts for more than 170tn litres of water annually (24% of all water used in agriculture)[4].

Clearly, we must sharply reduce food loss and waste if we are to successfully feed an additional two billion global citizens by 2050. Recent reports from both WRI[5] and the EAT-Lancet Commission[6] emphasise the need to reduce food waste to enable a sustainable future. Notably, Project Drawdown[7] ranked food waste reduction as the third most impactful intervention to counter global warming. Fortunately, awareness of the global food waste challenge is on the rise, buoyed by the work of NGOs, such as WRAP, Feedback, the World Resources Institute, the World Wildlife Fund and ReFED. These organisations are advancing work across multiple sectors to meet the United Nations’ Sustainable Development Goal 12.3 (aka Target 12.3), which calls for halving per capita food waste at the retail and consumer levels by 2030 and reducing food losses along production and supply chains.

**Wastage in foodservice**

Foodservice organisations have a unique opportunity to play a major role in advancing progress towards Target 12.3 due to their global reach, massive volume and extensive supply chains. Compass Group, for example, serves over five billion meals annually – that is about 15 million meals daily. Aramark serves more than two billion meals per year, while Sodexo serves 100 million customers daily in 80 countries. Global enterprises like IKEA and Google also serve millions of meals to patrons and employees annually. Such volume provides clear opportunity for these organisations to lead food waste reduction efforts at scale, and increasingly, consumers expect them to demonstrate responsible efforts in this regard. Further, because food waste reduction efforts result in triple bottom line benefits – reducing costs, reducing environmental harm and inspiring the workforce – they are an important driver of competitive advantage.

While many organisations address the recovery and redistribution of excess food, Leanpath is a company that focuses on helping foodservice organisations to achieve food waste prevention using a measurement-based approach. Its aim is to make food waste prevention an everyday practice in the world’s kitchens by providing the tools, analytics and expertise to enable responsible organisations to commit to cutting their food waste in half. The food waste prevention platform enables organisations to cut costs in a number of ways – the cost of the food itself, the associated costs of labour, production, utilities, disposal and the opportunity cost of lost sales/profit. Further, prevention of food waste maximises societal benefit, avoiding unnecessary consumption of resources and the associated environmental externalities that would otherwise be incurred in the production and transportation of food that ultimately winds up in landfills and freeing resources (such as human capital and labour) for other beneficial purposes.

Despite their best intentions, all kitchens have some level of food waste – and in many cases – a lot of waste (Figure 1). In US foodservice operations, between 4 and 10% of food purchases are discarded before reaching the consumer’s plate. For an operation with $1m in food spend, that translates to between $40,000 and $100,000 in cost for reasons such as overproduction, spoilage and trim waste. Between $9 and $23bn of pre-consumer
CUTTING FOODSERVICE WASTE

Food waste is generated by the US out-of-home restaurant and foodservice industry annually. For decades, food waste has been the ‘elephant in the kitchen’ – extensive yet largely invisible – and tolerated due to a societal culture of abundant food coupled with easy disposal options.

Leanpath aims to bring visibility to food waste in foodservice operations in multiple sectors, including hospitality, healthcare, colleges and universities, and in global business enterprises (such as Aramark, Sodexo, IKEA and Google). It is essential that kitchen teams uncover the types of food that are being wasted, the quantities and why, so that they can make operational changes to reduce their waste level while also taking steps to change team behaviour.

**Behaviour change**

Food waste is a behavioural problem – successful prevention requires the empowerment of frontline foodservice workers to track, measure and analyse food waste, thus creating a culture of food waste prevention.

The process begins by connecting culinary teams to the scope and scale of the global food waste challenge, while simultaneously demonstrating the substantial value in tracking and measuring waste. In addition, it is important that food waste tracking becomes ‘safe’ behaviour – without blame – maximising the tracking and measurement of waste helps the kitchen to learn from those transactions and take preventative action. As with any change initiative, positivity and meaning are essential, and visibility fosters engagement.

Compass Group’s Rachael Newmyer noted that Leanpath’s implementation at Google had started a conversation between chefs and managers, as well as line cooks, dishwashers and even senior leaders. Operating in 189 Google cafes in 26 countries, Leanpath has enabled the company to prevent 2.7m kg of food waste from going to landfill in the last five years. Another organisation in the education sector noted that most of the suggestions driving food waste reduction came from the frontline staff, indicating the power of an engaged, waste-conscious workforce.

**Tools for monitoring waste**

Leanpath provides a suite of integrated hardware and software solutions (bench scales, cameras, portable tablets, floor scales, and displays) with location-customised software that allows foodservice workers to track all cases of food waste during each meal service. The tracking process can be simply defined as measure, analyse, optimise and empower.

Tracking units are customised to align with client menu choices, food costs, pan sizes, disposition codes, and more. Each transaction is weighed and critical data, such as food type, waste reason (e.g. overproduction, spoilage), location source and disposition (e.g. compost, donation, trash) are immediately captured through a customised user-interface. A bench scale unit links this data to a digital picture of each food waste transaction – enabling chefs to gain powerful visual insights into wastage at a glance any time. These and many other transactional details are immediately stored in a cloud-based database. The data feeds an analytics programme, allowing foodservice operators to analyse the drivers of their food waste in any desired time period with a high level of granularity.

Shortly after installation, a ‘baseline’ level of food waste is established for each site, and change is measured against that baseline amount going forward. Leanpath’s coaching team works with chef champions in a consultative fashion, ensuring that all food waste is being tracked consistently and accurately, while also contributing suggestions for operational changes to maximise usage of food items while preventing the recurrence of food waste. Change opportunities are wide-ranging, including waste-smart forecasting, proper portioning, improved food preparation, increased repurposing, cooking-to-order later in shifts and buffet enhancements, to name a few. The process quickly generates positive results. In the US, the University of Illinois has reduced food waste by 63% (635,000 kg) since 2015 by implementing Leanpath tracking systems and making changes to reduce salad bar waste and increase repurposing opportunities. In Australia, the Novotel Brisbane cut food waste weight by 62% by revising production of high waste items, repurposing and exercising culinary creativity with items that would normally be discarded (e.g. turning orange peel into marmalade).

**Graphics and reporting**

The integrated dashboard provides graphics and reporting features, including waste overview summaries, detailed waste breakdowns, trend reports, participation reports, waste transaction listings – even talking points for chefs to utilise during weekly staff meetings. Users can adjust the date range to view data across various time periods, while also taking advantage of drill-down and sortation capability to slice their food waste data in myriad ways. In addition, they have the flexibility to view their data at the individual location level, for specific groupings of locations, or for a broad enterprise overview.

