FOOD STRUCTURE
STABILISING EMULSIONS

STRUCTURING WITH CELLULOSE
X-RAY CT IMAGING
RHEOLOGICAL CHARACTERISATION
SYNCHROTRON LIGHT SOURCE FOR ANALYSIS
AUGMENTED REALITY CUISINE
PSYCHOLOGICAL TESTING
BIG DATA
BIOENRICHMENT OF ANIMAL SOURCE FOODS
AQUACULTURE IN SCOTLAND
FOOD ANALYSIS SEMINAR

In food and beverage industries, it is essential to ensure high product quality during various steps in the production process, from the quality control of raw materials (e.g., natural products) to their treatment during and after production. Authorities constantly work on new regulations to ensure high food quality and safety, therefore, rising the demands of food testing laboratories.

09:00  Registration
09:30  Welcome and Introduction from Shimadzu and Merck
10:00  GCMS applications for the food industry
10:30  Determination of Pyrrolizidine Alkaloids in Plant Material using SFC NIS/MS
11:00  Analysis of gut microbial metabolites of polyphenols using LC-MS; application to personalised nutrition
11:30  Sample preparation for fatty & complex food materials, new tools for SPE & QUECHEXS providing higher efficiency and more reliable results
12:00  Lunch break
12:45  Analysis of pigeon-communication studies on hatching and rearing of young pigeons
13:45  Sample preparation for fatty & complex food materials, new tools for SPE & QUECHEXS providing higher efficiency and more reliable results
14:30  Coffee Break
15:00  Extraction of pesticide residues in food materials by solid phase extraction
15:30  A big appetite for data: Sendine Pipel demonstrates an application of big data to novel predictive models to help make informed decisions about food processing development, consumer health and food safety
16:00  Final discussion

VENUE
Shimadzu UK Centre of Excellence
Mill Court, Featherstone Road, Milton Keynes, MK12 5RD

TO REGISTER, PLEASE VISIT:
www.shimadzu.co.uk/food-seminar

3rd FOOD SCIENCE & TECHNOLOGY
QUARTERLY JOURNAL OF THE INSTITUTE OF FOOD SCIENCE & TECHNOLOGY

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IFST NEWS
**Farmers'COMMENT**

**CENTURY FOR CAMDEN BRI**

Camden BRI is 100 years old this year. To mark the occasion, the Annual Camden Lecture was delivered by Tracey and Dometon, who also celebrate their centenaries this year. Camden BRI's beginnings go back to the First World War, when the UK Government wanted to develop ways of preserving food to ensure food security in times of conflict. A milling facility for peasanst food, next to Camden railway station, was chosen as the base for this critical endeavour as it was located in the Vale of Evesham, a major source of fruit and vegetable production.

The war ended before the facility was established, but the project continued, and the Camden Experimental Factory came into being in 1919. It started off developing canned food processes and over the years its work spread into all areas of food production including scientific, technical and consumer research. Today, as Camden BRI, it is the world's largest independent membership-based food and drink research organisation, serving food and drinks companies across the world. It currently has over 2,500 member companies from 80 countries, including all of the top 10 UK retailers, the top 15 global food and drink manufacturers, and many of the world's biggest brands.

**Allergen labelling**

The Government has announced plans to introduce a new allergen labelling law to help further protect the UK’s two million people living with food allergy. The new legislation will mandate full ingredient labelling for foods which are packed for direct sale. These are foods that have been made and packed on the same premises from which they are being sold. For example, a packaged sandwich or salad made by staff earlier in the day and placed on a shelf for purchase.

Currently, these foods are not required to carry labels and information on allergens, as it is expected that the customer can speak with the person who made or packed the product for this information.

**Food chain review**

The findings of an independent review that will consider the food chain will for the first time be used to develop a National Food Strategy for England. This independent review will look at the entire food chain, from field to fork, including production, processing, sale and purchase of food (for consumption in the home and out of it). It will also look at the consumer practices, resources and institutions involved in these processes.

The review will be chaired by Henry Dimbleby, the co-founder of Leon restaurants, lead non-executive director at Defra and co-author of The School Food Plan; he will be supported by an advisory group and Defra officials. A call for evidence is being launched this summer and the review will publish its findings in summer 2020. The National Food Strategy will build on the work underway in the Agriculture Bill, the Environment Bill, the Fisheries Bill, the Industrial Strategy and the Childhood Obesity Plan. It is intended to be an overarching strategy for government, designed to ensure that our food system:

- delivers safe, healthy, affordable food, regardless of where people live or how much they earn;
- is robust in the face of future shocks;
- restores and enhances the natural environment for the next generation in this country;
- is built upon a resilient, sustainable and healthy agriculture system;
- is a thriving contributor to our urban and rural economies, delivering well-paid jobs and supporting innovative producers and manufacturers across the country;
- delivers all this in an efficient and cost effective way.

**Sustainable ingredients**

The focus on the preferences of the younger generation is increasing inclusion of insects as a common source of protein and nutrients. The researchers emphasise that commercialisation and processing technologies that focus on the preferences of the younger generation is the best way to normalise edible insects. Promoting insects as an environmentally sustainable protein source appeals to current attitudes in the younger generation.

Despite the growing demand for edible insects in urban areas, harvesting and indoor farming is limited because farmers associate insects with poverty and do not see it as a positive source of income. The researchers emphasise that commercialisation and processing technologies that focus on the preferences of the younger generation is the best way to normalise edible insects. Promoting insects as an environmentally sustainable protein source appeals to current attitudes in the younger generation.

**Century for Campden BRI**

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Eurobarometer of food safety

A new Eurobarometer survey commissioned by EFSA investigated Europeans’ overall interest in food safety, including factors affecting food-related decisions, main information sources on food safety topics, trust in different sources of information and understanding of the EU food safety system.

The survey was carried out by the Kantar network in the 28 EU Member States between the 9th and 26th of April 2019. Some 27,055 respondents from different social and demographic groups were interviewed face-to-face at home in their mother tongue.

The methodology used is that of the Standard Eurobarometer surveys carried out by the Directorate-General for Communication. It is the same for all countries and territories covered in the survey.

Key findings included:

- The most important factors for Europeans when buying food are where the food comes from (53%), cost (51%), food safety (50%) and taste (49%). Nutritional content is slightly less important (44%), while ethics and beliefs rank lowest (11%). Overall, 41% of respondents say that they are ‘personally interested in the topic of food safety’. Just over one fifth of Europeans (22%) say that safety is their main concern when choosing food.
- More than two thirds of Europeans (69%) say that television is among their main sources of information about food risks. This is followed by the internet (excluding social media) (46%), newspapers and magazines (38%) and family, friends and neighbours (37%).
- Two thirds of Europeans (66%) have changed their consumption after receiving information about a food risk. For 33% the change was permanent, for the other 33% only for a while.
- Changes in consumption behaviour are more common among women, those in the middle age bands, and those with higher levels of education.
- The most frequently cited concerns are antibiotics, hormone or steroid residues in meat (44%), ‘pesticide residues in food’ (39%), ‘environmental pollutants in fish, meat or dairy’ (37%) and ‘additives like colours, preservatives or flavourings used in food or drinks’ (36%).
- Trust is highest in scientists (82%) and consumer organisations (79%) for information on food-related risks, followed by farmers (49%), national authorities (46%), EU institutions (56%), NGOs (56%) and journalists (56%). Fewer people trust supermarkets and restaurants (43%), food industries (36%) and celebrities, bloggers and influencers (15%).
- Just over 2 in 5 respondents (43%) say that ‘there are regulations in place to make sure that the food you eat is safe’. Three in ten (28%) know that ‘to decide how risky something could be for you, the EU relies on scientists to give expert advice’.

FROM THE CHIEF EXECUTIVE
Jon Poole
Chief executive, IFST

January 2019 saw the launch of the Food and Drink Sector Council, a formal industry-led collaboration with government composed of businesses and organisations from every part of the food chain. Among the Council’s strategic priorities are agricultural productivity, nutrition, exports, workforce and skills, innovation, logistics and packaging. Quoting from the govt uk website: ‘The Council will be a mechanism for the industry to engage with government in order to increase the sector’s productivity.’

This is an opportunity for the sector as a whole to work strategically with government to find ways to address many critical challenges facing us all, relating to food and nutrition. This was followed in June this year by an announcement that Defra is to ‘lead the first major review of the UK food system in nearly 75 years’. This review is to be led by Henry Dimbleby and is expected to result in a national Food Strategy for England.

These are both significant developments that demonstrate the importance of food to the UK economy and, more importantly, in ensuring the security of our food supply into the future. Underpinning both initiatives are two critical factors – the availability of skilled people and investment in science and technology. Both are critical if we are to guarantee the continuous supply of safe, nutritious and affordable food.

During the early considerations around Brexit, IFST wrote to the Government to demand that any future Brexit negotiations should not jeopardise the UK food system’s access to appropriate skills in food science and technology. Anybody再多reafter the UK has left the EU should continue to have access to European research funding and continue to play a full and active role in future research collaborations.

Over the last few months though, since even before the original March Brexit deadline, we have heard very little about how these two challenges are being addressed, which is concerning. I was very pleased, therefore to receive a circular email from George Freeman MP this week, seeking support for his demands from government for a much bolder vision and an urgent commitment to address the critical challenges facing us all, relating to food and nutrition. The Government has agreed to these demands and is committed to address the critical challenges of science and technology. This is a significant development that demonstrates the importance of food to the UK economy and, more importantly, in ensuring the security of our food supply into the future.

In the lively Q&A’s that followed, Professor Gibney noted that more work on nutrient intake as a function of specific genotypes may yield clearer evidence for policy making.

The 2019 annual Lecture was supported by the Food and Government Chemists, the National Measurement Laboratory (NML), the Food & Drink Federation (FDF) and Leatherhead Food Research.

Michael Walker [ncl.nih.gov/pubmed/30868275]
**IFST Young Scientists of the Year 2019**

Congratulations to Alice Nield (University of Reading) and Sarayjet Bayo (Manchester Metropolitan University) who won the national final of the IFST Young Scientist Competition in the undergraduate and postgraduate categories respectively.

Alice impressed the judges with her presentation entitled Production of GOS from aerobic probiotics. Sarayjet talked about antimicrobial properties of potential bioactive compounds of Indian spices and herbs. Both articles are reproduced at the end of IFST News on pages 14 and 15.

IFST Young Scientist Competition provides undergraduate and postgraduate students based in the UK with a chance to present a recently completed project to their peers and a panel of food professionals. In addition to regional rounds in Scotland, Northern Ireland, North of England and South of England, this year we hosted a national final on 18 June in London.

Alongside the competition, we had the honour of having Dr Hazel Gowland, expert in food allergy risk, as our keynote speaker. She delivered a talk entitled Flat, bug or avoid – what to do about food allergies.

Thank you to all students who took part and special thanks to all academics who supported and universities who hosted our competition over the past few months.

**Science Communications Competition**

Congratulations to Catherine Baungaard from Liverpool John Moores University, who has won our first ever Science Communications Competition with her article on Quin-What? Cultivating Exotic Protein-Rich Crops in Europe. This competition provided undergraduate and postgraduate students based in the UK with an opportunity to write about the theme of this year’s IFST Spring Conference to develop their skills for science communication. Catherine’s winning article is reproduced at the end of IFST News on page 17.

**Plastic problems addressed in POSTnotes by IFST fellow**

We are delighted to announce that IFST POST (The Parliamentary Office of Science and Technology) Fellow, Caroline Wood, has co-authored POSTnotes entitled Plastic food packaging waste and Compostable food packaging. Plastic packaging is widely used in the food sector but plastic waste in the environment is of growing consumer concern.

On choosing the topic for her POSTnotes, Caroline said: “I was particularly keen to work on a very topical issue where my POSTnotes could have a significant impact. Plastic waste is an immense, complex problem with many of the possible approaches to solve it having their own disadvantages for the environment. Policy makers need to be informed so we don’t move straight from one problem to another. Hopefully, my POSTnotes will help in this respect.”

Each year IFST provides funding of £5,000 for a PhD student to spend three months at POST working on a food-related POSTnote. The POSTnotes are then dispersed amongst parliamentarians to provide insights on a topical subject within science and technology.

**IFST Special Interest Groups**

**IFST Special Interest Groups (SIGs)** enable members to connect and collaborate with others who share similar professional interests, including those from academia, manufacturing, retail and consulting. They cover important, relevant food science and technology topics and provide up-to-date information as well as the opportunity for useful discussions at events and via forums.

The events, including presentations and workshops, are well attended by IFST members and non-members. Special Interest Groups are managed by committees of volunteers, who meet both virtually and face to face. They are fully supported by the IFST central team.

**Food Safety Group**

Chair: Sterling Crewe CIFST

IFST Food Safety Group provides members interested in food safety with an opportunity to engage and share knowledge. The Group hosts regular discussion workshops and contributes articles to Food Science & Technology magazine as well as supporting relevant media enquiries and technical consultations.

Recent highlights (June 2019):

- Delivering a positive food safety culture – a practical approach featuring speakers from Shield Safety Group, Kitchen Conversation and Culture Compass, which received positive press coverage.
- Social media activity during the build up to World Food Safety Day, including interviews with experts and useful quotes.

**Food Science and Nutrition Group**

Chair: Lindsay Bagley CSci CIFST

IFST Food Science and Nutrition Group provides members interested in food science and nutrition with an opportunity to engage and share knowledge with others.

Recent highlights have featured speakers from organisations such as British Nutrition Foundation (BNF), Food and Drink Federation (FDF) and various manufacturers.

- Sweeteners: the next level (June 2019)
- What is a ‘pinch’ of salt? (October 2018)
- Vitamins and minerals – Small but Mighty (May 2018)
- Fibe: the rough with the smooth (October 2017)
- The big fat debate (September 2017)

**Food Regulatory Group** (formerly known as Food Law Group)

Chair: Sam Jennings FIFST

The Food Regulatory Group provides members interested in food legislation, regulatory affairs and regulatory compliance with an opportunity to engage and share knowledge with fellow members. The group is involved in a wide range of activities, including discussion workshops.

Recent highlights featuring speakers from organisations such as Food Standards Agency (FSA), Leatherhead Food Research, Ashbury Labelling, Department for International Trade and Trading Standards:

- Asking the right questions: theory and practice (May 2018)
- Not as free trade as you think! (October 2018)
- Focus future: a regulatory minefield? (March 2018)
- Food law and nutrition – the dynamic duo (September 2017)
- Health is wealth (June 2018)
- To-F-value or not? That is the question! (May 2018)
- It’s not always about the flavour (May 2017)

**Sensory Science Group**

Chair: Stephanie Mitchell FIFST

The Sensory Science Group provides members interested in food and drink sensory science with an opportunity to engage and share knowledge. The Group hosts a range of events including an annual conference and workshops, covering a wide range of topics relating to sensory properties, such as testing and analysis, consumer trends, neuroscience, impact of social networking, health and wellness. Formerly known as the Professional Food Sensory Group, the Group is this year celebrating its 20th anniversary.

The Sensory Science Group is also involved in accreditation and examination of sensory training and the revision and promotion of ethical and professional standards. It has close links with the European Sensory Science Society (E3S), an organisation promoting cooperation, shared goals, integration and international exchange amongst national organisations across Europe.

Recent highlights featuring speakers from academia and industry include:

- Changing perspectives in sensory science – past, present and future (March 2019)
- Celebrating individuality (November 2011)
- Health is wealth (June 2018)
- ‘To-F-value or not? That is the question!’ (May 2018)
- ‘It’s not always about the flavour’ (May 2017)

For more information please visit: ifst.org/organisations/accreditation-schemes/sensory-science/sensory-science-group/

**For more information on how to get involved with IFST Special Interest Groups, please contact: Natasha Medhurst CIFST, Scientific Affairs Manager via n.medhurst@ifst.org**

**Short Course Recognition Scheme**

We are very pleased to have launched a new recognition scheme for short courses and training offered by employers and external training providers.

