FOOD PACKAGING

INNOVATIONS IN PLASTIC PACKAGING

RECYCLING PLASTIC PACKAGING
FUTURE OF PACKAGING
MODIFIED ATMOSPHERE PACKAGING
SPOTLIGHT ON CHAP
PESTICIDES IN AGRICULTURE
BLOCKCHAIN
LISTERIA DETECTION
MEAT CONSUMPTION
SCIENCE AND SOCIETY
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<table>
<thead>
<tr>
<th>Acrylamide &amp; Furan</th>
<th>Mycotoxins</th>
<th>Foreign Body Investigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrition</td>
<td>Vitamins</td>
<td>Contaminants</td>
</tr>
<tr>
<td>Allergens</td>
<td>Taints</td>
<td>Additives &amp; Preservatives</td>
</tr>
<tr>
<td>Microbiology</td>
<td>GMO</td>
<td>Metals &amp; Minerals</td>
</tr>
<tr>
<td>Challenge Testing</td>
<td>Shelf Life</td>
<td>3MCPD &amp; Glycidyl Esters</td>
</tr>
<tr>
<td>Illegal Dyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Authenticity</td>
<td>Food Safety</td>
<td>Food Composition</td>
</tr>
</tbody>
</table>

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First for food analysis
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Innovations in plastic packaging

Barry Turner reviews some recent developments in plastic food packaging.

Plans for plastic recycling

Lisa Foster of Coca-Cola European Partners discusses sustainable packaging and the future of plastics in packaging.

The future of packaging

Paul Jenkins looks at the latest packaging innovation trends and discusses how the last year has shaped the future of packaging.

Clearing the atmosphere

Lynneric Potter explains the principles behind modified atmosphere packaging and discusses the problems caused by the shortages in carbon dioxide in the summer of 2018.

Good work, CHAPs

David George describes the role of CHAP (Crop Health and Protection) in driving forward the agri-tech revolution.

Pesticides in agriculture

In the first of a two-part article, Ralph Early discusses the historical and current use of pesticides focusing on the use of herbicides and insecticides.

Blockchain or bust for the food industry?

Tom Hollands, Wayne Martindale, Mart Swainson and John G. Keogh explore the benefits and pitfalls of Blockchain.

Sniffing out contaminants

Spiros Paramithiotis, Natasha Spadafora, Carsten Muller, Eleftherios H. Drosinos and Hilary Rogers look at current methods and future prospects for detecting Listeria in fresh fruit and vegetables.

Chewing the fat

Sterling Crew examines the environmental impact of increasing meat consumption and looks at strategies for addressing sustainability in food consumption and agriculture.

Science, food and society

Barbara Galliani of the European Food Safety Authority (EFSA) explains its current initiatives to improve openness and transparency by promoting stakeholder participation.
In the Autumn Budget, the Chancellor, Philip Hammond, announced a new tax on the manufacture and import of plastic packaging containing less than 30% recycled plastic. This was in response to mounting public pressure following media coverage of plastic waste mountains in some developing countries and the effects of plastic on marine life.

Our theme for December is food packaging and it is apparent from recent announcements by major players in the food sector that the industry is starting to take action to reduce the amount of plastic used in packaging and to increase recycling of the plastic in packaging. Large food companies and retailers are entering into partnerships with waste management companies and packaging producers to create value chains to ensure that there is a sustained demand for the recycled plastic, producing a circular economy (p4, p18, p22).

Large manufacturers are setting targets to improve the recyclability of plastic packaging and working to increase the recycled content (p4, p22). Deposit return schemes for bottles have been successful in other European countries and offer real potential in the UK (p22).

Innovations in packaging to reduce plastic waste include reducing the number of layers of plastic packaging and introducing bioplastics to make packaging more compostable (p18, p24). Reusable bottles and coffee cups can also help to reduce the amount of packaging waste generated (p22, p24).

Modified atmosphere packaging (MAP) is an important technology used to extend the shelf life of a range of food products (p28), hence contributing to reducing food waste. It is alarming that it has taken us so long to wake up to the dangers of plastic disposal and accumulation in the environment. A joint effort from government, industry and consumers is required to tackle this very pressing problem.