Trackers reinforce the power of the measurement process. Upon completion of each transaction, the user sees its financial cost, as well as the annualised cost of that specific transaction if it were to occur every day (as it often does in process-driven kitchens), along with various environmental impact equivalencies (Figure 2).

Trackers also display data for the top wasted food from the prior week, along with food waste trend data and the change in
food waste weight compared to the baseline level. As a result, the kitchen team receives continuous reinforcement of the financial and environmental costs of food waste – and they can be inspired to voice their own ideas on how to avoid repetitive waste (Figure 3).

To support the power of continuous messaging on waste, gamification is also built into – stimulating engagement with instant-win features that make food waste tracking fun. In addition, an ‘Alert’ feature amplifies the impact of tracking, providing electronic notifications of designated waste transactions (e.g. high cost items, such as lobster) to allow for immediate interventions – such as a positive conversation as to how that item might be repurposed, and/or how the ‘waste’ could be avoided in future.

Committing to measurement is the first action of prevention for organisations interested in reducing their pre-consumer food waste. Automated tracking is the basis of effective measurement and it captures the critical food waste data that in turn enables the actionable analysis that promotes operational and behaviour change in high-volume foodservice operations. Data inspires measurable improvement and the overall process leads to a highly engaged workforce.

**Post-consumer waste**

Beyond the kitchen, Leanpath also helps foodservice organisations go to the next level by addressing post-consumer food waste (i.e. plate waste). A new product (Spark), developed in concert with behavioural science experts, provides another method for utilising food waste data to drive positive behaviour change. The weight associated with consumer food waste transactions is captured with an integrated tracker and the data is then displayed on digital signage where it can be viewed by consumers and kitchen staff. Coupled with rotating, high-impact social messaging, the process brings the site’s food waste data to life in a critical way: it raises awareness among consumers about the level and cost of their food waste, thus nudging them to consider actionable change to reduce their waste. They might take less food when going through the buffet line, for example, with a conscious focus on taking only what they will eat. By educating and inspiring consumers in this way, the tool is useful for front-of-house applications to reduce plate waste and it can be particularly valuable in high-waste, all-you-can-eat buffet operations to encourage responsible decision-making.

IKEA Lyssach developed strategies to achieve a 45% reduction in food waste weight (and a 50% reduction in food waste cost); Food Manager Adrian Gurtner noted that in one year of using Leanpath they reduced half of their food waste.

While the focus is on prevention, by inspiring foodservice workers to optimise food resources, Leanpath’s process facilitates downstream food recovery options, such as donation and composting. As such, users can embrace circularity through a holistic, solutions-focused food waste strategy. Since 2014, Leanpath estimates that its measurement-focused approach has enabled the prevention of more than 16.1m kg of food waste globally, eliminating more than 112,000 metric tonnes of CO₂ equivalent. This translates to a savings of more than 54bn litres of water.

**Conclusions**

Our food system is essential for our survival. Yet it is far from perfect, and it is one of the greatest drivers of environmental harm. Food is central to many of the Sustainable Development Goals, and successfully cutting food waste in half by 2030 would provide a significant boost to many of them. Humanity is currently consuming more resources annually than the Earth can naturally replenish. Remaining within planetary boundaries requires minimising environmental impact through resource optimisation, and one of the best ways to do that is to sharply reduce global food waste. The world has a challenging UN-led goal to reduce food waste by 50% in the next twelve years, and responsible global foodservice operations can play a major role in achieving that goal. Getting there involves focusing on using automation to measure food waste and to promote waste prevention.

For foodservice organisations, the business case for implementing automated food waste tracking is clear. The related environmental and social benefits are the icing on the cake.

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**References and article available online at**

FSTJOURNAL.ORG/FEATURES/33.2/CUTTING-FOODSERVICE-WASTE

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Sugar reduction is never far from the headlines and has become a major focus for food manufacturers, retailers and food service providers. Scrutiny is translating into directives and guidelines from governments and industry bodies across Europe, and pressure from consumers, who are increasingly aware of the potential impact of excessive sugar consumption on their health.

The UK Government’s childhood obesity plan was launched in 2016 with the aim of encouraging the industry to reformulate products to lower children’s sugar intakes. Part two of the plan, published in June 2018, set out the goal of halving childhood obesity and reducing the gap in obesity between children from the most and least deprived areas by 2030. Guidelines from The World Health Organisation (WHO) strongly recommend that adults and children reduce their intake of free sugars to less than 10% of their total energy intake, ideally to 5%.[1]

The UK sugar reduction programme states that ‘All sectors of the food and drinks industry are challenged to reduce overall sugar across a range of products that contribute to children’s sugar intakes by at least 20% by 2020, including a 5% reduction in the first year’ – 2017, which was subsequently not achieved. The guidance suggests ‘reducing sugar levels in products, reducing portion size, or shifting purchasing towards lower sugar alternatives.’

Alongside the growing pressure from above and within the industry, the demand for reduced sugar products is being led by a new generation of consumers with a better understanding of the link between food and health. High profile TV investigations about how much sugar is in everyday products are fuelling particular interest in this issue.

The role of sugar in dairy products
There are many challenges for dairy product manufacturers trying to achieve sugar reduction targets without compromising taste, flavour and mouthfeel in their products. The product attributes that need to be considered in addition to loss of flavour are:

- impact on texture – structural changes to the product
- perception of sweetness
- visual appeal
- product shelf-life
- storage and processing parameters
- labelling requirements.

Reformulating a dairy product so that it delivers the same quality and eating experience with less sugar – especially in some applications, such as dairy beverages and ice-cream, – is an advanced technical challenge.

Lactose (a disaccharide formed of glucose and galactose units) is the only naturally-occurring sugar present in milk and is therefore also present naturally in most dairy products. It contributes greatly to the physical properties of dairy products. Since lactose is considerably less sweet than sucrose, other sugars or sweeteners are often added to dairy products in order to increase the sweetness to levels that consumers prefer. This is why some dairy products are being scrutinised for their ‘excessive’ sugar content. Sugars increase the viscosity or thickness of frozen desserts, yogurts and flavoured milks, which helps to increase the smoothness perceived in the mouth. Sugars are often used in lower-fat products to increase flavour, texture and to re-balance the mouthfeel in reduced fat recipes, which is an added challenge for those wanting to lower sugar content, while also keeping fat content to a minimum.