This IFST ‘badge’ of recognition will indicate that a course has been assessed by IFST and judged against a set of standards to be of a high quality and aligned to the needs of the food sector.

For more information please visit: ifst.org/organisations/accreditation-schemes/short-course-recognition-scheme/
Vegan energy sweets take top spot

A team of students from the University of Reading, pictured right, has won the gold prize at Ecotrophelia for their vegan energy sweets for endurance athletes. The Venergy team has developed lemon and lime flavoured energy sweets which provide a vegan, sustainable alternative to energy products, by tussling issues concerning ingredient and packaging sustainability. Each member of the gold-winning team took home a share of £2,000 and an invitation to become an IFST Young Ambassador.

In its seventh year, Ecotrophelia UK is a ‘Dragons Den’ style competition that challenges teams of UK students to develop an innovative, eco-friendly food and drink product. From idea generation through to the final packaged product, the teams get hands-on experience of what it takes to bring an eco-friendly food or drink product to market. The finalists pitched their products on 11 June and the winners were announced on 12 June at Campden BRI’s annual open day. The awards were presented by Lindsay Dobson of PepsiCo (prize sponsor).

Alice Bryant, Nutrition and Food Science student, Reading University said: ‘We are all delighted to have been chosen as the winners of Ecotrophelia UK! The awards were presented by Andrew Gardner, Operations Director at IFST said: ‘Our Dragons tell us the quality of the entries improves year on year, and this year is no exception. Team Venergy are rightful winners with their energy sweets. You will be seeing much more of them and the other finalists!’

The teams pitched their ideas to judges from top names in the food and drink industry including PepsiCo, Coca-Cola, Mondelez, Marks & Spencer, Unilever, Warburtons, Institute of Food Science and Technology (IFST) and Campden BRI. Venergy team will go on to compete against 16 other national teams from across Europe for the chance to win up to £5,000 at the Ecotrophelia European final, which will take place during Achema in Cologne, Germany on 6 and 7 October 2019. Bertrand Emond, Head of Membership and Training at Campden BRI said: ‘It’s fantastic to see so many young people engage with this competition and put forward such innovative products. Over 350 students from 17 different universities across the UK have now taken part since 2013. The 2017’s winning team went on to win silver prize in the European final with their vegan snacks made from cashewflower rice and fresh vegetables, building on the bronze prize the previous year, so we have high hopes for the teams again this year in October at Amagia in Cologne, Germany. We are also delighted by the interest shown and support provided by the industry.’

The UK heat of this Europe-wide competition was organised by UK food and drink research organisation, Campden BRI, in conjunction with the Institute of Food Science & Technology (IFST). In addition to IFST, other sponsors were from Europe and Australasia.

The take home message was ‘be deliberate and strategic in your role and take appropriate risks to develop yourself to become a leader of the future’. They encouraged me to seize the opportunity to evaluate what I currently do and create strategies for the future. I was delighted to represent the UK at the Emerging Leaders Network on behalf of the Institute of Food Science & Technology IFST.

The aims of the workshop were to build a sense of community, to interact with senior level food scientists and to identify personal skills and challenges. The seminars were intended to build upon skills already obtained through current and previous experiences and connect them together to help understand and tackle future challenges. Participants (10) shared experiences and connected with a wide array of different food scientists from the industry as well as academia. The focus was mainly within the Americas (both North and South America were represented but some participants were from Europe and Australasia). The take home message was ‘be deliberate and strategic in your role and take appropriate risks to develop yourself to become a leader of the future’. They encouraged me to seize the opportunity to evaluate what I currently do and create strategies for the future.

I would like to thank IFST for sponsoring me on this event and those judges who chose me as the UK’s representative. This experience has helped not only my own career within my role at Abertay University but it also helped me see the impact my role has on the Scottish Food and Drink sector, as well as the UK as a whole. If you are ‘Young’ or in my case ‘Newish’ to the food and drink sector, I would recommend submitting an entry.

Dr Jonathan Wilkin represents IFST at the IFST Emerging Leaders Network

Dr Jonathan Wilkin, Lecturer, Abertay University, represented IFST at this year’s IFST Emerging Leaders Network (ELN), which took place from 31 May to 2 June in New Orleans, USA. Here he reports from the event.

Food Allergy fact sheet

We are pleased to announce that we have released a new Food Science Fact Sheet on Food Allergy. It has been designed to provide the public with clear, concise and scientifically reliable information on this topic.

Food allergy never seems to be out of the spotlight as we continue to learn about allergy symptoms and severity. Those at great risk are teenagers and young adults, many of whom have never experienced a major reaction before.

As food allergy presents significant challenges for both consumers and those managing food businesses, this Food Science Fact Sheet answers the following questions:

What is a food allergy?

- What is a food intolerance?
- What are the major food allergens?
- How should food allergens be labelled?

Download the Food Science Fact Sheet at: ifst.org/sites/default/files/Food%20allergy.pdf

Dr Jonathan Wilkin BSc (Hons), PhD, IFST

Food Innovation at Abertay
Gluten protein network structure in steamed bread dough

The effect of baked wheat germ (BWG) on the gluten network structure in steamed bread dough was investigated. The secondary structure, free sulphhydryl (-SH) content, disulphide (-SS) bonds content and microstructure of gluten were analysed to evaluate gluten structural changes. The addition of different amounts of BWG (0, 2, 4, 6, 8, 10, and 12%) in dough resulted in decreased content of α-helix and β-sheet structures, but increased random coil, which indicates that a disordered structure was formed. The presence of BWG increased the -SH content but decreased the -SS-bonds content, which indicated fracture of disulphide bonds. Confocal laser scanning microscopy (CLSM) analysis indicated that steamed bread dough containing BWG had larger sized gas cell and granules of starch separated by the protein matrix, which weakened the gluten network structure. These changes may inevitably affect the viscoelastic properties of steamed bread dough. Zhao et al., 2019, https://doi.org/10.1111.jsi.14200

Freezing-thawing of starch – Stress

Normal and waxy corn starch gels were subjected to repeated freeze–thaw treatment at 0, 1, 2, 3, 4, 5 and 6 cycles with an interval of 24 h, and the effects on structural, physicochemical and digestible properties were investigated. The normal starch gels formed a homogenous structure while waxy starch gels exhibited a lamellar appearance, the number of holes and lamellae increased with increasing cycles. X-ray analysis showed that relative crystallinity increased with the number of increased freeze-thaw cycles. The hardness increased in both normal and waxy starch. The solubility and pasting breakdown viscosities decreased in normal starch but increased in waxy starch. Peak viscosity and setback viscosity increased in normal starch but decreased in waxy starch. The rapidly digested RS5, RS3 and slowly digested (RS5) content in normal starch increased and non-digestible starch (RS5) content decreased, whereas the RDS, DDS and RS content in waxy starch was almost unchanged as the freeze-thaw cycles increased. The molecular weight of both normal and waxy starch decreased with freeze-thaw treatment. Therefore, the repeated freeze-thaw treatment can change the physicochemical and digestible properties, which could be useful for starch-based food processing. Jing et al., 2019, https://doi.org/10.1111/jsi.14177

Biocurable phenolics in pumpkin, apple and potato powders

The study examined carrot, pumpkin and apple powders produced by hot-air-drying (50, 60, 70°C) of samples with different levels of fragmentation (cut, grated, blended). The rapidly digested and slowly digested temperatures and sample structure were shown to be important determinants of the quality of the powders. The best colour stability of carrot, pumpkin and apple was found for the grated sample and the blended sample dried at 70°C. The highest antioxidant capacity and reducing power were found for powders obtained after drying the cut samples at 70°C. Total phenolics and free radical quenchers were bioaccessible in vitro. The reducing power was markedly reduced after drying at 50°C. The analysed powders are a valuable source of concentrated bioactive ingredients, potentially useful as functional food components. Bomhak and Iwac, 2019, https://doi.org/10.1111/jsi.14270

Current understanding of bioaccessibility and bioavailability of food-derived bioactive peptides

Bio-functional peptides are now an important category within the nutraceutical food sector. Recent advances in modern analytical techniques are unlocking the secret of bioactive peptides with specific biological activities. The ex vivo and in vivo bioaccessibility and bioavailability of peptides obtained from milk, eggs, soy, meat and collagen are covered in this special issue. http://doi.org/10.1111.jsi.14164

IFST secures a further Science Council licence

We are pleased to announce that we have secured a further licence from the Science Council to award Chartered Scientist (CSci), Registered Scientist (RSci) and Registered Science Technician (RSciTech) status for the next five years. Professional recognition and improvement lie at the heart of everything we do at IFST. With an ever-greater number of possible career development pathways within the food sector, it is now more important than ever to be recognised by a professional, independent body. Ruth Ashby, IFST’s Registration and Assessment Officer said: ‘We are delighted to be working again with the Science Council in offering professional registration to the food science and technology sector. Professional registration provides an opportunity to showcase individual knowledge and expertise together with an ongoing personal commitment towards continued self-improvement in your professional life.’

Here at IFST we believe that the many facets of CPD ensure that professionals can be empowered to progress their own careers and, through reflective practice, can positively impact their role.”

To access the Search, please go to: IFST.org/search-food-safety-professionals

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As the professional membership body for the food and drink industry, IFST offers a range of professional recognition, CPD, publications, events and networking opportunities. For more information on how you can become a Member or Fellow of IFST, visit our homepage/call-for-papers-softfoods
Your gut bacteria can weigh up to 2kg, that is more than the weight of the average human brain[1]. Modulation of the human gut microbiome is associated with many health benefits such as alleviation of symptoms of Irritable Bowel Syndrome (IBS), Inflammatory Bowel Disease (IBD) and reductions in liver LDL cholesterol levels[2-4].

In this research project, a specific strain of Lactobacillus plantarum (Optibiotix product LPLDL, see Figure 1) was used. Previously, this had demonstrated the ability to selectively stimulate the growth of the cholesterol reducing probiotic bacteria and improve the survival in the gut [5]. After centrifugation and dilution of biomass with sodium phosphate buffer (pH 6.8), cells were lysed mechanically by bead beating to yield intracellular β-galactosidase crude enzyme, see Figure 2. This enzyme was used to catalyse the production of GOS via the transgalactosylation reaction using lactose as the substrate. GOS are prebiotic carbohydrates comprised of 2-8 saccharide units, with one of these being a terminal glucose or galactose unit. GOS selectively stimulate Bifidobacterium and Lactobacillus at the expense of harmful bacteria such as Staphylococcus aureus, see Figure 3[6].

GOS were synthesised over 36 hours, using 20 different production conditions. As lactose was consumed, it was either converted to GOS or hydrolysed to glucose and galactose (see control experiment). GOS yields peaked between 13 and 17 hours, before glucose and galactose increased. Anaerobically, GOS yields of 38% were achieved. There was a clear compromise necessary between a high enough temperature to allow for lactose solubility yet ensuring enzyme activity was maintained throughout. When grown aerobically, β-galactosidase was produced by the LPLDL strain and GOS were synthesised albeit with lower maximum yields of 15%. This is promising for the probiotic industry, suggesting that use of facultative anaerobic probiotics that respond well to oxidative stress could be used to produce a prebiotic, when using probiotics grown in either anaerobic or aerobic conditions. Conditions could be altered to achieve higher yields or comparable yields to that of anaerobic growth, such as varying growth time, temperature or lactose concentration to match the growth characteristics of the probiotic under aerobic conditions.

In conclusion, this research project demonstrated that GOS were produced from enzymes derived from aerobic growth of L. plantarum, offering significant improvements to current challenges in the food industry relating to anaerobic growth. This would allow for the scale up of this symbiotic technology to yield a viable product with the potential for selective increases in probiotics with known cholesterol reducing abilities, so that cholesterol could be reduced using diet-mediated strategies in those people with slightly elevated cholesterol levels.

We probably all know someone with elevated cholesterol levels, or perhaps some of you reading this have cholesterol being a main risk factor[7]. Cardiovascular disease (CVD) is the 2nd largest cause of mortality in the UK and with high LDL cholesterol being a main risk factor[8], the ability to scale up this technology in industry would allow for potential reductions in cholesterol before medication becomes a necessity. Whilst you are reading this article, at least one person in the UK will have paused away from CVD[9]. This puts into perspective the impact this disease has both in the UK and globally. The scale up of this technology using readily available aerobic technology would be stepping stone in both improving gut microbiology composition and reducing elevated cholesterol levels within the population (see Figure 4).

Food safety has increasingly become a fundamental health concern for consumers and a major challenge for food manufacturers due to the need to produce foodborne diseases caused by pathogenic microorganisms[10]. In the process of combating the impact of foodborne microorganisms, there has been increased use of synthetic chemical preservatives such as nitrates, nitrates, benzoic acid as antimicrobial agents. Studies showed that nitrates and nitrites when used in processed meat and products cause increased risk of colon cancer[11,12]. The utilisation of sulphites can result in allergic responses in sulphite sensitive persons. The use of synthetic phenolic antioxidants like butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) has been reduced, due to concerns about health risks[13]. Moreover, consumers are increasingly suspicious of synthetic preservatives and have increased desire for ‘CLEAN LABEL’. In the last decades, many research studies have focused on finding alternate antimicrobial agents for use in food to combat both pathogenic and spoilage microorganisms. Some of the studies have looked at potential bioactive compounds from natural plant based materials that could be used in food products, which inhibit growth of microorganisms and provide food safety and preservation effects[14].

Plant sources of natural antimicrobics

A number of spices and herbs contain natural antimicrobial properties and can be used to extend the shelf life of unprocessed and processed foods by reducing microbial growth[15-18]. Spices and herbs are natural plant materials, that are not only used as flavouring or colouring agents in food, but as standardised extracts for medicinal purposes, such as eugenol (from clove oil), and are also used in small quantities as preservatives in food[19]. Application in the preservation of foodstuff is mainly through inhibition of lipid oxidation, colour loss and as retardants of microbial activity[20]. Commonly used Indian spices and herbs are listed in Table 1.

Table 1 Some commonly used Indian spices and herbs

<table>
<thead>
<tr>
<th>Common name</th>
<th>Biological name</th>
<th>Family</th>
<th>Part used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay leaves</td>
<td>Laurus nobilis</td>
<td>Lauraceae</td>
<td>Leaves</td>
</tr>
<tr>
<td>Black pepper</td>
<td>Piper nigrum</td>
<td>Piperaceae</td>
<td>Fruit</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>Cinnamomum verum</td>
<td>Lamiaceae</td>
<td>Bark</td>
</tr>
<tr>
<td>Cloves</td>
<td>Syzygium aromaticum</td>
<td>Myrtaceae</td>
<td>Flower buds</td>
</tr>
<tr>
<td>Coriander</td>
<td>Coriandrum sativum</td>
<td>Apiaceae</td>
<td>Seeds</td>
</tr>
<tr>
<td>Cumin</td>
<td>Cuminum cyminum</td>
<td>Apiaceae</td>
<td>Seeds</td>
</tr>
<tr>
<td>Mace</td>
<td>Myristica fragrans</td>
<td>Myristicaceae</td>
<td>Aoli (seed covering)</td>
</tr>
<tr>
<td>Nutmeg</td>
<td>Myristica fragrans</td>
<td>Myristicaceae</td>
<td>Seed</td>
</tr>
<tr>
<td>Saffron</td>
<td>Crocus sativus</td>
<td>Iridaceae</td>
<td>Stigmas with style</td>
</tr>
<tr>
<td>Sesame seeds</td>
<td>Sesamum indicum</td>
<td>Pedaliaceae</td>
<td>Seeds</td>
</tr>
<tr>
<td>Thyme</td>
<td>Thymus vulgaris</td>
<td>Lamiaceae</td>
<td>Leaves with flowering tops</td>
</tr>
<tr>
<td>Turmeric</td>
<td>Curcuma longa</td>
<td>Zingiberaceae</td>
<td>Roots</td>
</tr>
</tbody>
</table>

With thanks to Professor Bob Rastall and Dr Vasnilla Rachmanindov (University of Reading) for their supervision and support and to Optibiotix for their sponsorship of this research project. References and article available online at: fstjournal.org/33-3/ifstnews

Figure 2 Light microscope image of Lactobacillus plantarum (LPLDL) probiotic under x 40 magnification

Figure 3 Half of the paper kata text was added as an additional note to the right side, to enhance readability.
Spices and herbs contain a variety of secondary metabolites – a variety of bioactive compounds such as phenolic acids, terpenes, flavonoids, and glucosinolates, which imparting antimicrobial effects. These bioactive components in spice extracts could be responsible for antimicrobial efficacy of spices. Cinnamon, which is a popular spice, has been granted generally recognised as safe (GRAS) by the US Food and Drug Administration. However, spice and herb essential oils lack at least one or more of the nine ‘essential’ amino acids compared to animal-based proteins, rendering them ‘incomplete’. But don’t worry! Combinations of plant-based protein sources in foods eaten throughout the day are enough to deliver the ‘essential’ amino acids we need. Interestingly, certain crops and seeds are termed ‘high-quality’ proteins, because they are almost equivalent to animal proteins. For example, quinoa and amaranth are considered high-quality because they contain the ‘essential’ amino acid lysine, while grain legumes (lentils, chickpeas) have a ‘high quantity’ of protein (about 20%) (Figure 3). These crops and legumes are perfect examples of protein sources that can help increase the transition towards more and attractive plant-based food products.