I would like to welcome Sterling Crew, Chair of the IFST Food Safety Special Interest Group and Managing Director of SQS Ltd, to the FST Advisory Panel. Sterling has been a regular contributor to Food Science and Technology and we are looking forward to his contribution to the Panel.

**EU implements ban on single-use plastics**

Single-use plastic items, such as plates, cutlery, straws, balloon sticks or cotton buds, will be banned in the EU under plans adopted in October 2018[1]. These products, which make up over 70% of marine litter, will be banned from the EU market from 2021, under draft plans approved by the European Parliament.

Products made of o xo-degradable plastics, such as bags or packaging, and fast-food containers made of expanded polystyrene have also been added to this list. The consumption of several other items, for which no alternative exists, will have to be reduced by Member States by at least 25% by 2025.

This includes single-use burger boxes, sandwich boxes or food containers for fruits, vegetables, desserts or ice creams. Member States will draft national plans to encourage the use of products suitable for multiple use, as well as reusing and recycling. Other plastics, such as beverage bottles, will have to be collected separately and recycled at a rate of 90% by 2025.

**Collaboration on plastics recycling**

Unilever and Veolia have signed an agreement to work jointly on technologies that will help create a circular economy on plastics across various geographies, starting in India and Indonesia[2].

The companies acknowledge that the issue of plastic waste is a shared responsibility that requires bold action across the value chain to develop and scale up collection and reprocessing infrastructure, which is critical in the transition towards a circular economy.

The work will focus on material collection, which will help channel recycled content back into the value chain. To help create an end market for recycled plastic, Unilever has committed to increase the recycled plastic content in its packaging to at least 25% by 2025. Veolia will work with Unilever to implement used packaging collection solutions, add recycling capacity and develop new processes and business models through this partnership in various countries.
UK initiatives to reduce pollution by plastic packaging

Circular Plastics Competition launched

A new £1.4m ‘UK Circular Plastics Flagship Projects Competition’ was launched at the inaugural annual meeting of the UK Plastics Pact, held in London in October, to support creative business ideas to stop plastic being thrown away.

The competition, which is managed by WRAP (Waste Resources Action Programme) in partnership with UK Research and Innovation (UKRI), forms part of the £20 million Plastic Research and Innovation fund (PRIF) announced in the Chancellor’s Autumn Statement in 2017. The aim is to engage Britain’s best scientists and innovators in helping to move the country towards a more sustainable circular economy in plastics.

The Competition is open to UK businesses with fresh ideas to tackle the issue of plastic waste. Grants will be awarded for between £100,000 and £500,000 subject to match-funding, to support piloting and evaluation with a view to wider implementation. Projects must address four central criteria:

- reduce the total volume of plastic packaging arising from the UK
- significantly improve the rate of UK plastic recycling
- reduce levels of confusion amongst citizens
- reduce the amount of plastic ending up in the world’s oceans.

Since nearly 70% of all plastic waste in the UK is packaging, new WRAP research and guidance addressing key issues around plastic packaging and the collecting and processing of post-consumer plastics were presented at the meeting, including:

- A report on design tips for making rigid plastic packaging more recyclable, including design choices to minimise environmental impacts and limit the resources needed to produce packaging.
- Updated National Recycling Guidelines on collection for recycling from UK households, including the collection of plastic films.
- Information about composition and volume of plastic waste collected via kerbside.
- A plastic packaging flow data report (PlasticFlow 2025) detailing the current levels of UK plastic packaging placed on the market and recycled, and the potential future levels up to 2025. The report also assesses the probability of compliance with national and European recycling targets and demonstrates confidence in meeting these.

Research on minimum thickness of plastic bottles for recycling, which found that, overall, thin packaging was no more difficult to sort and recycle than thick packaging. However, for rigid PET bottles, there was a minimum thickness of 0.05mm, but this was only present in <2% of the sample. The research confirmed that for effective sorting and recycling, a bottle should be presented as empty and flattened with the lid on.