Reformulating dairy products
There is no ‘one size fits all’ solution to achieving great tasting, reduced sugar dairy products. Manufacturers are using increasingly advanced formulations, ingredients and processing techniques to overcome the taste, texture and nutritional challenges of reducing sugar in dairy applications.

Dairy manufacturers look for ingredients that can withstand different processing parameters (high temperatures, freezing and thaw cycles and different storage or shelf life requirements). They aim to overcome the loss of sweetness and function that occurs when sugar is removed by introducing high intensity sweeteners (acesulfame K, sucralose, Stevia) and bulking agents (inulin, oligofructose and polydextrose). These ingredients can help provide functional benefits, such as enhanced mouthfeel, texture and taste, but they are not able to build back the flavour loss which occurs when reducing the sugar content of products.

Developing effective formulations
Reduced sugar solutions need to work successfully across a range of recipes, so an understanding of each individual matrix is required to develop a suitable, customised solution. Using sensory analysis of the base formulations helps to identify sensory differences between full sugar and reduced sugar bases, focusing on factors, such as sweetness, creaminess, intensity of flavour and flavour release. A combination of sensory and analytical data provides a hierarchical list of the key challenges that need to be overcome in a particular sugar-reduced formulation.

Using natural fermentation processes, dairy commodities, such as cream and milk, can be converted into concentrated dairy ingredients, which enhance flavour, mouthfeel and creaminess in dairy products and can be used to compensate for the reduction of sugar. The addition of these dairy-based flavours helps to enhance the creaminess, which is often lost in reduced sugar dairy products.

Reducing sugar levels can result in considerable changes to the structure of a product and thus has an impact on release of both sweetness and flavour. These issues can be addressed with the addition

Natalie Drake of Synergy Flavours explores the challenges of reformulating dairy products to reduce sugar content.
Reducing sugar levels can result in considerable changes to the structure of a product and thus has an impact on release of both sweetness and flavour.

of sweet natural flavourings tailored to the base, bringing the reduced sugar product closer to the full sugar product.

Sensory analysis can then be employed to qualify the effectiveness of the proposed solution. Using this approach, Synergy has been able to achieve a reduction in sugar content of up to 30% across dairy products, such as ice cream and yoghurts, while maintaining taste and nutritional content.

The future is still sweet

The UK food and beverage industry is making some significant strides towards achieving the targets that have been set out by government, but voluntary targets are just one part of the picture. The bigger challenge comes in educating consumers about the need to reduce sugar in the diet and the role of nutrition in health. Initiatives led by governments, brands, the media, charities and other organisations are important in changing consumer perception of products that carry the ‘reduced’ label.

References and article available online at fstjournal.org/features/33-2/sugar-reduction

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Sterling Crew reviews the UK’s Food Hygiene Rating Scheme (FHRS), which was introduced to improve the availability of information about hygiene standards of food businesses for consumers and to reduce the incidence of food-borne illness by increasing legal compliance.

Origin of FHRS
One of the key drivers for the Food Hygiene Rating Scheme (FHRS) was the Freedom of Information Act 2000, which defined the ways in which people may obtain reasonable access to government-held information. The concept was first put forward in 1997 and passed into legislation in England, Wales and Northern Ireland in 2000 and in Scotland during 2002. It enabled the media and public to make Freedom of Information requests to local authorities for details about their activities. This resulted in a growing number of requests for information on the hygiene standards in local food businesses, which prompted many councils to make this information available in a readily accessible format. It led to a number of different hygiene rating schemes being operated by councils, where information about inspections was made available on their websites.

However there were no uniform grading systems for food premises making direct comparisons difficult. In December 2008, the Food Standards Agency (FSA) board approved a six tier rating system called the Food Hygiene Rating Scheme (FHRS) for England, Wales and Northern Ireland (Table 1). Food Standards Scotland (FSS) adopted the Food Hygiene Information Scheme (FHIS), a two tier approach, with a ‘Pass’ or ‘Improvement’ rating. The aim of the schemes is to encourage businesses to improve hygiene standards and legal compliance and consequently reduce the incidence of food-borne illness. The FHRS was launched in 2010 and is now run in partnership between the FSA and local authorities.

Display of rating stickers became compulsory in Wales in November 2013 and in Northern Ireland in October 2016. Food Businesses in both countries are legally required to display their ratings in a prominent place, such as at the entrance or in the window of the premises. Disappointingly, in England, food businesses are encouraged but not required by law to display
Unsurprisingly in England, businesses with a higher rating are more likely to display the FHRS sticker than those with a lower rating.

Table 1 The Food Hygiene Rating Scheme gives food businesses a rating from five to zero, which is displayed at their premises and online so consumers can make informed choices about where to buy and eat food.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
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<tbody>
<tr>
<td>5</td>
<td>Hygiene standards are very good.</td>
</tr>
<tr>
<td>4</td>
<td>Hygiene standards are good.</td>
</tr>
<tr>
<td>3</td>
<td>Hygiene standards are generally satisfactory.</td>
</tr>
<tr>
<td>2</td>
<td>Some improvement is necessary.</td>
</tr>
<tr>
<td>1</td>
<td>Major improvement is necessary.</td>
</tr>
<tr>
<td>0</td>
<td>Urgent improvement is required.</td>
</tr>
</tbody>
</table>

their rating. However, all ratings can be found online and currently FHRS ratings for approximately 479,000 food businesses are on the FSA website, representing nearly 92% of those businesses in scope. The date of the inspection can be found on the back of the sticker and online. The rating given to a food business only reflects the standards of food hygiene found at the time of the inspection or visit by the local council.

Coverage
The FHRS covers businesses providing food directly to consumers, such as supermarkets, restaurants, pubs, cafés, takeaways, hotels, hospitals and schools. In Wales the scheme also includes business to business trade e.g. manufacturers, which no doubt the FSA will be monitoring to see whether these businesses should be included more generally.

The scheme covers how hygienically the food is handled, how it is prepared, cooked, re-heated, cooled and stored as well as how the food business manages systems for keeping food safe, training and ensuring good hygiene standards are maintained. The physical condition of the premises is also addressed encompassing cleanliness, layout, lighting, ventilation, pest control and other facilities. One of the key criteria assessed relates to confidence in management, which covers the business’s food safety management, such as their HACCP controls. The food hygiene rating is not a guide to food quality, customer service or cooking skills.

An FHRS visit does not preclude the inspector using the wide range of enforcement actions and other initiatives available to regulatory authorities alongside issuing a rating. If the standard of hygiene is so poor that there is an imminent risk to health, the inspector must take action and can issue an Emergency Prohibition Notice or close down part or all of the business until improvements have been made. Prosecution could also follow a visit where poor standards were found.