Figure 1 Proteins present in Greenhouse Gas Emissions for various protein-rich foods

WINNING ARTICLE IN THE SCIENCE COMMUNICATIONS COMPETITION BY CATHERINE BAUNGAARD OF LIVERPOOL JOHN MOORES UNIVERSITY

Quin-what? Cultivating exotic protein-rich crops in Europe

Quinoa (kima)!
Chances are you have heard of it, maybe even enjoyed it in a salad or stew. Thanks to innovative research and technology, exotic crops like quinoa and amaranth are making their debut out in the European fields and could be finding their way on to our dinner plates within exciting new food products.

A case of unsustainable protein demand

There is no doubt, British people love their protein. A cooked breakfast just isn’t the same without the rashers of bacon and we wouldn’t want to forget about the childhood favourites - hangers and mash. For centuries animal protein has been the centrepiece of the Western meal. Yet, it is no secret, our growing demand for protein is causing unprecedented damage to the natural environment. For example, our food systems are a major contributor to climate change, accounting for 30% of total global greenhouse gas emissions, of which meat and meat-derived products account for the majority (Figure 2). Additionally, animal-derived products take up more than 50% of Europe’s total water consumption, talk about being thirsty! But that isn’t the end of the story. Our over-reliance on monocultures, producing a single crop at a time, in wheat, corn and even bananas is placing our supply chains at greater risk from diseases and future climatic change, a seriously dangerous situation.

In addition, as the world population continues to grow, so too will the demand for protein. Furthermore, addressing how we can meet this protein need in a healthy and sustainable way, may be the biggest challenge society and the food industry face.

To meat or not to meat?
That is the question and with initiatives like ‘Veganuary’ becoming more mainstream, consumers are increasingly answering, no thank you.

Currently, there is no clear conscience of ‘sustainable eating’, opting for more flexitarian consumption patterns and demanding more plant-based products. A prime example was the overwhelming success of Greggs’ vegan sausage roll. This rapidly growing market of plant-based products represents a major opportunity to provide more and attractive plant-based options for consumers, while meeting nutritional needs and helping with the transition to more sustainable production. But how do we move food security, biodiversity, environmental and human health together to solve the challenges we currently face?

Well, before we dig deeper, we must first understand the differences between plant- and animal-based proteins from a health perspective. The protein in our food is comprised of 20 amino acids, the building blocks of protein. Nine of these amino acids are ‘essential’, which means our bodies are incapable of creating them, they come exclusively from our diets.

However, plant-based proteins lack at least one or more of these nine ‘essential’ amino acids compared to animal-based proteins, rendering them ‘incomplete’.

With thanks to supervisors - Dr Tribhan Dew, Dr Nazir Ahmad, Dr Daniel Anjog, Department of Health Professions, Manchester Metropolitan University. UK. Reference and article available online at fijournal.org/32-3/186

Table 2 Bioactive (phenolic) compounds found in commonly used spices and herbs as a major bioactive compounds

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-class</th>
<th>Example of spices and herbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyphenols</td>
<td>Flavonoids</td>
<td>Cinnamon, Ginger, Coriander, Cardamom, Clove, Thyme, Bay Leaves, Cumin, Black Pepper, Onion</td>
</tr>
<tr>
<td>Terpenes</td>
<td>Limonene</td>
<td>Fennel, Mustard, Curcumin, Turmeric, Ginger</td>
</tr>
<tr>
<td>Vanilloids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organosulphur compound</td>
<td>Jsodium Thiosulphates</td>
<td>Garlic, Onion</td>
</tr>
</tbody>
</table>

Figure 2 a) Bacillus cereus when exposed to nanomolar extract for 3h and b) E. coli when treated with nanomolar extract for 1h. (B. Dew & T. Anjog, Metropolitain University, 2023)

References

[1,14]

[2,5,11]

[12,13]

[15]

[16]
more plant-based proteins, leaving a positive impact on our health and environment.

**PROTEIN2FOOD**

To address the global protein challenge, PROTEIN2FOOD is developing high-quality and quantity plant-based protein products through improved and sustainable production methods and process optimization. Spanning the entire food value chain, the 19 international project partners are using a variety of scientific and technological approaches to further our understanding and development of innovative solutions and products. The project has four overall aims:

1. Enhancing protein production with effective breeding techniques
2. Increasing Europe’s arable land for protein production
3. Increasing agricultural biodiversity with novel crops
4. Developing protein-rich food products that are attractive to consumers

Here, we focus on two examples of scientific and technological research in crop production and food processing that have originated from the project, which could help the food industry solve the challenges of protein needs and their environmental implications.

**Crop production**

Currently, the main sources of plant-based protein are crops that are suitable for sustainable production methods and climate change impacts. As we move towards a less meat-dependent diet, it will also allow us to move towards more sustainable and well-managed crop production.

Identifying the most productive crop varieties will not only help the industry take advantage of the most genetically favourable traits but also help to maximise protein yield on limited land, it will also allow us to work towards more sustainable and well-managed crop production[8]. This novel use of technology has also helped breeders to find new combinations of ecosystems to create new cultivars with improved nutritional traits, whilst giving up Europe the advantages of the most genetically favourable crop traits and genomes for both production and consumption.

Got milk? Well, plant-based milk!

With the larger-than-life Dairy industry across the UK, it doesn’t come as a surprise that the plant-based milk market is based on being a new player in this competitive market.

**Sharing is caring:** from research to industry

There can be no doubt that plant-proteins are here to stay and have the power to revolutionise the food system. However, research and communication is research not implemented. Therefore, the advances in scientific and technological research created by projects such as PROTEIN2FOOD must be shared with the food industry to lessen our food systems’ inherent challenges, whilst increasing our protein production and helping us to lead healthier and more sustainable lives. PROTEIN2FOOD is an excellent example of how inter-disciplinary research project that could benefit the industry in providing new and innovative plant-based products and more sustainable processing techniques. In doing so, this will not only benefit the consumers, but also the environment. Hence, the project PROTEIN2FOOD is not only taking plant-based protein mainsteam, it hopes to create a new crop of plant-based proteins great against all.

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References and article available online at FSTjournal.org/33-3/68

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[1] The first step may be to change your mindset. Instead of focusing on fraud prevention to avoid regulatory sanctions, understand there is much more at stake than that.

[2] This can encourage members of the food supply chain to claim their ‘fair share’ of your company’s profits. There is plenty of potential for things to become desperate as subsidies fall away. Money should be near the bottom of the food industry’s concerns. The risks associated with food security will make light of the horsemeat scandal.


[4] The complexity of food supply chains – spread across a wide variety of territories – raises several questions about visibility. Do we really know what is going into our products? If someone in our supply chain is determined to deceive us? How can we ensure integrity within our borders? How can we control our partners’ procedures? Traditionally, factors promoting fraud are pressure, opportunity and rationalisation – where pressure can encourage individuals to act dishonestly and rationalise their behaviour.

[5] The uncertainty that comes with Brexit will make it more difficult for businesses to comply with others’ regulations.

[6] The first step may be to change your mindset. Instead of focusing on fraud prevention to avoid regulatory sanctions, understand there is much more at stake than that.

[7] Any instance of fraud is key. They are your eyes and ears, helping to increase market opportunities for the industry to further develop new varieties of plant-based protein products.

[8] Disenchantment

Protecting trust in your supply chain

The right culture which will flourish. As we will continue to export to the world and regulations are tightening from day one. There is talk of hi-tech systems to manage this, but Canada and the USA have been reasoning with this issue for many years.

References and article available online at FSTjournal.org/33-3/76

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Sustainable Pickering emulsions

Ioanna Zafeiri and Bettina Wolf of the University of Birmingham review the applications of Pickering particles in emulsion stabilisation and discuss recent results concerning the use of lipid particles and natural co-products from food manufacturing as Pickering emulsion stabilisers.

Much of our everyday nutrition is based on foods that are emulsions or have been emulsified at a certain stage during their processing. Emulsions are formed when at least two immiscible fluids, such as oil and water, are mixed. The generated permanently stable mixture consists of fine droplets of one liquid phase dispersed into the other. Oil-in-water (e.g. milk, salad dressings, mayonnaise) and water-in-oil (e.g. butter, margarine) emulsions are the two most common types of food emulsions. Due to the above mentioned instability, surfactants are traditionally used as a physical barrier to prevent droplets from coming together. However, in the last two decades, solid particles of micro- or sub-micron-dimensions have been gaining prominence as emulsion stabilising agents. Via the so-called Pickering mechanism, these colloidal particles can adsorb irreversibly at the oil-water interface, to sterically (i.e. mechanically) hinder typical destabilisation pathways, such as flocculation, coalescence or Ostwald ripening.

A diagram illustrating a particle and a surfactant-stabilised droplet of an oil-in-water (o/w) emulsion is presented in Figure 1, including two scanning electron microscope (SEM) images showing the surface of a droplet covered densely with particles. The particles in this instance are spherical silica particles that stabilise emulsion droplets in the presence of a trivalent salt. While this is not a system relevant to foods, it is an excellent example of the fact that once the particles have adsorbed at the interface, they will remain adsorbed. This is demonstrated in the second SEM image (Figure 1D) showing a droplet of the same emulsion following removal of the trivalent salt. Similarly, and relevant to...
The food industry has not been able to adopt Pickering stabilisation strategies on a large scale, mainly due to the lack of a reservoir of edible structures that exhibit a Pickering functionality.

The fact that these colloidal particles have the potential to reside permanently at the interface, makes the interface more robust and resilient. In turn, particle-laden interfaces are more tolerant to further processing after emulsion formation, and can act as a means to control lipid oxidation in foods. Moreover, due to the thickness of the compact interfacial film or ‘shell’, they can be stable for holding in place or protecting any active species, making them ideal candidates for the encapsulation and delivery of drugs/bioactive compounds. The potential applications on their composition, particles for Pickering stabilisation can be tailored to respond to triggered release of the encapsulated compounds, which could be specific flavours in the mouth or nutritious components for the gastrointestinal tract. Furthermore, they have shown great in designing and constructing particles that can be added into a process (e.g. milk) and manipulated to control the way for a precise control over particle-laden interfaces (e.g. spices, spreads, ice cream, whipped cream, margarine).

It is also common practice that particles with a Pickering functionality act in situ at the oil/aqueous interface to enable stabilization, either dynamically (solution of salt) or stably (solid particles). In lieu of this approach, there is high interest in designing and constructing particles that can be added into a process (e.g. milk) and manipulated to control the way for a precise control over particle-laden interfaces (e.g. spices, spreads, ice cream, whipped cream, margarine).

The latter characteristic can pave the way for a precise control over particle-laden interfaces (e.g. spices, spreads, ice cream, whipped cream, margarine). A complex mixing of factors, such as triglycerides (triglycerides, i.e. the principal components of fats and oils) and waxes, were chosen as the lipid-based material.

The approach was to form a simple micro/sub-micron emulsion in which the micro-/sub-micron droplets were eventually used as templates for the particles. More specifically, the lipid underwent heating above its melting point and was then emulsified with the aqueous phase that contained very small amounts of surfactant, using an ultrasound probe. The surfactant was of a simple (Tween 80) or a high molecular weight (sodium caseinate, i.e. produced in milk) and its role was to aid the breakup of droplets into small sizes during homogenisation. The size at the same time, minimising coalescence. The generalised hot oil/water emulsion was then cooled in order to solidify the droplets and form solid lipid particles dispersed in water.

Results showed that sub- microcrystalline lipid particles could be produced and their characteristics, such as size and size distribution, melting profile and interfacial behaviour, could be controlled by adjustments to surfactant type and concentration (Figure 2A), as well as lipid structure. Particles’ stability upon standing, shelf-life, emulsification and delivery vehicles or Pickering stabilisers which can be controlled by adjusting the size of the aqueous emulsions. A simple model colloidal system of oil-in-water (o/w) emulsions was formed by 100 μL of‘o/w’ Pickering emulsions diluted in water (Figure 2B).

Flavonoids (e.g. rutin hydrate) that are often used in beverages have been screened and employed for emulsion stabilisation (e.g. stabilisation of Pickering emulsions) due to their antimicrobial properties and ability to serve as stabilisers of simple o/w emulsions. The latter characteristic can pave the way for a precise control over particle-laden interfaces (e.g. spices, spreads, ice cream, whipped cream, margarine).

Lipid particles as Pickering emulsion stabilisers

Particles made of lipids have recently emerged as a very promising route in the development of particle stabilised emulsions. The potential stems from their superior biocompatibility and coupled with the versatility/functionality that their composition offers. The latter characteristic can pave the way for a precise control over particle-laden interfaces (e.g. spices, spreads, ice cream, whipped cream, margarine). A complex mixing of factors, such as triglycerides (triglycerides, i.e. the principal components of fats and oils) and waxes, were chosen as the lipid-based material.

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Results showed that sub- microcrystalline lipid particles could be produced and their characteristics, such as size and size distribution, melting profile and interfacial behaviour, could be controlled by adjustments to surfactant type and concentration (Figure 2A), as well as lipid structure. Particles’ stability upon standing, shelf-life, emulsification and delivery vehicles or Pickering stabilisers which can be controlled by adjusting the size of the aqueous emulsions was formed by 100 μL of‘o/w’ Pickering emulsions diluted in water (Figure 2B).
Particles derived from food manufacturing co-products as Pickering emulsion stabilisers

The research on plant-based co-products of the food manufacturing industry as feedstocks for particles with a Pickering functionality was triggered by the observation that cocoa particles, as a commercially available food ingredient, readily stabilised w/o emulsions. This property was attributed to the presence of lignin as a natural cell wall component in these particles, while the presently available lipids were demonstrated not to be a contributing factor. Lignin is present in vascular plants, usually within the cell walls and also between cells. It provides structural support and plays a crucial role in conducting water. After cellulose, lignin is the second most abundant natural material in plants, and it has found applications as a polymer that is less hydrophilic than cellulose and describes a class of material rather than a particular polymer structure. There are applications for plant biomass where it is desirable to remove lignin, for example extracting cellulose as feedstocks for producing bioethanol fuel, and hydrothermal processing followed by solvent extraction is a suitable method to achieve this. During the hydrothermal processing, i.e., heating the biomass dispersed in aqueous solvent to a temperature above the liquefaction temperature of lignin, in practice between around 180 and 250°C, the lignin is liberated from the cell wall and ‘extracted’ towards the surface of the biomass particle. As lignin is largely repelled by water, it deposits onto the surface appearing as microscopic small-surface-adhered droplets. As an example is shown in Figure 3. Coffee ground collected from coffee outlets were milled and then hydrothermally treated for 1 hour at increasing temperature. The lowest temperature selected was below the lignin liquefaction temperature and the particle surface (B) appears very similar to the untreated particle (A). It is evident that the treatment was more efficient with increasing temperature (C-F), although it appears that the surface-adhered droplets fused together following treatment at the highest temperature (F). The untreated particles stabilised w/o emulsions, whilst the treated particles stabilised w/o emulsions, although the w/o emulsions had a coarser microstructure (larger droplets). The minimum processing temperature required to impart w/o emulsion stabilisation functionality varies between feedstocks due to their differing biological make up. Hydrothermal treatment time also has an impact, for example for brewer’s agent grain wo have observed that processing longer at a slightly lower temperature, but still above 150°C, for example 8 hours as opposed to one hour, was an alternative process parameter combination to achieve w/o emulsion stability. As an alternative approach, the surface-adhered droplets may be extracted with ethanol, for example, and via solvent evaporation they can be transformed into sub-micron particles. This has been demonstrated for woody biomass33 but is equally applicable to co-products of the food and drink manufacturing industry, e.g., cocoa shell particles. As evidenced in Figure 3, their hydrothermal processing creates these characteristic surface-adhered droplets. Extracting and dripping the ethanol-dissolved extract into agitated water led to the formation of sub-micron particles that stabilise w/o emulsions. This development is still in its infancy with the preliminary results showing some promise for future developments, not only towards a new food ingredient, but also towards valorisation of waste and the creation of a circular economy.