THE UK PLASTICS PACT TARGETS FOR 2025:

- Eliminate problematic or unnecessary single-use plastic packaging through redesign, innovation or alternative (re-use) delivery models.
- 100% of plastic packaging to be reusable, recyclable or compostable.
- 70% of plastic packaging effectively recycled or composted.
- 30% average recycled content across all plastic packaging.

The UK Plastics Pact Roadmap to 2025 was published by WRAP in November 2018, identifying key actions businesses should take to reduce plastic packaging pollution in the environment.

The actions relate to a series of important milestones aligned with the targets of The UK Plastics Pact, which is the world’s first programme to tackle plastic waste through collaboration across the entire supply chain. The UK will act as a testbed for a planned network of country-specific global Plastics Pacts. UK Plastic Pact member businesses are responsible for 80% of plastic packaging sold through UK supermarkets and half of all packaging placed on the market.

The Roadmap is a guide for businesses and others to identify the actions that need to be taken and the timescale. It outlines some of the key challenges that must be overcome. It is expected to evolve over time, reflecting changes in policy and innovations. It also includes commentary on the complementary roles of government and citizens to ensure the UK moves towards a circular economy for plastics.

The Roadmap aims to move plastics from being a single-use disposable material to a valued resource, in line with the circular economy model, while avoiding unintended environmental consequences of actions, such as substitution or blanket removal, which could lead to increased greenhouse gas emissions and/or increased food waste. If the targets are achieved, all plastic packaging will be recyclable or compostable by 2025.

The roadmap also sets interim targets for increasing recycling and recycled content. Achieving this will require investment in the UK recycling infrastructure and would be expected to generate new jobs, while easing the pressure of plastic waste exportation.
Changing meal times makes you thinner

Modest changes to breakfast and dinner times can reduce body fat, according to a new pilot study.[5] The 10-week study on ‘time-restricted feeding’ (a form of intermittent fasting) led by Dr Jonathan Johnston from the University of Surrey investigated the impact of changing meal times on dietary intake, body composition and blood risk markers for diabetes and heart disease.

Participants were split into two groups – those who were required to delay their breakfast by 90 minutes and have their dinner 90 minutes earlier, and those who ate meals as they would normally (the controls). Participants were required to provide blood samples and complete diet diaries before and during the 10-week intervention and complete a feedback questionnaire immediately after the study.

Unlike previous studies in this area, participants were not asked to stick to a strict diet and could eat freely, provided it was within a certain eating window. This helped to assess whether this type of diet was easy to follow in everyday life.

Researchers found that those who changed their mealtimes lost on average more than twice as much body fat as those in the control group, who ate their meals at normal times. If these pilot data can be repeated in larger studies, there is potential for time-restricted feeding to have broad health benefits.

Those who changed their mealtimes ate less food overall than the control group. This result was supported by questionnaire responses, which found that 57% of participants noted a reduction in food intake either due to reduced appetite, decreased eating opportunities or a cutback in snacking (particularly in the evenings). It is currently uncertain whether the longer fasting period undertaken by this group was also a contributing factor to this reduction in body fat.

WRAP’s recent report Opportunities to Reduce Waste along the Journey of Milk, from Dairy to Home.[6] highlights the scale of milk wastes across the food chain; 330,000 tonnes of milk are lost each year, equivalent to 7% of UK production and worth more than £150m.

Milk waste in the home is by far the largest contributor, accounting for nearly 90% of UK milk waste with 290,000 tonnes thrown away every year. This equates to eighteen and a half pints per household. Milk waste in the supply chain, through breakages and leaks during transportation and in retail outlets, represents 30,000 tonnes, with an additional 13,000 tonnes of waste identified during processing.

The report identifies key actions that could help reduce milk waste by an estimated 90,000 tonnes per year, offering a potential combined saving of up to £40m. Actions are required across the entire value chain through processing, transportation, retail and in consumers’ homes.

Strategies for reducing milk waste in the home focus on storing milk at the correct temperature (0-5°C) and include encouraging consumers to check the temperatures of their fridges, the use of temperature sensitive labels on milk, extending the use of the Little Blue Fridge icon, with the message ‘keep in the fridge below 5°C’, increasing freezing and improving shelf life.