The scheme has a number of safeguards available to food business operators who believe that their score is unfair or wrong. They can appeal to the local authority or request a prompt re-inspection following remedial actions, although in the case of a re-inspection, the original rating is published until any improved rating is issued. There is also a right to reply and businesses can respond online to the rating given by the council, though this is used infrequently.

Consumer awareness
FHRS ratings are followed by consumers, the media and pressure groups that increasingly benchmark food businesses using FHRS data. In April 2019, the FSA published the fifth wave of its biennial ‘Food and You’ consumer survey (21), which collects information about the public’s reported behaviours, attitudes and knowledge relating to food safety and food issues. The survey found that the majority of respondents in England, Wales and NI (67%) reported having seen FHRS stickers.

Displaying a high hygiene rating is a good advertisement for businesses that meet the requirements of food hygiene law. The scheme has begun to resonate with the public with around three in five respondents mentioning that a good hygiene rating score (60%) along with good service (61%) and the price of food (60%) is important in their decisions about where to eat out.

Unsurprisingly in England, businesses with a higher rating are more likely to display the FHRS sticker than those with a lower rating. Over two thirds (67%) of those with a rating of five are displaying the stickers, compared to only 28% of those that have a rating of zero to three. A 2018 consumer survey, the FSA reported that 52% of respondents in England, 41% in Wales and 62% in Northern Ireland often or sometimes check hygiene ratings before eating out. The overall use of FHRS by consumers has increased since the previous wave from 46% to 51%.

Challenges and opportunities
Each local council is required to implement a risk based intervention programme with the frequency of inspections of food businesses depending on their risk to public health. The aim is for food businesses that pose a higher risk to be inspected more often than those that pose a lower risk. Inspection frequencies can range from 6 months to 3 years or longer, depending on local authority resource pressures, even though minimum frequencies are prescribed in Codes of Practice. To maintain the integrity of the scheme, there needs to be a consistent approach across the UK. A Which? report (24) found that in more than a third of areas in the UK, none of the highest-risk food businesses (classified by virtue of their size, nature and compliance standards) met minimum food...
hygiene standards in 2016/17. In one London Borough, none of the 34 high-risk food premises met hygiene expectations. In the past, some food operators have waited months and even years to be re-inspected.

The impact of local authorities’ finances on FHRS delivery cannot be ignored. A recent study by Unison reported that environmental health budgets per head of population have more than halved over the past decade, falling by 52.92% between 2009 and 2018. As a result, enforcement visits by environmental health officers have fallen by nearly a half, a 49.05% drop, and programmed inspections and visits to food businesses, which underpin the authority being able to provide an FHRS rating, have decreased by 40.95% over the same period.

Food businesses must register all their premises at least 28 days before opening. Registration is free and, remarkably, cannot be refused, although enforcement action can be taken by the authority against any business opening with poor food hygiene or safety standards. Local regulators are then meant to rate businesses within 28 days of opening. Performance at hitting this 28 day target varies across the UK. If a food operator makes, prepares or handles food that comes from animals for supply to other businesses i.e. a food manufacturer, they may require approval from the local authority before the activity commences. Approval can be refused by the local authority and it is an offence for such businesses to operate without approval.

A future improvement to the FHRS could be the introduction of a complementary integrated licensing system. In particular, a food licensing system could be adopted by local authorities to permit an activity that would otherwise be forbidden. The payment of a fee could self-fund the scheme. Such a licence may also serve to keep local councils informed about the type of activity and to give them the opportunity to set conditions and limitations even before a food business starts to operate. The FSA will be reviewing fees for inspections as part of its ‘Regulating Our Future’ review and in its strategic plan for 2015-20.

Online delivery platforms
Online food delivery platforms, such as Just Eat, Uber Eats and Deliveroo, are revolutionising food supply systems and can offer consumers greater convenience and choice. Their challenge is to give their customers confidence in the source restaurant or takeaway kitchens as online ordering generally offers greater anonymity to the originating kitchens.

The speed at which new food outlets, the so called online ‘dark kitchens’, start up makes it challenging for local regulators to ensure their arrangements are safe and compliant. There are concerns that some providers are not being transparent enough with their customers about the food hygiene rating of individual outlets or ensuring customers have the required food labelling or allergen information.

Recent media coverage has exposed online delivery platforms using food businesses with low FHRS scores. One TV programme illustrated the lack of controls by using a skip as a supply point. A BBC investigation found that half of outlets rated zero by the FSA in Manchester, Bristol and London appeared on delivery platform ordering apps.

A number of the online delivery platforms are now removing all restaurants and takeaways with a hygiene rating of zero and some are insisting on a minimum FHRS rating of 3 - sites whose ‘hygiene standards are Generally Satisfactory’. Customers can check the premises rating on the FSA website before purchase, but it is questionable how many will take the extra time to do this.

Just Eat is piloting arrangements to prominently display the FHRS rating for businesses on its platform in Northern Ireland initially, reflecting future intentions in Northern Ireland to legally require a business’s FHRS rating to be displayed on relevant online or advertising material. Hopefully, this will be widely adopted.

The latest FSA FHRS Consumer Attitudes Tracker reports that a high percentage of respondents in England (85%), Wales (87%) and Northern Ireland (97%) thought businesses providing an online food ordering service should display their food hygiene rating where it can be clearly seen.

Possible conflict of interest
Local authorities cannot charge for an FHRS visit but they can charge for re-rating inspections. Some authorities in England and all in Wales and Northern Ireland charge a fee to recover the costs of carrying out a re-
rating inspection (£150–£160). Some authorities sell ‘advice’ visits in advance of their FHRS inspections, creating a new revenue stream for cash strapped councils. The cost of advice visits and re-visits is variable across English councils; some are charging £250 a visit, which could be argued is above simple overhead recovery, while many still do not charge. As such the position in England is inconsistent and unfair to businesses.

A paid advisory pre-FHRS visit from the local authority allows businesses to resolve potential problems privately, averting embarrassment and potential prosecution. It can be argued that this practice is blurring the line between the roles of regulator and paid consultant thereby generating a potential conflict of interest and calling into question the objectivity of any subsequent FHRS score. The creation of internal ‘Chinese walls’ may go some way to ameliorating this accusation, however, professional private sector providers, many employing qualified Environmental Health Practitioners, can provide such a service to help protect the integrity and independence of the council’s regulatory role. Approved private sector organisations could also carry out the FHRS re-visits or even rating inspections freeing regulatory authorities to focus on their important enforcement role. There are however obvious local authority operational and political concerns about the privatisation of this service.