Conclusions and future perspectives

Pickering stabilization of emulsions, as well as foams, is clearly an attractive proposition. The interfaces created during processing are in many cases irreversibly stabilised, unless a de-stabilisation mechanism (e.g. for the delivery of a bioactive) is programmed in. Such Pickering-stabilised systems therefore tend to be robust against additional ingredients which may destabilise interfaces in the composite stabilised emulsions and foams. However, they may still need to be protected against visual separation, e.g. by the addition of an anti-settling agent. Depending on the manufacturing requires the provision of suitable ingredients providing this functionality and these, to the best of the authors’ knowledge, are not commercially available for the food and drink industry at present. Future developments are needed to overcome this hurdle, ensuring the development of clean-label ingredients to satisfy consumers’ demands. There is huge opportunity in the increasing use and development of material in the composite structures which comprise the cell walls of land and ocean plants; it is also exuded by some bacteria. The paper/pulp industry has functionalised cellulose from such sources through innovations in processing, e.g., steam explosion or homogenisation, to create fibrous material to enhance structuring properties. The textile industry has pioneered the ‘regeneration’ of cellulose into fibres and sheets through the use of solvent/anti-solvent technologies. Above all, it is exuded by some bacteria. The paper/pulp industry has functionalised cellulose from such sources through innovations in processing, e.g., steam explosion or homogenisation, to create fibrous material to enhance structuring properties. The textile industry has pioneered the ‘regeneration’ of cellulose into fibres and sheets through the use of solvent/anti-solvent technologies, which are clear and green, and create stratified finishes. The question therefore is can the food industry benefit from such insights and enable the use of a material that is ordinarily insoluble and inert? The obvious outcome would be to use cellulose to replace the structuring capabilities of highly refined hydrocolloids, starches, and cellulose gum and cellulose gel, have traditionally been used in the food industry as, for example, thickening agents and fillers. Work has been carried out to investigate the functionality of cellulose derivatives, which are known to be ‘blocky’ in structure, imparting varying degrees of solubility and hydrophobicity. Highly hydrophobic derivatives are insoluble in water, but soluble in more non-polar solvents, and the soluble and food grade versions are able to gel upon heating. The more hydrophilic (and blocky) derivatives can be induced to gel at body temperature. "Natural" ingredients More recently, there has been a focus on the creation of...
alternative cellulose-based ingredients as ‘natural’ particles. Citrus fibres (in a number of different forms – from different suppliers, e.g. Fiberstar’s Citri 8 or Herbasol’s Herbacel AQ+) and powdered cellulose (Sacco Holdi) fibres (e.g. Solka-Floc from International Fiber Corporation and Borregaard’s SenseFi) are examples of currently available materials. They can be used as they are, or modified further, if required. SenseFi products are microfibrillated, which makes them particulate and interactive with a high water-binding capacity[3,4] whereas Solka-Floc materials come with different aspect ratios providing the opportunity to build food microstructures with different textural attributes. Herbacel AQ+ swells when hydrated and its particles can be functionalised further if the aqueous dispersion is homogenised. All such materials can also be modified in a ball mill, creating varying ratios of amylopectin to crystalline morphologies. The advantage of creating amorphous cellulose, is that it then recrystallises upon hydration[5,6].

In order to make use of cellulose, either in its isolated form, or as a part of natural hierarchical assemblies, a detailed and fundamental understanding of its molecular and supramolecular structures, how they are influenced by typical or novel processing steps and how they interact with other hydrocolloids typically used in industry is required[7]. Aspects of thermodynamics and kinetics are therefore worth consideration, in line with the more conventional thinking behind product formulation.

Controlling cellulose interactions with other polymers

It is now well known that mixtures of food polymers can ‘interact’ in different ways during formulation. They may specifically bind to one another or be repulsive to one another forming separate phases. Such concepts can be utilised to explain the functionality of cellulose materials and to assist in formulation. Specific interactions, sometimes known as ‘synergistic interactions’, often have their origin in the molecular structures related to polysaccharides with β-1,4-glycosidic linkages, where cellulose is a β-1,4-glucan. Indeed it is known that the hemicelluloses (e.g. xyloglucans, galactoglucomannans and arabinoxylans) influence the properties of the plant cell wall through direct binding to the cellulose micro- and macrofibers. Using this approach in formulation could provide new and additional functional properties, such as enhanced thickening or gelation within food product microstructures. To this end it has been shown that Lucinuc bean gum (a β-1,4-mannan) can both protect cellulose crystallinity during ball milling and subsequently enhance the rate of recrystallisation upon rehydration[9]. This concept has recently been exploited in the creation of cellulose based 3D structures[10] utilising the capability of the binder jetting process to control temperature and moisture content, such that the rates of recrystallisation are sufficient to withstand the pressures exerted on the structure as layer-by-layer the macrostructure is formed[11]. CAD-designed macrostructures containing xanthan gum (a β-1,4-glucan), enabled by bespoke design of the food grade ‘ink’, can therefore be built (Figure 1). A benefit of this approach, all-be-it still a niche technology, is the potential to build complex micro- and macrostructures using this low caloric food material. In a world striving for low energy density foods, to begin to combat the obesity epidemic, such enabling technologies are attractive and just need the enthusiasm and commitment of industry to make them happen. Specific interactions, however, are still hotly debated in academic circles and therefore development work using advanced technologies, such as NMR (nuclear magnetic resonance), DSC (differential scanning calorimetry) and rheological testing, is underway to provide evidence for such interactions.

There has been development in the fluorescent tagging of polysaccharides and, when visualised using confocal laser scanning microscopy or fluorescence microscopy, their location relative to the cellulose fibres can be confirmed. Figure 2 shows the location of xyloglucan and psyllium, both covalently tagged with fluorescein isothiocyanate (FITC), interacting with Solka-Floc 900. Xyloglucan coats the surface of Solka-Floc 900, and the particulate nature of psyllium attaching to fibrillated Solka-Floc 900 (non-covalently stained with methyl blue) is apparent. The results from the work with xyloglucan, galactomannans and glucomannan suggest that changes in polysaccharide structure, influenced by solvent type, affect their interaction with cellulose[12]. The nature of such interactions may provide structural elements in e.g. replacing gluten networks in baked products, or high energy density starch or fat.

The inert nature of cellulose suggests that it would act as a dispersed phase in a continuous polymer matrix and the properties of the mixture would be dependent upon the dispersed phase volume of the cellulose. Figure 3 shows the efficiency of different types of cellulose in providing effective volume...
occupancy, with the low aspect ratios of MCC and Solka-Floc 300 requiring much higher concentrations (by weight) than fibrillated cellulose.

The laws of colloid science apply to systems in which it is known that polymers may cause depletion flocculation of a dispersed phase. In a recent publication, mixtures of bacterial cellulose and maize starch were shown to occupy separate phases[1].

However, there are some unexplained effects of cellulose on starch gelatinisation, which also tend to suggest a ‘specific interaction’ between the two-glucans (starch being an β-1,4-glucan). Such a specific interaction is not necessarily expected from a molecular dynamics perspective, but does begin to raise questions regarding colloidal polymers (e.g. starch) interacting with β-1,4- extended helical polymers (e.g. starch).

They too are dispersions and when they are mixed with xanthan gum, some interesting phenomena begin to emerge. Mixtures which have the same final concentration of each component, but with a mixture of mixing different ratios of given concentrations of stock solutions and dispersions, are attained by the molecular structure of the xanthan gum, which is also known to affect the efficacy of ‘specific interactions’ with other β-1,4-linked glucans.

To investigate this further (Table 1) other dispersions were used, at matched dispersed phase volume, and generated at the same 75:25 mixing ratio of xanthan solution and particulate dispersion. What is evident is that describing this phenomenon is not straightforward: the hierarchical structures of citrus and apple fibres are effective at enhancing mix viscosities compared with xanthan alone; specific interactions’ might be at play given the enhancement seen by the ‘inert’ celluloses. Previous research has shown that Solka-Floc and MCC, the available apple and citrus fibres are more effective than cold water swellable apple and citrus fibres. Rheological measurements indicated that all cellulose suspensions showed viscoelastic gel-like behaviour; however the non-fibrillated particulate structure of citrus fibres released the tannin more effectively and faster.

### Table 2. Potential sources of ‘natural’ food structuring agents

<table>
<thead>
<tr>
<th>Source</th>
<th>Potential applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus waste</td>
<td>Taste perception</td>
</tr>
<tr>
<td>Fine-milled pear</td>
<td></td>
</tr>
<tr>
<td>Brewers’ spent grains</td>
<td></td>
</tr>
<tr>
<td>Alcoholic protein</td>
<td></td>
</tr>
<tr>
<td>Protein separation from</td>
<td></td>
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<tr>
<td>out-of-specification</td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
</tr>
<tr>
<td>Vegetable fibres</td>
<td></td>
</tr>
<tr>
<td>Oat fibres</td>
<td></td>
</tr>
<tr>
<td>Grape and pomegranate</td>
<td></td>
</tr>
<tr>
<td>Black gram waste</td>
<td></td>
</tr>
</tbody>
</table>

### Table 1. Zero-shear viscosity of mixtures of stock solutions/ dispersions of low pyramidal (LP) and high pyramidal (HP) xanthan with citrus fibre (CF) – LG (CFAB) – and apple fibre (AF) – LP (CFALP).

<table>
<thead>
<tr>
<th>Component</th>
<th>LP (CFALP)</th>
<th>HP (CFAB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF gato</td>
<td>97 ± 0.1</td>
<td>97 ± 0.1</td>
</tr>
<tr>
<td>MCC</td>
<td>87 ± 0.9</td>
<td>87 ± 0.9</td>
</tr>
<tr>
<td>F commented</td>
<td>87 ± 0.9</td>
<td>87 ± 0.9</td>
</tr>
</tbody>
</table>

This work highlighted above has used commercially available cellulose-based materials, but there is increasing interest in utilising materials, which are often termed ‘waste’ (co-products / b-products) from either the field or factories. Surfaces of the agricultural and food industries provide particularly promising sources of materials for food structuring applications (Table 2).

This work having been undertaken at University of Nottingham and includes work sponsored and supported by EPSRC Centre for Innovative Manufacturing in Food. CDT in Additive Manufacturing, Circular Economy: Waste to Energy (re)Shaping and Transformation in the Engineering of Polymeric Materials, EPSRC supported and funded by University of Nottingham and includes work sponsored and supported by EPSRC Centre for Innovative Manufacturing in Food. CDT in Additive Manufacturing, Circular Economy: Waste to Energy (re)Shaping and Transformation in the Engineering of Polymeric Materials.

### References and article available online at

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At the University of Nottingham Tim continues to progress the area of polysaccharide research. He is indebted to the researchers he has had the privilege to work with: Antonio Sulli, Faisal Haji, Ami Abbaszadegan, Beverly Saffar, Ann Kogant, Mitta Lad, Marie Janin, Charles Winkworth-Smith, Deepa Agarwal, Sabrina Paes, Shaomin Sun, Sonia Holland, Jade Phillips, Yi Ren, Anvish Maran, Barbara Siroka, Roger Illibet, Bill MacNaught, Paulo D. De Capria and Zainuddin Umar.

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### STRUCTURING WITH CELLULOSE

**Structuring with cellulose**

**References and article available online at fstjournal.org/features/33/3-structure-with-cellulose**

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X-ray CT imaging of food

Alix Cornish of Campden BRI explains the benefits of X-ray computed tomography in measuring food properties and highlights applications for this technology.

Food products often have delicate structures with fine walls and high internal porosity. Measurement of these structures is important for new product development (NPD) trials, product benchmarking and troubleshooting. X-ray computed tomography (CT) is a technique that allows internal food structure to be visualised and measured without any destructive sample preparation.

Conventional imaging techniques generally produce 2D images of the surface or cross-section of a sample. Labour intensive methods, e.g. sectioning to produce thin slices, or chemical fixation to produce contrast, are frequently used to prepare samples for these 2D imaging procedures. However, these processes are usually destructive and the resulting 2D information is often insufficient to draw conclusions regarding the 3D structure. Moreover, these destructive techniques can introduce artefacts which confuse the interpretation of these measurements. X-ray CT can overcome these problems by providing 3D images of foods.

Technical aspects of X-ray CT imaging

Objects are placed within an X-ray beam and rotated; the X-rays are absorbed by the object. Dense regions cause more absorption than low-density regions, and thicker regions of the object cause more attenuation than thinner regions. A series of shadow projections are recorded.

The shadow image produced at each angle provides information about the size and density of the object in that orientation. Computer software is used to reconstruct the 3D shape from a series of shadow projection images, recorded over 180° (or more).

The maximum resolution depends on the specific instrument, but standard benchtop systems are capable of imaging down to 1μm (pixel size). There is a trade-off between sample size and resolution, due to the limited number of pixels across the width of the detector, so the highest resolution is only achievable for small samples.

Figure 1 shows X-ray projection images recorded from a twist snack product. Positions on the sample where the X-ray beam has penetrated just one layer show up bright and regions where the X-ray beam has penetrated a thicker region of the product, show up darker. Tiny dark spots are also visible on these images. These are caused by dense salt crystals and seasonings on the surface of the product, which attenuate the X-rays to a greater extent than the snack product itself.

These, and many more projection images are processed using computer software to generate a 3D model. The 3D model can be viewed and manipulated on the computer to study the internal structure or to make measurements.

Distribution of composition

Contrast in CT imaging is due to atomic composition. Heavier elements are much stronger attenuators of X-rays than lighter elements. At an atomic level, the majority of food is composed of carbon, oxygen and nitrogen. These three elements have very similar masses (they are adjacent to each other in the periodic table) and attenuate X-rays to a similar extent. Therefore, X-ray CT is generally not capable of distinguishing different components, e.g. protein or sugar, to allow the distribution of such components to be mapped within a product. However, there is sufficient contrast to image food ingredients that contain heavier elements, e.g. salt. This technology also works well for aerated products, where good contrast is observed between the solid food component and air within the structure.

Measurement of food properties

Pore size distribution – discrete bubbles

Porous structures exist within many categories of food products e.g. bakery products, extruded cereals and aerated confectionery and dairy products. The size and distribution of bubbles is...
important for the size, shape, structure and texture of the overall product. Bubble size distribution heavily influences the texture of products and is therefore an important sensory attribute. Consequently, it is vital to understand the size distribution of bubbles in porous foods. The type of bubble structure is also important. Some products, such as aerated chocolate, contain discrete bubbles entirely surrounded by the product material, in contrast with products, such as bread, that contain an interconnected network of bubbles. Others, such as some types of extruded products, such as bread, is not possible using destructive imaging of products, such as bread and cake. These porous networks typically only contain one air void, with a complex interconnected shape. In order to obtain meaningful information about the size of the internal network, a parameter called ‘structure separation’ is often calculated. This mathematical procedure involves measuring the maximum size of spheres that can fit at every location within the interconnected porous network. The distribution of these maximum sphere sizes is then measured. An analogous procedure can be performed on the solid phase of the product in order to calculate a distribution of wall thicknesses. It is also possible to measure the change in structure as a function of height through a product and the anisotropy (directionality) of the pores.