The most significant waste identified during milk processing arises from separating cream from milk, which produces a material known as ‘separator desludge’. This is usually sent straight to drain, but WRAP believes this is a potentially rich resource with high nutrient value proteins. Further processing into materials suitable for food, or animal feed applications could reduce waste by an estimated 10,000 tonnes and cut disposal costs by around £1m a year.

Other practical interventions to avoid milk waste in depots and retail stores include reviewing bottle design and specifications to avoid breakages and leaks, which are the major causes of waste at this stage of the product journey.

WRAP will work with the sector through the Courtauld 2025 Dairy Working Group to help ensure the recommendations are implemented and plans to track improvements and innovations to pack design and labelling over time through its Retail Survey. Progress will also be reported as part of a new target within The Dairy Roadmap – to increase product and packaging design features that help prevent consumer food waste.
Food waste pilot

The Government has announced a new pilot scheme supported by £15m of additional funding to reduce food waste from retail and manufacturing sources[7]. The scheme will be developed over the coming months in collaboration with businesses and charities and will launch in 2019/20.

Currently around 43,000 tonnes of surplus food is redistributed from retailers and food manufacturers every year. It is estimated a further 100,000 tonnes of food – equating to 250 million meals a year – is edible and readily available but goes uneaten. Instead, this food is currently used for generating energy from waste, anaerobic digestion or animal feed.

Further action to cut food waste from all sources is being considered as part of Defra’s Resources and Waste Strategy, which will be published later this year. Defra is commissioning work to improve the evidence base around food waste, including understanding why more surplus food is not being redistributed. This work will inform the design of the scheme, aiming to drive down food waste.

The new scheme follows the £500,000 Food Waste Reduction Fund announced in December 2017 to support food waste reduction throughout England. In July this year it was announced that funds have been awarded to eight charities across the country. The Food Waste Reduction Fund grants will help provide the resources needed to expand their work and will further inform development of the new scheme.[8]

AMR E. coli in UK retail meat

The FSA has published the Year 3 (2017) results of an EU survey commissioned to assess the frequency of certain types of antimicrobial resistant (AMR) E. coli in raw UK retail pork and beef[8]. These findings have been collected on behalf of the European Commission as part of an EU-wide seven-year surveillance study. The data is fed back to the European Commission on a yearly basis and reported in the EU Summary Report on Antimicrobial Resistance.

Samples (314 beef and 310 pork) were purchased from retail premises in England, Scotland, Wales and Northern Ireland and tested for specific types of AMR E. coli. Overall, results showed that less than 1% of the samples were positive for ESBL or AmpC E. coli, which are specific types of AMR. These results are similar to those measured in Year 1 of the survey. However, one beef sample was found to be contaminated with an E. coli containing the mcr-1 gene, which confers resistance to the antibiotic colistin.

This is thought to be the first discovery of an mcr-1 positive E. coli from retail beef in the UK. Although the meat came from outside the UK, further testing indicated no contamination with this E. coli on other samples and at this stage the source of the contamination has not been pinpointed. However, a risk assessment has been carried out and the FSA says that the risk to public health is very low.

In the recently published 2015 EU report, the UK survey results compared favourably to those from other European countries. [8]
A WORD FROM THE PRESIDENT

David Gregory
President, IFST

Writing this at the end of October, it seems every meeting or conference I attend ends with a discussion about the implications of Brexit and what exactly will happen after March 2019.

At the recent celebration of the first anniversary of the University of Reading’s hub of the European Institute of Innovation and Technology Food Initiative, the conversation was around future access to European research funding, the ability to collaborate across frontiers and the attraction and retention of the best researchers. Elsewhere, conversations are around issues like our future relationship with EFSA, which has equally been taking note that 22.5% of its scientific panel members and 25% of some of the more specialised panel members in recent years have been UK nationals.

I am sure many readers of this column have been scrutinising the technical notices prepared by the Department for Exiting the European Union on how to prepare if the UK leaves the EU with no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on meat, fish and the dairy products if there is no deal. The technical notice on ‘Health marks on me...'}

With a stimulating title **Nutritional Science over Gut Feel**, our IFST Spring Conference 2019 will take place on 4 April 2019 at the University of Birmingham.