**Conclusions**

This FHRS is an ever evolving programme of work dedicated to raising food safety, hygiene standards and legal compliance via improved transparency. It has become an essential element of the regulatory gestalt.

The FHRS has undoubtedly been a great success. It is popular with members of the public, food enforcement agencies and responsible food business operators. The scheme supports consumers in making informed choices about where to eat or shop for food. It provides local authority food inspectors with a simple and proven tool to drive up food hygiene standards. For responsible food business operators it is a way of demonstrating their commitment to high standards of hygiene and enables them to differentiate themselves from the competition.

The loss of revenue following a poor hygiene rating, as customers choose to eat elsewhere, is a motivating factor for food businesses to improve their hygiene practices. This transparency has seemingly led to significant improvements to business hygiene compliance levels year on year since the introduction of the FHRS. Over 90% of food businesses in scope are now rated FHRS 3 (Generally Satisfactory) or above, with approximately 70% rated FHRS 5 (Very Good).

Food safety and hygiene must be a top priority for a food business operator regardless of size. Although compliance with food hygiene law does not eliminate the risk of food-borne illness, research indicates that premises with higher food hygiene rating scores are less likely to encounter outbreaks and have better results in microbiological analytical surveys.

Calls for the mandatory display of food hygiene ratings in England and Scotland continue. The lack of compulsory display persists in undermining the scheme’s credibility and effectiveness. The FSA has signalled its intention to push for a statutory scheme in England, but there is still no sign of the necessary legislation being tabled largely due to parliamentary focus on Brexit.

The FHRS could be enhanced by increasing the consistency and, probably more importantly, the frequency of inspections (and re-rating inspections) across the UK. Strong legislation and weak enforcement compliance is not protecting consumers. The potential conflict of interest and inconsistency of local authority paid pre-FHRS advice inspections also needs to be addressed.

The scheme could be given further breadth to address specific areas of growing public concern, such as adequate allergen management. It might also benefit from innovative alternative methods of delivery, such as approved private sector involvement, to take some of the burden off overstretched and underfunded local councils.

Licensing of food operations could be part of a solution for enforcement agencies. The impact of social media on food hygiene standards should not be underestimated. Consumers are said to be the new regulators, with organisations such as Tripadvisor giving the public an online facility for an influential, shared, instant and continuous customer review. The FSA’s ‘Regulating Our Future’ programme, focused initially on processes for food business registration and subsequent checks by enforcement agencies and is now addressing the processes for enforcing food standards. This may provide an opportunity to review and enhance the FHRS.

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**Sterling Crew**

FIFST, FCIEH, FRSPH, CEnvH, CSI

Co-Founder of Kitchen Conversations. Managing Director SOS Ltd. Strategic Advisor Shield Safety Group and Dynamic Risk Indicator, Chair of the IFST Food Safety Group, Independent Scientific Advisor and Board member of Campden BRI, Audit Governance Board member Eurofins auditing.

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Interest in cell-cultured meat has been steadily gaining momentum since the first laboratory-grown burger was unveiled in 2013 by scientists from Maastricht University in the Netherlands.

In general, the process for producing cell-cultured meat requires a few ‘satellite’ cells, which can be obtained from a muscle sample taken from a living animal. These cells can then be transferred to a bioreactor containing a scaffold upon which the cells can attach and grow in a nutrient-rich (and preferably animal-free) medium. The scaffold provides structural support for the cells and promotes muscle fusion, creating ‘strips’ of muscle fibres. The fibres can be mechanically stretched to increase size and protein content and the resulting tissue is harvested and processed into a boneless meat product.

Laura Clews of IP firm, Mathys & Squire, reviews some of the latest techniques being evaluated for the production of cell-cultured meat.
A significant amount of research relating to cell-cultured meat has focused on the formation of processed meat (such as hamburgers and meatballs) and formulation of an economical manufacturing process. In order to effectively scale up production, a suitable scaffold (which is cost effective and preferably edible) to support the growing cells is required. To date, progress in manufacturing such products is advancing beyond all expectations, and slaughter-free meat could be in our shopping trollies sooner than expected. For example, JUST Inc (with laboratories in San Francisco) aims to sell its first cell-cultured meat products this year, whilst Mosa Meat and US-based Memphis Meats aim to have their products on supermarket shelves by 2021.

This focus on producing processed cell-cultured meat is due, at least in part, to the complexity of unprocessed meat, which includes bone, blood vessels and connective tissues, making this structure difficult to replicate. An appropriate scaffold that aids cell alignment will be required to develop unprocessed cell-cultured meat. A significant amount of research and ‘out of the box’ thinking will be needed before we can expect to enjoy a cell-cultured steak or rack of lamb.

In the race to provide a suitable solution to this problem, varied approaches have been taken by companies and research groups within this sector and some are seeking patent protection for new inventions. Some examples of scaffolds being trialled for forming either processed or unprocessed meat are discussed below.

**Starch fibre mats**

Researchers from Pennsylvania State University and the University of Alabama have collaborated to produce a method of forming edible starch fibre mats using a cost effective wet-electrospinning technique. Starch has the benefit of being one of the least expensive natural fibres.[1]

The wet-electrospinning technique typically comprises a polymer solution, a syringe with a metal needle, a coagulation bath and a grounded collector. The polymers required to form the scaffold are first dissolved in a solution, which is placed inside the syringe and subsequently forced through the needle at a constant flow rate. At the same time a high voltage is applied to the solution. The electric charge draws and stretches the jet of the polymer solution as it is directed to a coagulation bath containing ethanol and water, which precipitates the polymer fibres from solution. The resulting polymer fibres are collected on a rotating drum submerged in the coagulation bath. The thin starch fibres provide a high surface area scaffold upon which cells can adhere and grow to form a structured meat product.

The electrical field that forms between the nozzle and a rotating collection drum draws the starch into long threads.

In a study recently published in Food Hydrocolloids, the researchers built an inexpensive electrospinning device partially using the children’s toy, Lego® to form the rotating drum collector (shown in Figure 1).

The research found that the formation of suitable starch fibres was dependent on the speed of the rotating drum and the amount of ethanol in the electrospinning bath used to collect the fibres.