Frozen products
It is important that samples remain static during conventional CT scans to avoid artifacts related to sample movement. For soft samples that flow over time, such as dough, this can cause problems. A route to overcome this is to freeze sample prior to scanning and to keep the samples frozen, and hence static, during the scan.

Food industry applications
Measurement of food structure is important during NPD trials, especially where a complex or novel structure is being developed. Another application for CT imaging is during product benchmarking, where it is important to characterise the products as completely as possible, in order to identify specific attributes that need to be changed to better match the target product. Differences in structure can result in very different mouthfeel and even tastes. CT imaging can also be used as a troubleshooting tool if problems arise during the production process. CT images can be used to highlight structural problems that are not visible using other imaging techniques.

Figure 4 3D model showing the bubbles inside a piece of aerated chocolate, colour coded to correspond with size – where purple represents the smallest and red the largest bubbles.

Measurement of food structure is important during NPD trials, especially where a complex or novel structure is being developed.

Modelling of food structure
X-ray CT scanning can be used to provide input for finite element modelling (FEM). The measurements can be binarised to give a 3D representation of the boundaries between the solid and gas phases, which can be exported to FEM software to define the geometry for modelling. It is also possible to export 3D images from CT instruments for use in 3D printing.

Structural mechanics models are used in many mechanical engineering applications to assess the loads on components and to optimise their design. For processing equipment, this can include assessment of the torque required from a motor, or the thickness of a process vessel to withstand the expected load. Finite element modelling (FEM) is also useful for design of food packaging to ensure it provides sufficient mechanical protection for the product while remaining practical to open and while using the minimum amount of material to save cost and to minimise environmental impact.

Modelling of the mechanical properties of food materials themselves is also useful to understand effects on food texture and to model interaction with processing equipment and packaging, for example to ensure that loads during conveying and transport will be sufficiently low to avoid damage to the product. Food products and processes are becoming increasingly complex. However, computational power is also increasing. X-ray CT data combined with FEM provides a way to model complex food products, reducing the need for lengthy pilot trials.

Other applications
X-ray CT is not limited to food structure research. There are several other applications that are relevant to food, for example foreign body investigations. The traditional approach for these involves removing the object from the food product for destructive analysis. CT techniques can be used to identify how the object is situated inside the food product without destroying it or the surrounding food material. It is therefore possible to gain insights into how the object got there, and in particular, at what stage the foreign body entered the product. For example, if a foreign body was introduced into a bakery product before baking, the cell structure surrounding the foreign body would be intact. If the foreign body was introduced into the product at a later stage, tears and holes would be visible, marking the path of entry.

This technique can also be used to investigate packaging defects. For example, leaking bottle caps can be investigated for faults, without the need to open the bottle.

Conclusions
X-ray CT imaging offers solutions for a diverse range of problems where there is a requirement to see inside products in 3D, without destroying them. It can be used to measure the pore size and wall thickness distribution in a wide range of products, such as bread, cakes and chocolate. The bubble size distribution in bread dough can also be measured. It is even possible to image products dynamically during baking to generate movies that show how features, such as crusts, and defects, such as dense streaks in cakes, are formed.

Article available online at ftjournal.org/doi/10.1111/1548-7965.13233 x-ray CT-imaging
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Rheological characterisation of foods

Reducing production losses
Advanced Measurements for Industrial Application (AMFIA) is a new research group within the School of Chemical Engineering at the University of Birmingham. This group has been set up specifically to address industry needs to reduce preventable production losses and to improve process performance and monitoring. The group’s specialty area lies within mixing/blending of fluids; however, the activities also extend to projects within the aerospace and pharmaceutical sectors.

New/existing product development is an ongoing activity in any fast-moving consumer goods (FMCG) environment. Key for any development is scaling up from a pilot to full-scale production. Traditional approaches often only focus on pilot scale development without paying sufficient attention to a formulation’s manufacturability. This can often make it very challenging for operators and process engineers to deliver an optimal product quality and consistency and often involves post launch changes and adjustments. Such changes can mean additional on-costs and a reduction of line rates.

These critical challenges also limit the ability to achieve more efficient and flexible processes. A way to overcome these hurdles is to use an Industry 4.0 approach and in situ measurement techniques. When it comes to fluid handling, complex rheological characterisation is one of the most desired measurements in industry as the micro and macro structure of formulated products is strongly related to their rheological properties. Currently there are only a limited number of products that can deliver such measurements live and on a non-invasive basis.

Detection and quantification of flow
At present, industry mainly uses electromagnetic flow meters and Coriolis flow meters for rheological measurements. The disadvantages are obvious with electromagnetic flow meters, which in general are only calibrated on water. Coriolis flow meters often struggle with multiphase flow. Technologies, such as ultrasound (Doppler) velocimetry or other systems based on active acoustic emission, are high in energy consumption, costly and limited in their penetration depth or their ability to measure multiphase systems.

For complex rheological measurements, there are even fewer options available. In fact, most of the in-line or in situ rheological measurement techniques that are available in the marketplace can only describe the viscosity of a fluid at a fixed shear rate. The non-linear relationship between shear rate and shear stress, means that viscometer measurements cannot provide reliable information for the characterisation of complex fluid rheology. Much more reliable off-line measurement, such as the cone and plate rheometer, are used to acquire a detailed flow ramp (shear rate vs shear stress curve). However, this approach has the drawback of the length of time required for measurement that can easily exceed 30 minutes, which is well beyond the desired live measurement timeframe. Also, such rheometer measurements require line sampling, meaning the potential introduction of product contaminants. An off-line measurement can only deliver an indication of the product/process performance, but will not deliver a true picture of the state of the fluids in the pipe. Other modern technologies, such as Electrical Resistance Rheometry (ERR) work well, however, they are only applicable for conductive fluids, limiting
their ability to offer an easy off the shelf solution.

In-line measurement of rheology

One of AMFIA’s most recent innovations has been in the in-line measurement of rheology. The basic idea is to move away from a traditional rheology measurement by using an Industry 4.0 approach. The group has found a way to measure rheology live amongst other factors within a processing pipe. The patent pending technology (GB1909291.5), named Rheality, is designed as a plug and play system and works for any single and multiphase fluid passing through a pipe.

The technology works on a combination of transient energy release measurements and machine learning. The fluid passes through a specifically designed pipe segment, which causes it to release transient energy. This is detected by a piezoelectric sensor on the outer wall of the pipe segment. With the help of self-developed algorithms and statistical analysis, the incoming data is reduced by over 99% and selected features are given to machine learning.

The machine learning algorithms are trained to predict the following features on a live basis:
1. Relative rheology,
2. Blockages and leakages in the pipe system,
3. Solid/gas content for multiphase systems,
4. Flow and flow rate.

Rheality consists of two main components, which are a specifically designed pipe segment and the piezoelectric sensor kit. The signals detected by the sensor are complex, have very high information content and many data points. The data is converted in a first step from a time signal into a frequency spectrum (Fourier transform) (Figure 1).

In order to reduce the number of data points, in a first step, self-developed filters are applied. Further data point reductions are based on statistical analysis algorithms, the creation of signal rankings and point selection and finally a principal component analysis. This initially simplifies between 1,000,000 and 500,000 raw points to 5,000 to 1,000 data points.

The last step is the use of supervised machine learning. As a learning algorithm, the quadratic SVM is used, which can solve classification problems. This type of machine learning is based on four key principles: the hyperplane, maximum margin hyperplane, the soft margin and the kernel function. Principle schemes for each of these are given in Figure 2.

Rheality is a non-invasive and non-destructive measurement method that can predict complex rheological problems and measure flow features live. Machine learning prediction accuracies are 95% or better (measured on previously unseen data sets). The system works both for single and multi-phase systems, as well as for laminar and turbulent flow.

Call to industry

AMFIA has been awarded an Innovate UK (ICURe Midlands) grant to further develop applications for this technology. The purpose of the grant is to visit companies in the FMCG sector in the UK as well as worldwide to explore opportunities to apply the technology. This will enable us to build industry collaboration and to give AMFIA the unique opportunity to get in touch with industrial partners.

We wish to gain an understanding of how rheology and flow are measured currently, how important this information is for the production process and its impact on the process and product.
What is Diamond Light Source?
Diamond Light Source is the UK national synchrotron facility, producing X-ray, infra-red and ultraviolet beams of exceptional brightness for research purposes. This brilliant light, combined with state of the art technological platforms, is extensively used by the scientific community to undertake structural, chemical and imaging investigations of a broad range of materials on very fast timescales and under industrially relevant conditions.

Claire Pizzey of Diamond Light Source describes the potential benefits of using the UK national synchrotron facility to undertake characterisation of foods and food ingredients to enhance understanding of their properties and behaviour.

With rising raw material costs around the world and increasing pressure for local food supplies, sustainability and waste reduction are key drivers for the food industry, particularly for global supply chains. Following food scares, consumers are demanding higher levels of quality control and traceability for food security, this is of vital importance in a very competitive market with new products frequently introduced.

Consumer trends, particularly the focus on health and nutrition, also represent research and development challenges for the food industry and meeting these diverse requirements is key to long term business success. Innovation in these areas requires a fresh approach, a good understanding of the science behind the product or process and access to the widest possible variety of research and development tools. Diamond Light Source’s advanced characterisation facilities are actively supporting this innovation.

Diamond Light Source is the UK national synchrotron facility, producing X-ray, infra-red and ultraviolet beams of exceptional brightness for research purposes. This brilliant light, combined with state of the art technological platforms, is extensively used by the scientific community to undertake structural, chemical and imaging investigations of a broad range of materials on very fast timescales and under industrially relevant conditions. Diamond’s capabilities are very well suited to a wide variety of materials research applications ranging from aircraft fan blades to catalysts, hydrogen storage materials and batteries to high performance coatings and fuel additives and complex formulations for the pharmaceutical, food and consumer products industries respectively.

Located near Didcot in south Oxfordshire, the research facility is used by approximately 8,000 scientists from the UK and overseas every year. These scientists (called ‘users’) are predominantly from academia (90%) and publish over 1,000 high impact journal articles each year as a result of their experiments, which are free at the point of access and awarded via a peer review competition.

Commercial activity plays a very important role at the Diamond Light Source and 10% of the facility operational time is dedicated to proprietary use by industrial clients. Clients range from the large multi-national household names through to SMEs and start-ups with 150+ companies worldwide making use of Diamond’s facilities in their R&D programmes by 2018.

Diamond is a not-for-profit limited company funded as a joint venture by the UK Governments through the Science & Technology Facilities Council (part of UK Research and Innovation, UKRI) in partnership with the Wellcome Trust. Diamond’s Industrial Science Committee provides guidance on opportunities for a wide range of industries to be engaged in research at the Diamond facility and identifies industrial research priorities that help to shape Diamond’s operational strategy. Companies currently and previously represented on the committee include Unilever, GlaxoSmithKline, AstraZeneca, Johnson Matthey, Infield, Rolls-Royce, Tate & Lyle and National Nuclear Laboratory.

In order to facilitate the use of the Diamond facility by researchers working in industry, an Industrial Liaison team has been established, comprising highly qualified scientists experienced in a range of techniques, enabling the translation of diverse research problems into meaningful analytical solutions. Diamond offers a range of services including full experimental design and a data collection and analysis service, ideal for those with limited time or no prior knowledge of the techniques. Working with initiatives, such as the STFC Food Network+, enables Diamond to gain a greater understanding of the pressures facing the agri-food sector and to tailor its offering to suit the needs of the food industry.

How is Diamond’s facility used by the agri-food industry?
Diamond provides specialist ‘Formula 1’ analytical techniques for the atomic to microscale characterisation of materials...
Understanding the local structure spectroscopy changes in real time (for example during processing and monitoring experiments, closely mimicking the characteristics) of materials with chemical specificity is of importance in answering central questions in many scientific disciplines. A key advantage of the use of synchrotron facilities is the ability to perform element-specific investigations of materials with high sensitivity. The unique capability of X-ray absorption spectroscopy (XAS) is its ability to investigate the local electronic and geometric information around a particular element irrespective of its state or environment. This powerful technique is suitable for studying solids, even in gaseous and can cover the vast majority of the periodic table.

Case study: Measuring the mineral content of wheat

This element-specific sensitivity has played a key role in a project led by Dr Andrew Neal and his colleagues from Rothamsted Research, in collaboration with scientists from Diamond and Aarhus University[12]. Plants with little or no meat, fruit and vegetables can lead to deficiencies in micronutrients, such as iron and zinc, due to low intake or bioavailability of minerals, where the problem is affecting an increasing number of people worldwide and is particularly acute in Africa, the eastern Mediterranean and south-east Asia, where it can lead to serious health problems, such as anaemia.

The Health Grain Programme is focused on improving national value of diets by breeding mineral-enriched wheat to increase the mineral content of flour. Understanding the mineral type and content in the wheat is essential for subsequent studies of the digestibility of the wheat. In order to facilitate this, the scientists performed measurements using cross sections of individual wheat grains. They used Diamond’s beamline I18, to perform high resolution X-ray fluorescence (XRF) mapping and X-ray absorption spectroscopy (XAS) experiments. The combination of techniques allowed the team to generate high resolution chemical maps of the wheat grain cross-sections (using XRF) and then select regions of interest within the maps, focusing on areas of high metal distribution to perform XAS measurements to obtain information about the local structure, oxidation state and complexation of the elements. The elements investigated were iron (Fe), zinc (Zn), manganese (Mn), copper (Cu) and nickel (Ni) (Figure 1).

Figure 1: X-ray imaging studies on some example food products. X-ray imaging allows high speed visualisation of a sample or retrieval of three-dimensional (3D) information to view and measure the internal structure of a sample (tomography).

Case study: Investigating the purity of lactose crystals

Lactose, the main carbohydrate constituent of milk, is extracted from whey, a by-product of cheese and yoghurt production, mainly for environmental reasons, but it holds significant value in its own right. Purified lactose exists in two main crystalline forms (called anomers), α-lactose and β-lactose, and is commonly used as a food supplement or a pharmaceutical-recipient. Bothomers are present during the nucleation and growth of a specific crystal structure, which can affect the purity of the precipitated crystals and in particular the α-lactose monohydrate is formed very slowly. It is therefore difficult and time consuming for the dairy industry to achieve a high yield of recovery and to obtain crystals of sufficient size, shape and purity. The team made use of two different, highly controlled crystallisation techniques and focused on determining the effect of crystallisation process parameters on the characteristic properties of lactose crystals including morphology, size distribution, level of agglomeration, crystal structure, purity and overall recovery yield. The study provided a greater understanding of the process parameters that are most effective in obtaining a high purity product in a significant yield.

X-ray imaging of food products

X-ray imaging is a non-destructive technique that has a very large range of applications in fields as broad as bio-medico, materials science, engineering, environmental science and food technology. X-ray imaging techniques allow high speed visualisation of a sample or retrieval of three-dimensional (3D) information to view and measure the internal structure of a sample (tomography). Advantages of synchrotron X-ray imaging include: much faster measurement times compared with laboratory based instruments, small beam sizes and special optics to produce images with a resolution of less than 1μm, and enhanced contrast available by tuning the X-rays themselves. The techniques can be used to monitor structural changes with varying processing conditions to optimise product behaviour. (Figure 2). It is particularly helpful for detecting cracks, voids and bubbles and so can be used for a wide range of food products, such as foams, porous solids and complex structures e.g.
Unilever, below right, used X-ray imaging to understand the microstructure of ice cream over temperature cycles.