We have confirmed an amazing line-up of speakers and will open the registration shortly.

**IFST Spring Conference (SC19)**

**Past president elected to IUFoST**

We are pleased to announce that our Past President, Professor Margaret Patterson OBE, has been elected as one of the seven Members of the IUFoST Governing Council. IUFoST consists of over 60 adhering bodies, of which IFST is one, and represents more than 150,000 food scientists throughout the world. It is a non-profit, non-governmental, global scientific organisation for food science and technology. Its mission is to promote international cooperation and information exchange, provide education and training to food scientists and technologists around the world and promote professionalism among food scientists and technologists.

IUFoST plays a crucial role by supporting programmes and projects that address worldwide needs specifically in food security, food safety and education.

Margaret has a BSc in Food Science, a Master’s degree in Organisation and Management and a PhD in Food Microbiology. She was a Principal Scientific Officer and Project Leader at the Agri-Food and Biosciences Institute (AFBI) based in Belfast. She led a research team responsible for microbiological aspects of novel food processing technologies. In particular, she was involved in research on high pressure processing of foods and food irradiation.

Margaret has acted as an External Consultant on Food Safety for the International Atomic Energy Agency, the World Health Organisation and the Food and Agricultural Organisation. She was President of the Society for Applied Microbiology in 2005-2008.

She served as President of Institute of Food Science & Technology from 2013-2014.

In 2014, Margaret was named by the Science Council as one of the UK’s 100 leading practising scientists and she was also awarded an OBE for services to the agri-food sector, particularly in food safety and quality.

Margaret said: ‘I feel very honoured to have been elected onto the IUFoST Governing Council. Working together to help ensure safe and sufficient food supply is a key goal of IUFoST and the organisation aligns well with IFST’s objectives of advancing food science and technology, encouraging professionalism within its members and cooperating with all organisations and groups that share the same objectives.’

More information coming soon at: ifst.org/events
Teenager Natasha Ednan-Laperouse died in July 2016 from anaphylaxis caused by sesame. The recently completed inquest heard that an artichoke and olive tapenade baguette, bought at Pret a Manger at Heathrow Airport, which included sesame as part of its recipe, was the cause of death.

Pret a Manger relied on UK law that permits no allergen labelling on products that are not prepacked, or which are prepacked on the premises where they are sold. Instead of labelling on the packaging itself, it is permitted to prompt consumers to ask about allergens. This is done by ‘signposting’ with a label attached to the food, or on an easily-seen notice where the intending purchaser chooses their food.

The business must indicate that the details can be obtained by asking a member of staff and ensure that allergen information is available and easily accessible to the consumer. A ‘prepacked food’ legally refers to a food item which cannot be altered without opening or changing its packaging, as opposed to foods packed on the sales premises at the customer’s request or prepacked for direct sale.

We welcome Pret’s commitment to meaningful changes in allergen labelling, announced by CEO Clive Schlee, and support Michael Gove’s intentions to urgently consider the situation after the coroner called on the Government to examine labelling rules, specifically on whether large businesses should be able to benefit from regulations, allowing reduced food labelling on products made in shops.

We are calling for a change of culture in businesses, regulation and enforcement, so that people with allergies can readily find the information they need to keep safe. Sterling Crew, Chair of IFST’s Food Safety Group stated: ‘I believe when businesses are fully complying with the regulations, and such tragic cases still occur, the law needs to be reviewed’.

IFST calls for culture change over allergen labelling

Statements fully updated

As part of our commitment to provide relevant and clear science-based information about food science and technology, we have updated our Information Statements on Mycotoxins and on 3-MCPD, 3-MCPDEsters and Glycidyl Esters.

Our Information Statements are peer-reviewed by IFST’s Scientific Committee.

For more information, please go to: ifst.org/resources/resource-search?f[field_resource_categories]=385

In search of top table triva champions

IFST’s Student Group is hosting its first ever University Food Challenge on 27 February 2019.