**Porous protein scaffold**

Israeli company, Aleph Farms, announced that it had produced the first prototype of a cell-cultured steak in December 2018, with thin strips of steak costing around $50 to produce. The company admits that the size and flavour of the steak requires some further research before the product is ready for commercialisation. It has collaborated with the
Technion – Israel Institute of Technology, Haifa, to develop the manufacturing method, which includes a bio-engineering platform and innovative approaches to an animal-free growth medium to nourish the cells.

Aleph Farms is reported to use a combination of six technologies, which provide a more economical manufacturing method. These techniques include innovative approaches relating to an animal-free growth medium to nourish the cells, and bioreactors (the tanks in which the tissue grows). Little information on the specifics of these technologies seems to be publicly available. However, a recent patent application by Technion Research & Development Foundation Ltd published in January 2019 (WO 2019/016795), discloses a method of forming cell-cultured meat on a porous scaffold. The method comprises the steps of incubating a three-dimensional porous scaffold formed from a textured protein, such as a soy protein, and a plurality of cell types including myoblasts (muscle cells) and at least one other cell type (i.e., adipocytes (fat cells), fibroblasts (which produce the structural framework of animal tissues), progenitor cells (satellite cells), or endothelial cells (cells which line the interior surface of vessels). Once the porous scaffold has been incubated with the different cells, they are allowed to expand on the scaffold. Muscle cell fibres are then formed through the fusion of myoblasts into multi-nucleated fibres (myotubes).

Grass as a scaffold
A research group at the University of Bath in the Department of Chemical Engineering has come up with an alternative method to formulating a suitable scaffold for cell-cultured meat. Dr Marianne Ellis, working with a multidisciplinary team with expertise in biochemical engineering, biology and biomaterials, has focused on scaling-up the manufacturing process of cultured meat. The researchers used stem cells extracted from an animal, which are fed a mixture of glucose, vitamins, minerals and amino acids. The cells are then transferred to a bioreactor containing grass as a scaffold, on which they can attach and grow. To date, the team has used rodent cells to test the effectiveness of this scaffold, but research is underway to use a combination of six cell types, including myoblasts (muscle cells), or endothelial cells (cells which line the interior surface of vessels). Once the porous scaffold has been incubated with the different cells, they are allowed to expand on the scaffold. Muscle cell fibres are then formed through the fusion of myoblasts into multi-nucleated fibres (myotubes).

Decellularised spinach leaves
A method that uses decellularised spinach leaves (i.e., spinach leaves in which the cellular material has been removed) to produce a scaffold for tissue engineering has been developed by Glenn R. Gaudette, a professor of Biomedical Engineering at Worcester Polytechnic Institute in Massachusetts. A patent detailing the decellularisation method (WO 2017/160862) was published in September 2017. This work is based on the similarities in the vascular structure of plant and animal tissues (Figure 2).

The method first decellularises spinach leaves by applying a solution containing 10% sodium dodecyl sulphate (SDS) in deionised water for five days. After this, a clearing solution (0.1% TritonX100, 10% sodium chlorite in deionised water) was applied to the leaves for two days[4]. The resultant leaves were colourless and translucent, forming an acellular scaffold consisting of extracellular matrix (ECM), preserving an intact vascular network (Figure 3).

Gaudette, is collaborating with Dr Marianne Ellis of the University of Bath to assess the potential of this technique to develop muscle cells from the stem cells of a cow. If successful, spinach leaves could provide a low cost and edible scaffold for producing more complex meat structures.

Conclusions
Cell-cultured meat has the potential to reduce the amount of land, water and antibiotics required for traditional farming practices. This field is moving rapidly with some processed cultured meat products already poised to enter the marketplace. Unprocessed meat products represent a more elusive target, but research is underway to develop scaffolds that allow the formation of the characteristic texture of a T-bone steak.
Serving up graduates

Introduction
Ask any food business leader to list the key challenges they face and it is likely that difficulties in recruiting qualified staff will be somewhere near the top. Staff shortages, particularly in food science, technology and engineering, are a perennial problem which can threaten business sustainability. Today’s modern food marketplace is dominated by pre-prepared, ready-to-eat and convenience foods, which are changing food culture. In many respects the food industry has distanced people as consumers from the nature and sources of food and the idea of food as a career. Many young people today simply do not gain first-hand experience of food as a raw material to convert into meals by cooking in the home, as did previous generations. Hence, they do not develop curiosity about where food comes from or the different kinds of food business that produce the diversity of products available.

The food industry’s qualified staff shortages represent an opportunity for universities. Within Britain’s university sector, only a small number of the 130 institutions deliver undergraduate and postgraduate programmes in food science, technology and engineering to prepare graduates for the food industry. However, attracting UK school leavers onto food courses is still challenging and such courses often prove more attractive to overseas students.

University of the food chain
In many ways Harper Adams University[1], located in rural Shropshire, may be thought of as Britain’s university of the food chain. In contrast to many universities offering food courses, it is principally an agricultural university. Its campus is located at the centre of a 635 hectare working farm, which allows students direct access to farm experience and insight into the methods involved in modern agricultural food production. Central to the institution’s mission is the education of students in the science, technology and management topics involved in the production of agricultural foodstuffs, their transformation through processing and manufacture, and their marketing and retailing as food products.

The university began life in 1901 as a purpose built agricultural college[2] and has grown very substantially since then. It was awarded university status in 2012, making it Shropshire’s very own university. Today the student body numbers some 3,000 undergraduates pursuing four-year degree courses, while around 200 students take taught masters courses each year and 50 to 60 PhD students are registered for postgraduate research at any time. Harper Adams has both taught and research degree awarding powers and its academic awards relate principally to the disciplines of agricultural engineering, crop and animal sciences, environmental sciences, entomology, food technology, agri-food marketing and veterinary nursing. Much of its focus is on the provision of qualified staff for the land-

Ralph Early, formerly Professor of Food Industry and Head of the Food Department at Harper Adams University, describes the rapid development of food courses at Harper Adams and the ethos behind course design.

“In many respects the food industry has distanced people as consumers from the nature and sources of food and the idea of food as a career.”

CAREERS
based food industries. Apart from education, the university has consistently been dedicated to research and innovation in relation to agriculture and food production, as illustrated by establishing its position as a world-leader in precision agriculture. Indeed, the university’s ‘Hands Free Hectare’ project demonstrates this perfectly, with two crop production cycles now completed in which the growing and harvesting of barley for beer production was achieved by means of autonomous agricultural vehicles, entirely without direct intervention by human beings on the land itself.