References and article available online at: fstjournal.org/features/33-3/ shining-a-light-on-food

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**Confectionery or meat.**

**Case study:** Investigating the 3D structure of ice-cream using X-ray imaging. X-ray imaging at Diamond has been used extensively by Unilever to explore the microstructure of ice cream[3]. The quality of ice cream is considered to depend on the size of constituent air cells and ice crystals - the smaller and rounder the better. Product quality and shelf life can be strongly affected by the temperature variations that can commonly occur during storage and distribution, including by the end consumer, where a significant number of the overall freeze-thaw ‘abuse’ cycles take place. Ice cream is a complex multi-phase soft solid material that consists of ice, air, fat and sugar, containing three states of matter: gas, liquid and solid. An understanding of how the freeze-thaw cycle can influence ice formation is important in controlling ice cream microstructure. The crystal size is small, the material is opaque and the structure is easily disturbed by the modification required by most analytical methods, all creating challenges for detailed microstructural analysis.

A team from The University of Manchester and Unilever performed X-ray tomography of ice cream microstructure over temperature cycles from -20°C to -7°C using Diamond’s instrument I13-2. This instrument provides high flux X-rays tuned to mainly investigate the 3D microstructure and spatial resolution to allow 4D in-line phase contrast imaging to be performed.

These non-invasive experiments allowed Unilever scientists to investigate the 3D microstructure while largely maintaining the natural product environment and provided a greater understanding of how the mechanism of ice formation. The results aided the determination of the influence of processing conditions during manufacture and informed the development of formulations.

**Using the Diamond synchrotron facility**

There are two main routes to working with Diamond through our proprietary and peer-reviewed access modes.

Up to 10% of the available experimental time at Diamond is set aside for proprietary access, the most popular choice for our industrial clients. The Industrial Liaison team acts as the main point of contact for our industrial partners and can offer a range of services including a mail-in data collection and full experimental design, data collection and analysis service.

Some of our partners prefer to perform their own experiments and simply obtain access to the instruments with some technical support. Some prefer to send their samples for a full analysis service while others participate in the experiments to varying degrees.

Our flexible approach means that we can prepare a tailored package depending on the project needs and we charge only for the time and services used. We are able to offer support with as much or as little of the project as necessary.

Government funding streams may also prove helpful, previous industrial partners have attracted Innovate UK funding for their projects with Diamond and we are currently partners in the Bridging for Innovators (B4I) scheme, which provides funding for UK based companies to access Diamond and other facilities to overcome product, process or manufacturing challenges.

**X-ray imaging at Diamond has been used extensively by Unilever to explore the microstructure of ice cream.**

Full technical support is available from initial consultation, experiment design and data collection through to analysis and reporting, no specialist expertise is required.

Mike Cadoux of QReal describes a future in which 3D augmented reality (AR) cuisine starts a revolution in visualising, ordering and storytelling around food.

Take a ride on a New York City subway sometime and observe the people completely engrossed in their phones – hunched over, thumbs sliding, oblivious to the world. If you had seen this reality just ten years ago, you would have assigned it to science fiction. This will continue to happen in a multitude of ways as artificial intelligence, robotics and bioengineering shape our near-term futures in ways that are hard to fathom now.

**The 3D age**

The way we experience food media will drastically change in the coming years. The media landscape has transitioned from text to pictures to video and will soon enter the 3D age. 3D content will not make all others obsolete, just as video did not kill the picture. It will, however, become a necessary part of the digital experience. When a brand comes out with a new product, it will be launched with creative text, high end photography, theatrical video content, and lifestyle 3D models for online retail showcasing. While currently customers make food choices based on a thumbnail picture or a couple of lines of text, augmented reality (AR) will bring that dish directly onto the table in front of them. They will use their phone to inspect the cuisine in detail. The experience will also include multimedia content ‘placed’ in the world around the dish. In AR, content is no longer fighting for screen

Augmented reality cuisine
space – the world is your canvas. The biggest tech companies in the world, from Google to Apple to Microsoft to Facebook, are all investing billions of dollars to bring this reality to life as quickly as possible. According to Tim Cook, CEO of Apple, augmented reality is going to change everything.  

Building 3D models  
QReal is one of the first companies to develop technology to capture 3D food images for AR. To-date, 3D modelling has been based on technologies, such as CAD (computer aided design) or CGI (computer generated imagery), which can create very realistic models, but cannot capture an organic form like food in real-life detail. A cartoon pizza does not make you want to eat it. QReal has been working for years on real-life detail that can trick the brain into thinking the food is truly there, creating a reality that is as close as possible to the real thing. The photographic process is technical, but can be taught to partner organisations. They capture the photographs and send them to QReal for processing and optimisation, the content is then loaded to the web, social media or an app.  

AR can be presented right through the web on most iOS and Android devices. A single line of code, replacing a thumbnail, can bring users to a rich experience with a few clicks on any website. The social media channels were some of the pioneers in bringing this technology to life. Snapchat has been inundating its user base with AR for years, without users even knowing that they are experiencing it. Apps have been powering AR experiences for years; brands like IKEA have allowed you to place furniture in your home to test its fit. The biggest change for brands will be a heightened focus on enhancing craveability and transparency through AR experiences.  

Impact of AR  
There are vast implications for the widespread use of AR. The biggest change for brands will be a heightened focus on enhancing craveability and transparency through AR experiences. Showing a pretty picture is nice, but creating desire and educating the consumer is incredibly powerful. QReal has been working with a number of universities on studies of the impact of AR cuisine. These institutions, including Oxford University, Newcastle University and The University of New South Wales, are investigating the potential impact AR will have on consumers. So far, all the studies have demonstrated the power of AR to influence consumer behaviour.  

Stimulating hunger is incredibly powerful, but we also want to understand its impact on actual decision-making. Our goal is not just to heighten the brand through AR, but to also increase sales or up-sell to customers. A study carried out on QReal’s AR food models in collaboration with the University of New South Wales Business School, King’s Business School, Maastricht University and the University of Sussex and published in the Journal of Retail, found that the AR-enabled frontline improves decision comfort, motivates positive WOM (word of mouth) and facilitates choice of higher value products.  

The study also found that, “on the revenue side, the effect of AR on decision comfort also explains the increase in choice engagement of participants when assessing their choices.” The researchers found that the ability of AR to offload mental imagery to the technology (or, to put it simply, the customer does not need to use too much imagination) was an incredibly powerful tool in promoting positive decision-making. Craveability is a goal for all food-based companies wishing to impart a deep-seated desire among customers for their foods. This has large impacts for both branding and sales.  

With the coming of AR, cuisine, creative food images will become less important and transparency in food will necessarily increase. There is no ideal perspective in 3D or AR, it is not possible to take a photo of a burger from the right angle to make it look towering or show the lettuce and sausages just at the right glistening angle when the object is displayed in 3D. Customers will gain full access to the virtual dish; they will inspect it from all sides and render opinions on the whole, not the specific shot. Customers will gain full access to the virtual dish; they will inspect it from all sides and render opinions on the whole, not the specific shot.  

The future  
AR is also close to being able to show everything at true scale. Depth sensing cameras are coming to phones (they are already on many of them) and these will enable the technology to exactly scale items to size. Shoes will fit on feet, dresses will fit your form and burgers will be presented in a specific size. It will afford the customer ample opportunity to compare the 3D image of the dish with the representation in the media. This movement has already begun with the pervasiveness of Instagram in restaurants, which have been forced to post their dishes online. The world of AR media, product showcasing and storytelling is well on the way. It will increasingly be applied to fashion and household items as well as high fidelity digital cuisine. Everything discussed above is available today and its impact will be felt in the near future. The brands that understand and plan for it will reap the benefits of being positioned to capitalise on a revolutionary new technology.

References and article available online at https://qreal.io/
Traditional market research methods often rely on explicit feedback from respondents. These questionnaires ask direct questions and tap into System 2 thinking, which is relatively slow, logical and deliberate. Product developers have found, however, that despite products performing well in explicit market research, they often do not succeed in the market and this brings into question the validity of explicit methods in predicting consumer behaviour.

In the last few years there has been an interest in using well-established psychological tests within a market research context. These implicit tests are designed to tap into faster, instinctive, sub-conscious processing, known as System 1 thinking and do this without overtly asking the question being investigated. This implicit response may be more representative of real-life decision-making processes at point of purchase because many of our decision-making processes occur unconsciously. Unlike explicit tests, implicit responses remain free of bias and are neither influenced by social norms nor our desire to say what we think people want to hear.

For these reasons, implicit tests may be a better predictor of real-world behaviours and so of the performance of a product in the market.

Implicit methods are powerful for researching emotion because emotions are difficult to verbalise and simply being asked about our feelings changes the way we feel. Being able to identify the emotions evoked by a product is valuable as research has shown that generating emotion increases consumer engagement and encourages repeat purchase. Emotions are instant and impact behaviour in an impulsive and unconscious way and so implicit methods offer a way to explore the emotional impact of brands and products.

**Implicit testing methods**

A wide variety of implicit methods are being explored in food and beverage research, including fMRI (functional magnetic resonance imaging), EEG (electroencephalogram), heart rate monitoring and eye tracking. This article focuses on reaction time-based tests. These tests are usually performed by a respondent with a keyboard.

The Implicit Association Test (IAT) assesses associations between two targets (e.g. two brands) and a bipolar attribute (e.g. poor quality and good quality) using categorisation tasks requiring quick responses. The fundamental premise of the test is that faster responses are expected when strongly associated concepts are paired.

One of the main barriers to using IAT for food and drink assessment is that it cannot be used for more than two stimuli or two attributes. This, and the multiple exposures to stimuli required, means it becomes laborious and repetitive leading to sensory fatigue and lack of attention by the respondent. Additionally, the IAT varies the association of the targets with the left and right key presses. Critics claim this creates confusion and noise in the data from excessive incorrect key presses.

Like the IAT, semantic priming relies on response speed. It was originally used within market research to measure the strength of associations between psychological attributes and a range of media brands. It revealed large statistical differences between the brands, which had not been demonstrated by explicit methodologies. The method uses the idea that priming (exposure to a stimulus) influences the reaction to a following stimulus at an automatic level: if the...
following stimulus is congruent with the prime, reaction to that stimulus is expected to be faster. The theory behind this is that concepts are stored in brain across clusters of neurons. Closely related concepts will be stored across overlapping clusters of neurons, meaning that some neurons triggered by the second stimulus will have already been triggered by the prime and will therefore respond more quickly to the second stimulus. Semantic priming methods measure the strength of association between the prime and the following stimulus. A benefit of semantic priming over the IAT is that it allows the use of more than two stimuli. In addition, the quantitative output can be used to compare all stimuli in the test and allow them to be ranked or grouped to give a more multidimensional output than the IAT. Neither the IAT nor semantic priming are designed to measure attributes at the level of an individual but rather averaged across the consumer group.

Sensory Dimensions has worked alongside Truthsayers on multiple implicit methods including semantic priming. This kind of test can be carried out on a computer or on a mobile device or tablet, and this combined with the fact that an implicit test can incorporate multiple stimuli and many attributes means it is very versatile. A range of different kinds of attributes can be used as part of this test, for example, emotional, sensory, functional, descriptive, usage occasions, or a mixture of all these. Stimuli being tested could be a brand logo, interacting with packaging, smelling a fragrance or tasting a food or drink product. You can compare how your product or brand is perceived compared to that of a competitor, find out the emotions your product generates to ensure that your marketing is effective, and gain an insight into consumer product experience, or make sure your product, packaging, and brand are all in line with one another.

**Format for semantic priming tests**

Implicit tests can be more fun for respondents than explicit tests because they are more game-like, requiring quick responses and giving feedback when incorrect responses are given. Respondents are instructed to hit a certain key on the keyboard when ‘Yes’ appears on the screen and a different key on the keyboard when ‘No’ appears. They have an opportunity to complete this task as a warm-up before being given a stimulus to ensure they are familiar with the task. The pairing of ‘Yes’ or ‘No’ with the keys is randomised across the consumer group as a whole but kept consistent within an assessor to prevent confusion-based errors. Reminders of which keys to press are always on screen during the test.

After the warm-up, respondents are instructed to interact with the stimulus. What form this interaction takes will depend on what is being tested; it may be looking at a brand logo or tasting a drink for example. Then, for each stimulus the attributes being tested are flashed up on the screen (one at a time in a randomised order) followed by the word ‘Yes’ or the word ‘No’ and respondents should hit the corresponding ‘Yes’ or ‘No’ key on the keyboard (Figure 1). Their response is dependent on whether they say the word ‘Yes’ or the word ‘No’, not the attribute that preceded it.

The attributes are repeated in blocks and between each block respondents re-exposed to the stimulus to ensure it stays fresh in their minds. Each attribute is paired with ‘Yes’ and ‘No’ in a randomised order. The reaction time between the appearance of ‘Yes’ or ‘No’ and the key press is recorded. Respondents are required to make a quick response within a time limit of less than a second in order to avoid allowing time for rational thought. ‘The idea behind the test is that a congruent pairing of an attribute with the word ‘Yes’ or ‘No’ will elicit a faster response than an incongruent pairing’[6].

It is important to recognise that although there are a lot of reaction time-based tests around, many are not implicit. In many cases they are just speeded up versions of explicit tests. Fast explicit tests ask respondents to make conscious evaluations very quickly e.g. would you buy this? The answer here depends on the respondent – they have a choice. This means that they could lie, give a biased response, or choose any answer at random without thinking about their opinion. The fact they have a choice means their response relies on System 2 processing and therefore is not associated with any specific emotion. The semantic priming implicit task was used to investigate how strongly emotional attributes were associated with each snack. The attributes were selected after a review of other literature involving emotional profiling of food products, including the Exsense profiles[7] and best-worst scaling[8]. All attributes addressed were positive emotions, which were not synonyms of one another. They were not specific to particular snacks but could be associated with consumption of any indulgent product.

The study found that each of the snacks had a distinct emotional profile. Maltesers made people feel sociable and happy, toffee popcorn made people feel free spirited, satisfied and comforted, and cinema popcorn made people feel adventurous and proud; chocolate buttons made people feel happy and the premium chocolate-dusted popcorn made people feel slayed, joyful, sociable, proud and excited. The strength of association was described by a number between 0 and 100 (Figure 3). A score close to the 100 indicates a strong negative association between the emotion and the snack, a score close to 0 indicates a strong negative association between the emotion and the snack, while 50 is the neutral point.

**Emotional profiling of chocolates and their packaging**

We have used this method to explore the congruence of the descriptive, emotional, and usage profile attributes associated with chocolates, their packaging, or attributes of the box. We found that the box was extremely well received and associated strongly with attributes, such as modern, desirable and generous. However, when paired with the box, some attributes were not supported by those of the wrappers and whilst the product itself was very highly liked, it too was not aligned with the premium expectations generated by the box and the brand. Overall the product was highly liked with a high propensity to purchase. It was considered fun and great for sharing, features which positioned it as a treat and everyday gift for younger people but less appealing as a more sophisticated gift item.

**Emotional profiling of laundry liquids**

Another study aimed to define the drivers of choice for two brands of laundry liquid so that these functional and emotional benefits could be incorporated into targeted on-pack messaging and brand communications so that they better retain loyal customers and attract new ones. Liking for both the fragrances measured explicitly was very similar. However, implicit testing showed that the brands generated very different emotional reactions amongst their user groups and that the fragrances cued different functional benefits. One brand was associated with emotions, such as caring and friendly, and a long lasting smell, all day all day, great fragrance. The other brand was more associated with functional gains, such as strong on stains and dependable.

**Implicit methods offer an exciting and versatile tool that is relatively new to the sensory and consumer research field.**

Their application is the subject of several research programmes but it is clear that these techniques have great potential to complement our traditional explicit research methodologies and further our understanding of consumer choice and purchase behaviour.

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select the right data. Predictive analytics and scientific modelling are interesting areas of data science and the activity in this space is growing. Applications can range from traditional methods using advanced statistics for assessing various future scenarios to machine learning techniques, including artificial intelligence.

Data science requires a multidisciplinary approach and a broad range of skill sets, from mathematics and statistics, computer science and machine learning to artificial intelligence (AI). Data science also needs to have strong ties to the actual domain knowledge in order to ask the right questions and

The collecting, centralising and formatting of data via spreadsheets, hard copies, documents, Internet of Things (IoT) or other means is the first step into digitisation of data, followed by the structuring, validating, analysing and visualising of this data. Only then is it possible to develop more advanced models that serve to inform R&D (from product design to launch), safety (including exposure and microbial food safety), consumer health and strategy.

Probabilistic Exposure Modelling
Probabilistic Exposure Modelling has been used and applied for a number of decades (Figure 1). As part of an overall risk assessment of a food contaminant, pesticide residue, additive or a novel ingredient on a population of consumers, an exposure assessment has to be carried out. As an approximation, the exposure can be quantified by the amount of food consumed multiplied by the concentration of the contaminant in this food. However, when looking at exposure within and across consumer populations, this simple calculation can become quite complex. A chemical can be present at varying levels in a large variety of foods, consumed in varying quantities, in different combinations, by different

Sandrine Pigat of Creme Global explains how to navigate big data by applying traditional predictive models to help make informed decisions about food product development, consumer health and food safety.
Another example of using data science, and specifically predictive models, in the food industry is to assess the impact of a dietary change on nutritional intakes and subsequently health outcomes.

Tests are typically carried out via durability or challenge studies that span weeks or months. During these studies, the microbial counts and quality outcomes of interest are documented at defined time points and under defined environmental conditions. Using experimental data to predict the stability of different products, i.e. when developing new products with new formulations, is an example of an area where predictive modelling can be applied. These models can provide cost and time effective guidance on the projected shelf life and stability of a new product or a product modified processing.

This work may consist of developing a statistical model from experimental data, for example preservatives, food additives, pH etc., and measuring the microbial stability of different products. The model will predict whether a new product formulation is stable and will estimate the probability associated with this prediction. Similarly, predictive models can be built using product or ingredient parameters, such as colour, texture, sensory characteristics etc. The aim is to determine the shelf life of this product based on the known parameters and experimental data. This work can take months or years of taking measurements for selected parameters. Decision and development times can be shortened using the insights from these mathematical models. In addition the critical parameters for product stability and shelf life can be identified and separated from the non-critical parameters.

Tools that can be used to assess product shelf life and safety from a microbial perspective are called predictive microbiological models. Predictive models have been developed for both spoilage and pathogenic organisms and growth, survival and heat inactivation models are available for use. The models usually include variables, such as temperature, pH, salt or equivalent water activity and initial contamination levels. Primary models describe changes in microbial numbers or other microbial responses over time. The model may quantify colony forming units (CFU) per ml, toxin formation, substrate levels (which are direct measures of the response) and absorbance or impedance (which are indirect measures of the response). A mathematical equation or function describes the change in a response over time with a characteristic set of parameter values.

Secondary models describe the responses by the parameters of the primary models to changes in environmental conditions, such as temperature, pH, or water activity. Tertiary models are computer software routines that turn the primary and secondary models into ‘user-friendly’ programmes for model users in the form of software applications and expert systems. These programmes may calculate microbial responses to changing conditions, compare the effects of different conditions, or contrast the behaviour of different microbial organisms. Once parameters have been entered into the system, a prediction can be produced. The prediction will usually be in the form of a growth curve, but parameters, such as lag time and time to reach a specified microbial level at a specified time,
are also predicted. Note that the above models cannot always replace the actual experiments, but they can help steer formulations, new products being developed or process changes and can greatly increase the likelihood of success from the experimental testing.

Modelling product reformulation and impacts on the population

Food and drink companies are constantly innovating their product ranges. Product reformulation and new product development play a big role in meeting consumer needs for safe and healthy products. Mandatory or voluntary targets set by public health stakeholders for ensuring healthier nutrient profiles of foods are another important reason for product development.

Within Food Drink Ireland, 15 member companies participated in a research project[3] with the aim of assessing the impact of new food and drink development and reformulation on nutrient (sodium, total fat, saturated fat, total sugar and energy) intakes in Irish consumers using anonymised data and scientific modelling. The shift in the consumption of products sold from 2005 to 2017 was incorporated into this model, taking into account the shift in consumer preferences via volume sales data, the change in product composition, the discontinuation of old products and introduction of new products by the participating companies.

As a database on consumer behaviour, the national Irish nutrition surveys were used, including The National Teens’ Food Survey (2005 – 2006), National Children’s Food Survey (2003 – 2004), National Adult Nutrition Survey (2008 – 2010) and National Primary School Nutrition Survey (2010 – 2011). These were combined with the collected nutritional data on the company products gathered for the years 2005 and 2017. For applicable food and drink products, original composition data from the surveys was replaced by the gathered company data, with given foods being represented by multiple brands. Volume sales data for a given brand and food category were used to create weighted distributions of concentrations to represent the market.

To account for the rest of the market not represented within the data, optimistic and conservative scenarios were created. The optimistic scenario assumed that other brands followed similar reformulation and consumer preference patterns, whereas the conservative scenario assumed that all other products on the market remain unchanged over time. The latter is likely to be an underestimate because other companies and retail own brands are actively reformulating and the reality is likely to be somewhere in the middle.

Data on approximately 1800 food products and over 25,000 concentration data points were collected and incorporated into the intake model. The overall findings of the project help to quantify the impact that industry actions have had on consumer intakes over a 12 year period.

The use of data science is unlocking information from existing data sets that was previously not available.

Animal nutritionists have traditionally focused on formulating diets to keep animals healthy and well, and producing efficiently. But there is an increasing awareness of the importance of the nutritive value of meat, milk and eggs for human health. ‘One Health’ is the philosophy that health should be simultaneously optimised for animals, humans and the environment.

New developments in this area include the ability of animal nutritionists to influence nutritive value by changing their way animals are fed and managed.

Nutritional deficiencies

Nutritional deficiencies can have a profound impact on the health of humans and animals. These deficiencies result in an increased risk of disease, reduced growth and development, and decreased productivity. In human populations, nutritional deficiencies can result in a range of health problems, including malnutrition, anemia, and various chronic diseases. In animal populations, nutritional deficiencies can result in lower productivity and death.

The biggest impact could be seen in a reduction in total sugar intakes ranging from 3.2g/day in children to 0.8g/day in adults. The second biggest impact was observed in the reduction of saturated fat intakes, with other nutrient intake reductions being less impactful.

A future aim of this work is to measure the impact of changes in package sizes of products and to conduct further monitoring of food reformulation and new product development. The launch of the report involved the industry stakeholders as well as the Irish Food Safety Authority demonstrating the importance of collaboration for improving public health related matters.

Conclusions

The use of data science is unlocking information from existing data sets that was previously not available. Data science is having a very positive influence on food product development by supporting more efficient and scientific decision making and replacing or complementing traditional food science methodologies. However, some challenges still remain, such as access to the right expertise to ask the right questions, understanding and applying the correct methodologies, the availability and quality of the data used and handling the uncertainties that will inevitably arise.

The application of scientific modelling, data science and new technologies are quickly maturing bringing the knowledge and the expertise required to continue to grow this important toolkit that has become an integral part of many organisations in the food sector.

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Conclusions

The use of data science is unlocking information from existing data sets that was previously not available. Data science is having a very positive influence on food product development by supporting more efficient and scientific decision making and replacing or complementing traditional food science methodologies. However, some challenges still remain, such as access to the right expertise to ask the right questions, understanding and applying the correct methodologies, the availability and quality of the data used and handling the uncertainties that will inevitably arise.

The application of scientific modelling, data science and new technologies are quickly maturing bringing the knowledge and the expertise required to continue to grow this important toolkit that has become an integral part of many organisations in the food sector.
DALLs annually (2016 Global Burden of Disease).

The mineral intakes of children are an area of particular concern. Calcium is essential to bone development and it is especially concerning that females aged 11-18 years have a calcium intake that is almost 30% below the lower reference nutrient intake. This is associated with a reduction in milk consumption. Calcium deficiency is compounded by associated sub-optimal magnesium and vitamin D intake.

Odyn, an EU-funded project, estimated that >40% of the EU population are deficient in vitamin D. Vitamin D plays a role in the maintenance of normal bones, muscle function and teeth, and also contributes to the normal function of the immune system. Poor consumption of calcium, magnesium and vitamin D in children is associated with an increase in osteoporotic fractures in later life. Indeed, the frequency of osteoporotic fractures has already increased in many countries, and it is estimated that the prevalence will double in the EU by 2035[5].

It is projected that the total annual public health care cost savings in the EU would be €187bn if vitamin D deficiency were eliminated.

Consumers consistently show low levels of omega 3 fatty acids intake and therefore have a low omega 3 status. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are two key long chain omega 3 fatty acids, derived from marine sources. The European Food Safety Authority showed that compared to the target intake of 250mg EPA+DHA per person per day that should be consumed, 15-19 year olds are consuming just 24mg and the ‘best’ group – the 50-64 year olds – are only consuming 160mg. Worldwide only a small minority of the population (<20%) exhibits optimal blood omega 3 fatty acids levels (Figure 1). The reason these low levels are of such concern is because elevated blood levels of EPA and DHA are strongly and consistently associated with protection from heart attacks, strokes, Alzheimer’s disease, depression, cancer, diabetes mellitus, and improved brain health – all leading causes of death and disability in the UK.

Nutrient supplementation

Broadly speaking, some of the foods that are rich in these nutrients do not seem to be on our ‘favourite foods list’ (e.g. oily fish, which is a source of both vitamin D and omega 3 fatty acids) and some are seeing a decrease in intake for other reasons (e.g. meat and milk). In the case of the omega 3 fatty acids EPA and DHA, these are naturally only found in marine sources. In fact the 250mg per person per day recommended intake level is specifically identified as coming from oily fish. For those who do not like to eat oily fish, supplements are available, but research shows that, after a time, medium and long term supplement consumption can wane. In addition, the bioavailability of the fatty acids contained in supplements is not as good as the bioavailability of fatty acids contained in oily fish[8]. Furthermore, over the past 10 years, the EPA and DHA content of oily fish has decreased by almost half because of the diet of the fish has changed.

The agri technology company Devilish Foods has been developing the most efficient and convenient regime to imbue chicken meat with the omega 3 fatty acids EPA and DHA, normally only found in marine sources. Research has confirmed that the omega 3 fatty acids in the chicken most were bioavailable to those consuming the chicken. After only six months of eating omega 3-enriched chicken and eggs, there was a substantial shift in the ‘omega 3 index’ distribution (Figure 3). The omega 3 index is a way of assessing whether people are in a high risk category (low circulating levels of EPA and DHA) or in a low risk category (high circulating levels of EPA and DHA). The number of people in the high risk category halved after just six months of eating omega 3-enriched chicken and eggs[9]. Scaled up to the global level, the effects of moving swathes of people from high to low risk would represent a potentially huge economic saving.

This enveloping of animal nutrition and health into human nutrition and health is more generally referred to as One Health – using approaches that simultaneously optimise animal, human and environmental health. Livestock animals will use some of the omega 3 fatty acids, and some of the vitamin D, and all the other nutrients to promote their own growth and development first, before depositing the excess nutrients into meat, milk and eggs. For example, scientists have shown that animals fed high omega 3 diets have better fertility, immune function and health and those fed high vitamin D diets have better immune function. Nutritive value and the health-related functionality of food is being used to re-define the sustainability credentials of meat and milk in the context of their high nutritive value[9,10].

One Health

An event at the House of Commons in February 2019 explored the role of the agriculture and agri-food sectors in delivering positive health outcomes in support of the 2017 UK Life Sciences Industrial Strategy (Figure 4). It was suggested that a One Health approach providing nutritious food to promote consumer health would be additive to the proposals already contained in the strategy.

Animal nutritionists are formulating diets and regimes that use fish oil, and more increasingly algal oil, to increase the levels of omega 3 fatty acids in animal products.

References and articles:

[1] Stark et al
[2] Odin, an EU-funded project
[3] Stark et al
[4] One Health

Figure 4, (left) House of Commons (February 2019) exploring the role of the agriculture and agri-food sectors in delivering positive health outcomes in support of the 2017 UK Life Sciences Industrial Strategy (Figure 4). It was suggested that a One Health approach providing nutritious food to promote consumer health would be additive to the proposals already contained in the strategy.

Over the past 10 years, the EPA and DHA content of oily fish has decreased by almost half because the diet of the fish has changed.

Figure 2 Omega 3-enriched chicken

The mineral intakes of consumers falling into different omega 3 index risk categories (low circulating EPA+DHA and green indicates low risk, high circulating EPA+DHA). From Houton et al. (2017)

Figure 3 The effect of eating chicken and eggs enriched or not with omega 3 fatty acids on the proportion of consumers falling into different omega 3 index risk categories (low circulating EPA+DHA and green indicates low risk, high circulating EPA+DHA). From Houton et al. (2017)

Figure 1 Global blood levels of the sum of eicosapentanoic acid (EPA) acid and docosahexaenoic acid (DHA) acid (referred to as ‘omega 3 index’); red indicates high risk (low circulating EPA+DHA) and green indicates low risk (high circulating EPA+DHA). From Stark et al. (2016)

Figure 2 Global blood levels of the sum of eicosapentanoic acid (EPA) acid and docosahexaenoic acid (DHA) acid (referred to as ‘omega 3 index’); red indicates high risk (low circulating EPA+DHA) and green indicates low risk (high circulating EPA+DHA). From Stark et al. (2016)
Blueprint for aquaculture in Scotland

With waves up to three times higher than traditional farming sites, stronger currents and deeper waters, fish farming offshore is no mean feat. On these ‘high energy’ sites, jobs as seemingly straightforward as feeding fish can become a significant undertaking because of the extremity of the elements. Great difficulty, though, can also mean great opportunity. Being located offshore means more space and the remoteness of these sites makes them suitable for sustainable expansion with the potential to improve the health and welfare of the farmed fish and reduce impacts on the local ecosystem.

A high-energy site is being tested off the island of Westray, Orkney, a first in Scotland. If the site continues to be successful, it could be a blueprint for the future of Scottish aquaculture.

Sam Houston of the Scottish Aquaculture Innovation Centre describes recent trials of offshore salmon farming and explains why this approach has potential to increase both sustainability and productivity in the sector.

Breaking ground at sea
Established by Cooke Aquaculture and supported by the Scottish Aquaculture Innovation Centre (SAIC) and Marine Scotland, the Skelwick Skerry site has four out of a planned eight cages installed. The ambitious project received a European Maritime and Fisheries Fund (EMFF) award from Marine Scotland to financially support the project.

As the first of its kind to open in Scotland, Skelwick Skerry represents a potential turning point in how fish are farmed. Its achievements to date indicate that this could be an important moment for the future of the industry.
The site offers greater opportunity to sustainably grow fish farming because farming offshore vastly increases the number of potential sites. The deeper waters and stronger currents disperse dissolved and particulate wastes more quickly.

The first cohort of salmon was transferred to Skelwick Skerry in November 2018, weighing an average of 2.5kg. After rapidly growing over the following 6 months, the first harvest was in November 2018, weighing an average of 2.5kg. Fish performance at the site has been positive and, although it is difficult to draw conclusions from a single input of salmon, the health of the fish has been good and mortalities very low.

The Annalie can carry a few tonnes of feed on her deck but the crew must load them into the hoppers at sea, which is dangerous in rough conditions. When the salmon require more than five tonnes during a day, each one tonne bag must be loaded by the workforce's crane. For this reason, two alternatives to the current routine are being considered by the management at Cooke to reduce the number of missed feeding days.

The site consists of a mooring grid and four flotation cages, each with a circumference of 15m. The cages are fabricated from high density polyethylene (HDPE), which is flexible. Deep, wide nets – over 28,000m³ each (HDPE), which is flexible. Deep, wide nets – over 28,000m³ each – provide plenty of space for the salmon to move about and escape the action of the waves.

All activities at Skelwick Skerry are under the whim of the weather and particularly the wind, which generates the waves. Oftentimes in the north-east Atlantic south-western winds blow, generating very large waves but with long wave-lengths, gentle giants as opposed to shorter, more violent waves.