**Taking the plunge**

Harper Adams has a long history of teaching agriculture-related courses, however, the addition of food technology courses to the curriculum is a relatively recent occurrence. In 1996, the university took the step of appointing its first food science lecturer with the brief to develop and deliver food science and technology modules to undergraduate students studying mainly agriculture and agri-food business courses.

Initially a hand-full of optional food technology modules were inserted into the curriculum to provide an understanding of the fate of agricultural produce beyond the farm gate and of the principal sectors of the food industry. The modules proved to be popular, not least because students realised that a grounding in food technology could open doors to promising careers in the industry.

Harper Adams University has exceptionally strong links with the agri-food industry. As the number of undergraduate students opting to take food technology modules increased so the number of graduates being appointed into technical roles in food businesses also increased. This indicated that purpose designed food courses were meeting the needs of the food sector. Additionally, routine contact with food industry managers, often in companies providing industrial placements, reinforced the need to develop graduate food courses. These factors led to the decision to expand the university’s curriculum and in 1998 the MSc course in Food Marketing and Quality Management was launched. The course was designed specifically to provide a conversion route for graduates wanting to retrain for careers in the food industry and it ran for almost a decade. Importantly, it provided experience in the delivery of courses designed expressly to serve the graduate staffing needs of food businesses.

**The food course portfolio**

Experience gained through delivery of the MSc food programme led to the decision in the early-2000s to offer a purpose designed undergraduate degree programme in food technology. Marketing research provided the necessary intelligence which informed curriculum development and subject balance, i.e. the weighting between science and technology modules and marketing and business management modules. A valued comment made by many food business managers concerned the need for multi-skilled graduates who could ‘hit the ground running’. Harper Adams University’s model for undergraduate courses has always included year three of its four-year degrees as an industrial placement year. This was implemented in the new food course structures, thereby proving instrumental to the preparation of students for the real-world.

While the original plan was to develop one course, in the event two food technology
courses were launched in 2005, following completion of the standard processes of obtaining course development approval and validation from the Higher Education Funding Council (HEFCE) and the Quality Assurance Agency (QAA). Student recruitment into the BSc (Honours) Food and Consumer Studies and BSc (Honours) Food Quality and Business Management courses was initially modest but increased fairly rapidly to sustainable numbers.

By 2016 the time was right to revise the original courses and make additions to the portfolio. Today Harper Adams offers four food-related BSc (Honours) courses: Food and Consumer Studies, Food Manufacture with Marketing, Food Technology and Product Development and Food Technology with Nutrition. Each course reflects Harper Adams’s continuing commitment to supporting the graduate needs of the food industry.

In addition to the development of the undergraduate portfolio, the MSc in Food Technology and Business Operations Management has been replaced by the MSc in Food Business Operations Management and its linked academic awards at PgC (Post-graduate Certificate) and PgD (Post-graduate Diploma) levels.

**Course design considerations**

The development of a food technology degree course involves the synthesis of natural science disciplines with selected management sciences to equip graduates to work in diverse roles in the food industry. Apart from ensuring that a food technology course has the right subject mix, the importance of enabling students to develop practical skills cannot be understated. Educationalists refer to Kolb’s experiential learning theory (Figure 1) as a reference point for academic course development and his Learning Cycle proposes that Concrete Experience (doing and gaining experience) is necessary to allow Reflective Observation (the review of experience), which leads to Abstract Conceptualisation (stimulating modification of an existing abstract concept or the creation of a new idea, i.e. learning from experience) followed by Active Experimentation (applying ideas and knowledge gained in order to increase experience). As the name suggests, Kolb’s Cycle is an iterative process which reinforces experience with theory and theory with practise. In this respect, hands-on practice has to be an essential part of the development of graduate food technologists and, importantly, this must be recognised in curriculum design.

Because the development of Harper Adams’s food technology courses was undertaken with guidance from and in close cooperation with representatives of the food industry, the module mix was fine-tuned to deliver graduates with the range of knowledge and applied skills that employers require. Additionally, emphasis was given to development of the core skills that employers identify as essential attributes of employable graduates: communication, numeracy, information and communication technology (ITC), problem solving and working with others.

These factors were already well understood as critical considerations, given Harper Adams’s century-long experience in education. An apparent limitation during the course development phase was, however, the lack of practical food technology facilities at the campus.

**Food technology facilities**

Food microbiology presented no problem as the campus is well equipped with a range of laboratories, including microbiology facilities. The delivery of food technology practical classes covering for instance, food processing, preservation and packaging, was achieved through access to food processing halls in a partner college. Funding (around £4m) for the conversion of a former farm building at the centre of the University’s campus into a food technology unit was obtained from Advantage West Midlands’s (AWM – the regional development agency) in 2007. This resulted in the creation of the West Midlands Regional Food Academy (RFA), the function of which was to educate graduate food technologists and to serve the region’s food industry – mainly SME (small and medium sized enterprise) food businesses – by the provision of training and business development services for a period of 10 years. The facility was completed in 2009 and includes a general food processing hall, a cheese room, a development kitchen, an instrument room, a sensory evaluation unit and a food-grade lecture theatre adjoining...
Recent developments
Harper Adams’s undergraduate and postgraduate food technology courses are now well established, with lecturers drawn from the university’s five agriculturally orientated academic departments.

In 2011, 20 food lecturers, technicians and administrators were brought together in a single academic unit: the Department of Food Science and Agri-Food Supply Chain Management. In keeping with the well-established ethos of serving the needs of the food industry, the new department created a set of postgraduate courses designed expressly for the development of supervisory and management staff in the red meat, poultry and dairy sectors, with some students progressing to the award of MSc in Meat Business Management.

These courses and consequent interactions with the meat, poultry and dairy sectors led to the development of the degree apprenticeship courses[8], BSc (Honours) Food Industry Technical Professional and BEng (Honours) Food and Drink Advanced Engineer, launched in 2018.

Alongside further development of courses, the food department worked with Dairy Crest in the conception of its Innovation Centre now located at Harper Adams’s campus and officially opened in 2016. An industry-academia collaboration has developed, which brings dairy technologists into regular contact with academic staff and students in a variety of ways, including through guest lectures, project work and industrial placements.

Such is the innovative nature of the project that in 2016 it won the Times Higher Education Award for the Most Innovative Contribution to Business-University Collaboration.

These recent developments reflect the progressive nature of Harper Adams University’s food department and its commitment to working with the food industry. Further illustration was provided in 2017 with the launch of an annual Food Science Summer School, in partnership with the Institute of Grocery Distribution (IGD).