However, the site can also experience strong north or easterly winds. Often these winds whip up shorter but higher frequency waves. These waves pass more quickly through the site and can cause workboats to pitch violently, running the risk of damaging the cages if they are moored to them at the time.

The cages, net and mooring system design become of paramount importance under the environmental leads. The cage design preferred by the site operators has the sinker tube supported directly by the net. This helps the net and cage components move in unison with one another, minimizing any abrasion caused between the two.

To combat the dangers associated with this method of fish farming, technologies more suited to this new environment are now being examined. This, it is hoped, will simplify processes and reduce the number of days on which salmon cannot be fed due to weather conditions.

**Feeding strategies**

Currently, feeding is carried out using a hopper and blower system on the deck of the site’s dedicated workboat, the Annalie. The hopper can carry up to five tonnes of feed. The crew will travel to the site every day and feed each of the cages in turn. To deliver the feed, the vessel must moor up against the cages, plug into the underwater camera systems and blow feed over the water surface. Therefore the violent waves described above can render feeding too risky, primarily because the movement of the vessel could damage the cage, leading to fish escaping.

The Annalie can carry a few extra tonnes of feed on her deck but the crew must load them into the hoppers at sea, which is dangerous in rough conditions. When the salmon require more than five tonnes during a day, each one tonne bag must be loaded by the workforce’s crane. For this reason, two alternatives to the current routine are being considered by the management at Cooke to reduce the number of missed feeding days.

The site offers greater opportunity to sustainably grow fish farming because farming offshore vastly increases the number of potential sites. The deeper waters and stronger currents disperse dissolved and particulate wastes more quickly.

**The Scottish aquaculture sector**

Salmon is Scotland’s number one food export, so it is not too dramatic to argue that the impact of new and improved fish farming methods could be massive on the economy. Whether conditions, more robust equipment and ways of farming fish more suited to offshore sites must all be considered. If successful, this could be of great benefit to the local and national economy.

To reach its growth targets, industry will be keen for more sites like Skelwick to come to fruition at the median of 70%.

Increased specifications of equipment and technology means a requirement for increased investment.

Acquaculture is already a key employer in Scotland’s rural and inland areas. Skelwick Skerry, for example, has created eight jobs and supports even more roles in the supply chain, from fish processing to sales.

Salmon producers registered a combined turnover of £1.227bn in 2018. When economic multipliers are considered, this could mean that salmon contributed about £2bn to Scotland’s economy. High-energy sites may only be responsible for a small percentage of that at the moment but this share is likely to grow.

**A model for growth**

Skelwick Skerry is an excellent example of public-private collaboration and the site should be seen as a blueprint to salmon producers with similar ambitions. As more tailored technology is developed to increase environmentally-friendly growth, SAIC is keen to support the innovation required to expand into new locations by linking research with the needs of the industry.

Salmon is Scotland’s number one food export, so it is not too dramatic to argue that the impact of new and improved fish farming methods could be massive on the economy.
 Sulphur dioxide and sulphites (E220 – E228) are chemical compounds, that are naturally occurring (sulphur dioxide is naturally present in wine or beer for example) and are most commonly used as preservatives in a wide range of foods. They are used to extend the shelf life of products as well as to kill bacteria, and are popular due to the fact that they will maintain the colour in products and can have a softening effect, which is particularly desired within the dried fruit market.

Unlike most allergens, protein or DNA cannot be extracted from sulphites – meaning that a highly sensitive analytical chemistry route is the only way to screen for them in food and food products.

Although there are historic techniques for determining sulphites, they have known limitations and accuracy issues with the limits set out in Annex II (amended by Commission Delegated Regulation No. 78/2014).

Traditional analysis and its limitations

Sulphites are determined in foods by relatively straightforward procedures. Most commonly, these involve a distillation process in which the sample is dispersed in an acidified solution to convert all sulphite forms to sulphuric acid (a solution of sulphur dioxide) and the free sulphur dioxide is distilled over into a trapping solution to be quantified. In the Monier-Williams method, a standard approach used by many laboratories, the sulphur dioxide is flushed from the refluxing acidified solution using a stream of nitrogen gas and the gas is trapped in a solution of hydrochloric peroxide. Once in solution as sulphuric acid, the sulphur dioxide is oxidized by the peroxide to sulphuric, i.e. the sulphite ion is oxidised to sulphite ion. The final determination of the sulphuric acid produced is accomplished by titrating with standard sodium hydroxide solution.

This method works very well for most sulphited food types, where sulphites are present at concentrations of tens or hundreds of ppm. It does however, have its limitations. Firstly, as originally devised the method requires setting up the glassware for each sample to be separately refluxed for 40 minutes to evolve and trap the sulphur dioxide. In the modern routine analytical laboratory this is much too time-consuming. Fortunately, today we have rapid distillation units that generate steam to introduce into the acidified sample suspension and bring about complete distillation in just six minutes.

The second limitation of the original Monier-Williams method is its sensitivity and robustness at very low concentrations of sulphur dioxide. The limit of detection of this method is around 10ppb. This is also the limit set in legislation, mentioned above, for declaring sulphite allergens in foods. Being confident of the presence or absence of sulphite in a product is obviously of great importance for a food producer and the original Monier-Williams method is far from satisfactory for this purpose.

In the PAS laboratories an adaption of the Monier-Williams method has greatly improved both the sensitivity and accuracy of this determination at levels around and below 10ppm.

The new approach – sensitive and accurate

The PAS method employs first a six-minute distillation step in which sulphur dioxide is collected in a hydrogen peroxide trapping solution. This solution containing sulphuric acid is then tested using ion-chromatography with a conductivity detector to separate the sulphite ion chromatographically and quantify this with a highly specific detection method.

This method has several advantages: Firstly after each distillation is complete, the analyst does not have to spend time titrating the peroxide-trapped sample. These samples are simply put onto the chromatography system to be run in a queue — usually overnight.

Secondly, the instrumental approach, with specific and sensitive conductivity detection, gives a lower detection limit of 2ppm and a lower method uncertainty. No longer are the errors associated in determining a titration end-point a factor.

Finally, this approach by specifically measuring sulphate ions (the product obtained from oxidation of sulphites in the sample) avoids any uncertainty over whether the conventional titration with sodium hydroxide is measuring solely sulphuric acid or potentially other acid species co-distilled into the trapping solution.

This extra confidence is extremely important for the reliable measurement of low sulphite concentrations around the legal declaration limit.

The future of sulphites

With the UK food market moving to an increasingly health aware stance, as well as the growing popularity of the ‘food-to-go’ market, the demand for dried fruits and vegetables (and products derived from such as fruit bars) is increasing.

This means that manufacturers are looking for ways to prolong shelf life and therefore the profitability of their products – something that sulphites, when used properly, are extremely adept at doing for they maintain colour and texture whilst killing bacteria.

With new and sensitive techniques, manufacturers are able to effectively monitor sulphites within their products to ensure that they maximise their product potential whilst conforming to legislation. The sensitivity of these new techniques also ensures that consumers have the confidence that they can safely derive products of their choice.

In response to the UK Government’s policy to increase the quality and quantity of apprenticeships in the UK, Mondelez International is actively increasing opportunities for apprenticeship schemes across our UK business through investment in developing our people. In the UK, we currently have over 80 apprentices completing their training and have plans to recruit at least a further 20 in 2019.

A apprenticeship with Mondelez gives you a taste of life outside the classroom and fantastic exposure to the FMCG industry, whilst also developing your technical skills that will be essential as your career progresses. At our Research, Development & Quality (RDQ) Chocolate Centre of Excellence in Bournville, there are new colleagues with varying career paths who develop Mondelez Early Career Path and now have progressed into senior roles. Apprenticeships are fast becoming more popular and competitive, and with a high demand for talent within the food industry there are several avenues in.

Mondelez’s confectionary products do not just appear on supermarket shelves, there are many people working hard to create the products and packs for our consumers. Teams of engineers, scientists and product developers at our Bournville and Reading sites ensure our products move from the prototype stage to factory line and finally, onto shelf. Besides apprenticeships there are other schemes that Mondelez offers to those completing degrees, including internships, graduate roles and as direct entry candidates. Here we introduce a few of our heroes who are enjoying successful careers at Mondelez.

Apprenticeships, a new route to the top

Hayleigh Curtis

Hayleigh Curtis joined the business in 2006 and became the first R&D apprentice in over 20 years. Now a Senior Scientist, Hayleigh started in a part-time role at Cadbury World whilst studying at college. Upon completion of her apprenticeship, she furthered her academic learning through completing a company sponsored degree in Natural Sciences (BSc) through the Open University, whilst also working full-time. Her own drive and love for science and maths early in her career, have seen Hayleigh progress through the business rapidly. Through her strong technical abilities and know how, her roles have seen her travelling the world, learning from peers and subject matter experts. Now in a role that Hayleigh saw as her dream job, a Senior Scientist in chocolate masses, she has a passion for supporting other apprentices whilst promoting a company that she is very proud to work for.

Ryan Hadley

Ryan Hadley, who started as an apprentice and is now a Technician within RDQ Productivity, always wanted a job within the food industry. Through the support of Mondelez International describe the wide range of career opportunities and training available within the company.

Emilee Richardson and Teresa Ennis

In the food and drink sector
Olivia Bowry decided upon an apprenticeship with Mondelez following her GCSE’s, having previously studied Home Economics at school. Whilst working towards her level three apprenticeship, she realised a real passion and excitement for developing and launching new products. Following the completion of her apprenticeship, Olivia is a Process Technician and is witnessing her work being brought to life with new products launching in markets around the world.

“I have worked with many talented colleagues who taught and mentored me with patience and understanding. Now, towards the end of my career, I am enjoying repaying this debt by taking a more active role in the technical mentoring of colleagues.”

Economics at school. Whilst following her GCSE’s, having an apprenticeship with Mondelez, Olivia Bowry decided upon an apprenticeship with Mondelez as a Confectionary Apprentice. I then moved into Chocolate Manufacturing upon completion of my 2-year apprenticeship. I then spent a further five years within Chocolate Making as an operator on two different production lines before becoming a Distribution Co-ordinator who was responsible for third-party customer order fulfilments and on-site fulfilments as well as day to day planning of the production and labour. I then moved onto one of the new manufacturing lines, which were installed as a result of Mondelez’s £75m investment in Bourneville. I became the In-Line Lead for my shift, meaning that I was personally responsible for shift performance as well as planning the logistics for product changeovers. I have become a multi skilled operator, working closely with the trades personnel, resulting in many talents.

In my current role as a Technologist within the RDQ Pilot Plant, I have a broad and varied focus within the Chocolate Making team. I believe my journey thus far has set me up for success in my role and allowed me to be a cross-functional member of the team, the Cottelliers.

Andy Cottellier

Sometimes it is not clear early on in your career what it is that drives you as an individual, or where your passion and interests may truly lie. Taking the long view your career is a marathon and not a sprint, and with every opportunity there is a chance to learn something new, and ultimately to become a subject matter expert.

Starting as a confectionary apprentice with Cadbury in 1976, Andy Cottellier was one of the ‘original’ Cadbury apprentices, and is a fantastic example of how you can develop a lifelong career within Mondelez. He was recently recognised by Rolf Hargrave (Mondelez RDQ Executive Vice President) for his lifelong achievements. He ‘spent some of his early career in chocolate feedstock development and this evaluation of our key ingredients sparked his interest in fats and oils.

Andy characterised the physical properties of cocoa butter and some of the testing methodologies that he developed early on in his career are still in use today. Then in 1997, Andy brought his technical insights to manufacturing through numerous roles within the Bourneville factory. During his time in supply chain, Andy has held both managerial and technical positions. After ten years in manufacturing, he ‘came back home’ to RDQ, bringing his core technical skills and practical experience to bear on chocolate development and as a Fats & Oils subject matter expert.

Andy Cottellier, Senior Associate Principal Scientist explained: ‘I consider myself very fortunate to have spent my whole working life at Cadbury, Kraft and now Mondelez International. Starting as an RDQ apprentice, then being formally educated to graduate level in Chemistry, and now returning to a permanent role and develop the wider team. I believe my journey thus far has set me up for success in my role and allowed me to be a cross-functional member of the team, the Cottelliers.

Sarah Boyd

Sarah Boyd is a chemical engineer who started her Mondelez career 10 years ago on the engineering graduate scheme. Over this time, Sarah has worked in RDQ and Manufacturing including project engineering, shift management, RDQ product, pack and process. These roles have taken her across many of our UK sites. Most recently Sarah was the Mondelez RDQ lead for Cocoa Life, a scheme that Mondelez has developed in partnership with cocoa crop farmers to transform the cocoa supply chain. Currently Sarah is the Business Development Section Lead for our UK seasonal portfolio, which includes products such as Roses, Heroes and Crème eggs at the heart and home of Cadbury manufacturing, Bourneville. Furthermore, through her depth of experience, Sarah has most recently become a Chartered Chemical Engineer.

Teresa Ennis

Teresa Ennis, a Food Science graduate from the University of Reading, landed her first role in 2013 at Mondelez as an intern, since then the internship programme has doubled in size. Teresa Ennis, Senior Engineer commented: ‘I started at Mondelez as an intern in the Cocoa and Chocolate Solutions Team – I remember thinking, wow! That’s the coolest sounding team ever! I worked on small scale chocolate making, which gave me great understanding of the science behind…'

Mondelez International, PO Box 12, Bourneville Lane, Bourneville, Birmingham, B30 2LU

Visit the Mondelez website to see open and upcoming positions.

Send early career enquiries to: earlycareersenquiries@mondelezinternational.com

Graduate opportunities

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CAREERS
In an era of fake news and many uncertainties when it has become less easy to establish truth from untruth, particularly for complex issues, well written information that can be trusted has increased worth. The whole area of GM crops can certainly be called an issue with many considerations, complexities and controversy. Controversy has been caused by misunderstanding, partial understanding or no understanding and the manipulation and distortion of information. GM crops began as an exciting revolution more than 20 years ago with genuine aspirations to improve agriculture for farmers and society. Where GM crops have been adopted, they have been an enormous success, in fact of paradigm shift – increasing yields and farmer profitability, decreasing use of chemicals and in some cases preventing crops from being completely wiped out and preventing disaster. These positive aspects do not normally come through in the usual narrative surrounding GM crops – they have been subject to massive misinformation. The point is not often made that GM food has been subject to the largest scale testing of any product ever known to man through billions of meals eaten, particularly in the US, and there has not been a single case of harm. Yet the field has been dominated by words, such as contamination and multinational companies, and erroneous reports of harm, such as to Monarch butterflies and farmer suicides. Pressure groups have blocked the adoption of GM crops that could literally save lives. This is serious stuff. What a relief, then, to be able to read a truthful, dispassionate book without an axe to grind, which not only presents the facts but is also funny, clear and very accessible. Ian Godwin is a professor of plant molecular genetics at the University of Queensland. Even if we do not trust politicians or authority figures anymore, academia can still be considered a bastion of truth and impartiality. Where would society and civilisation be without the teaching, learning, discovery of knowledge and progress brought about by universities. Godwin’s book presents an authoritative account of the history of GM crops going back to their beginnings, including the science behind the technology and the first products that came to market. A wonderful story is woven of science, discovery and anecdote, with Australian directness and humour. Godwin explains and entertains. Information is drawn from many quarters from biologists, farmers, nutritionists and activists and from Godwin’s direct experiences over 30 years. The book is wide-ranging and includes information about the development and history of agri-tech chemical companies and subjects such as organic food. The exciting new development of gene editing through CRISPR is highlighted. The book enjoys and celebrates science and life. One feels that a major injustice against GM crops and indeed science has been in some way corrected by this book. There are a number of pictures, illustrations and figures accompanying the text, which effectively illustrate the points made. Citations are included, so that source material can be consulted. Thank you, Professor Godwin, for writing this book; it is really excellent and highly commended. The book is relevant for anyone interested in the truth about GM crops, including biologists and agriculturalists, from school level upwards, and the public; it should be mandatory reading for anyone wishing to form an opinion and comment on the matter.
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