Harper Adams is one of five universities offering such summer schools for the benefit of year 12 pupils throughout the UK, so providing the opportunity to gain insight into careers in food and the food industry. The Food Science Summer School is designed to stimulate curiosity about food and, as one of a hand-full of British universities offering food technology and food engineering courses, Harper Adams University is well placed to provide the academic stepping-stone to food careers.

Conclusion
As a comparative new-comer to the education of food technology graduates, Harper Adams University has made rapid progress in a relatively short time. Its success is in large part due to the quality and dedication of its teaching staff and the support they receive from the university as a whole.

However, by far the most important ingredient in Harper Adams’s work to prepare graduates for food industry careers is the food industry itself and particularly the many food businesses that actively support the university in so many ways, helping to produce the food technologists and engineers the industry so clearly needs.
Transferable skills

Christina Dietz

When I chose subjects for my A-levels, I was 100% sure that I wanted to become an architect. Six months later, during an internship for the upper secondary school, I discovered this was definitely not what I wanted and that I better look for another career path. I spent my childhood on my parents’ and grandparents’ farms. My grandparents had a guest house and I had been involved in farming and cooking even before I went to secondary school. Because of my love for food, cooking and developing new recipes, I decided to start an apprenticeship as a chef. It was not easy but definitely one of the most valuable experiences due to the knowledge that I gained on raw materials, food preparation and processing methods. Additionally, I learnt a lot in terms of organisation and time management. I would recommend those who are not sure what to do after A-levels to get some hands-on experience via internships or placements.

Another factor that inspired me to choose a career in the food industry was a television report on the development and application of flavouring preparations in foods and beverages at Symrise, one of the global players in the flavour industry, headquartered close to my hometown in Germany. I was fascinated by the work of the flavourists and the product development team. A few years later, I had the opportunity to work at Symrise, conducting my Bachelor’s thesis project in one of their application technology and sensory departments. The project focused on the development of meat-reduced sausages and included the investigation of different meat and fat replacements and meat flavour preparations. As part of an international team consisting of highly experienced chefs, food technologists and flavourists, I developed different meat products, soups and sauces for various flavour applications.

After completing my Bachelor’s studies in Food Management at the University of Applied Sciences Weihenstephan-Triesdorf, I moved to the Netherlands for a Master’s programme in Food Technology at Wageningen University focusing on product design. Working or studying in a different country broadened my horizons! It provides the opportunity to learn a new language and expand your international professional network.

I then moved back to Germany to work in the product development department of a food supplier. In this company, I developed vegan and vegetarian meat substitutes, and flavour and spice mixes. Shortly thereafter, I was hired by a company that produces chocolate and fruit-based fillings, spreads and sauces. Moving to another company enabled me to apply transferrable skills, to broaden my knowledge base, and to see things from another perspective.

In 2017, I moved to the UK to undertake a PhD project in Sensory and Brewing Science at the University of Nottingham. I am delighted to be able to work in a very international, inspiring and supportive environment on a multidisciplinary and application-oriented project. My PhD is funded by Totally Natural Solutions Ltd, a company that produces hop aroma and bittering products for the brewing and beverage industry. The project focuses on the sensory and analytical characterisation of hop oil fractions that have been sustainably extracted using ‘green’ solvents in order to obtain clean-label flavouring preparations. By analysing the sensory and physico-chemical profiles of these hop oil fractions, it is possible to localise volatiles that drive specific aroma and flavour sensations and in addition, sensory interactions that involve taste and mouthfeel characteristics. This research will not only benefit producers in the brewing industry, but also provide the basis for future research projects on the investigation of hop flavour in beer.

Apart from being a student member of the IFST, I am currently involved in the European Sensory Science Society - Student and Early Stage Researcher Group (E3S-SESRG), the Young EFFoST (a sub-group of The European Federation of Food Science and Technology), and the British Society of Flavourists. Being engaged in professional associations or societies has enabled me to be involved in the organisation of events and conferences, to build professional platforms for networking and to engage with my peers all over Europe.

“Being engaged in professional associations or societies has enabled me to be involved in the organisation of events and conferences, to build professional platforms for networking and to engage with my peers all over Europe.”
I am originally from Finland, where I completed my Bachelor’s degree in Food Technology and a Master’s in Cereals Science. Prior to that I was contemplating becoming a teacher but was drawn to food science because of my interest in science, the dynamic nature of the industry, the potential to develop and how it impacted on people’s lives.

In Finland we have a culture of working during long summer holidays and it is common to work part-time alongside your studies, so I had previously spent time working in a brewery, a couple of different bakeries and a consumer research company.

My Master’s involved a six-month exchange trip to Sweden, where I studied plant and animal science. I also went on a three-month placement at Campden BRI in 2014 after which I was delighted to be offered a position there as a bakery technologist. This role was practical, involving making various baked goods and analysing product quality. After a year I was promoted to the post of senior bakery scientist, which involved managing long term research projects, and last year I became an ingredient research team leader. In this role I cover new ingredients research, such as plant proteins and egg alternatives. I have presented research to the food industry and spoken at seminars. I have also been able to travel, in the UK and overseas, and have been fortunate to start my PhD with the company’s support.

If you’re in the food industry, Campden BRI is a great place to work. The people are friendly and its broad expertise in all areas of food means that there are many opportunities to learn and develop. There is also the potential to diversify into other areas of food science that you may not have considered previously.

I mentioned the people who work at Campden BRI, but it’s also the people we work for who make it a fascinating place. Campden BRI is a membership-based organisation, which means that food companies direct its research and scientific activities. ‘By industry, for industry’ is its motto and for a good reason. It has over 2,600 companies from across the world as members, so you can sit in meetings with senior representatives from the world’s largest food and drink manufacturers, the top supermarkets and world-leading household brands – all at the same time! It does feel like a privilege working for an organisation that is at the heart of the food and drink industry.

The work we undertake for clients is also immensely rewarding. Sometimes they come to us with problems or ideas and we solve them or make them happen, knowing that ultimately we have a direct and positive impact on people’s day to day lives.

For anyone considering a career in food science, Campden BRI should definitely be on your list. It is keen to develop its staff from within. Many people have been here for over 30 years and worked their way up the organisation. There are also many young people here, so there’s a genuine caring and dynamic vibe. When you network with so many key food industry executives, opportunities can arise there too!
Wiley Spectra Lab provides researchers with access to 2.3 million MS, NMR, and IR spectra – the broadest and largest collection in the world. This expert spectral data system uses empirical data and advanced software to help chemists, toxicologists, and life scientists confidently identify chemical substances.

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