This competition will pit teams of undergraduate students against one another in a food science trivia contest to crown a 2019 Student Challenge champion. It will cover a wide variety of food-related topics, including food safety, food law, manufacture, nutrition and sensory science.

Are you taking advantage of the myCPD system?

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myCPD is IFST’s tailored online system designed to help you manage your own learning and growth with ease. It is available to registrants (free) and members (£15).

For more information, please visit: ifst.org/cpd-learning/mycpd

Food additives made easy

As the use of additives in food products continues to raise some concerns among consumers, we have released a new Food Science Fact Sheet to provide clear, concise and scientifically reliable information on this topic.

It answers the following questions:
• What are food additives?
• Why are food additives used?
• What are E numbers?
• What do additives do?
• How are food additives controlled?
• How do I know if additives are in my food?

To download this Food Science Fact Sheet, please go to: ifst.org/sites/default/files/Food%20Additives.pdf
Salty solutions

Alice Nield  
University of Reading

On 17 October 2018, IFST’s Food Science and Nutrition Group hosted an interesting debate about the industry challenge of reducing sodium in our diet entitled What is a pinch of salt? Discussion was led by Kate Halliwell, Head of UK Diet and Health Policy at the Food and Drink Federation (FDF) following presentations by four industry professionals, all with experience of sodium reduction.

Sarah Coe, British Nutrition Foundation, reiterated that sodium is an essential nutrient, but intake must be significantly reduced in the interest of consumer health. The achievable population goal is 6g per day, however average intakes in 2014 were still high at 8g/day, despite significant progress in the last ten years. SACN’s review of potassium replacers states that the benefits outweigh any risks but that potassium replacers should be clearly labelled due to associated health risks for vulnerable groups, e.g. those with kidney disease.

The reduction of sodium within the savoury snack industry was highlighted by Sue Gatensby, PepsiCo. Pressure from media and voluntary and regulatory organisations mean sodium reduction is high on the health agenda for the industry. However more consistency in targets is needed particularly as legislation varies between countries. Great progress has already been made within the product portfolio. Sue stressed the importance of being guided by consumer acceptability of taste and convenience. Ensuring food safety has not been breached. Dinnie Jordan from Kudos Blends provided an insight into the technical challenges of sodium reduction in bakery. One third of the sodium in bread comes from salt (sodium chloride), with 2/3 from baking powder. 50% salt reduction within bread has been achieved, but to achieve government targets of <170mg/100g, the sodium content within baking powder (sodium phosphate and sodium carbonate) still needs to be addressed. Replacement of sodium phosphate with potassium phosphate seems to, for the moment, provide good quality products but challenges still remain in certain bakery items, e.g. scones and crumpets, with a high baking powder content.

Finally, new technologies in sodium reduction were discussed by Lindsay Bagley, Eureka, confirming the multi functionalities of salt for taste, preservation and processing. Consumers need time to adjust to a new taste profile, with saltiness being enhanced by glutamate, addition of natural sweetness as well as herbs and spices. Reducing salt, and introduction of potassium, can lead to bitterness, which can be masked by use of inorganic salts as well as amino acids and increased acidity. Other techniques for increasing perceived saltiness relate to salt structure: pulsed delivery, increasing surface area of crystals and using hollow spheres as in Soda-Lo. Sodium does not provide a high percentage of total ingredients, so there is sufficient room for industry to embrace a combination of strategies to tackle sodium reduction.

Discussion was led by Kate, with very thought-provoking questions posed. It was agreed that potassium replacers have increased opportunity to further reduce sodium, however negative implications on taste will need to be monitored. Great progress in sodium reduction has been seen so far, however further reduction is more challenging as novel methods/ingredients have to be sought. For a broad impact on total population sodium intake a whole industry approach is necessary to achieve the 6g/day ideal. The issue surrounding potassium replacers for vulnerable groups is a concern, and the debate over potassium labelling was raised. No quantitative declaration of potassium is seen on UK products, partly because content varies heavily with season. The example given was potatoes, a huge component of savoury snacks. Potassium analysis of products is not routine within industry; it would be an expensive addition to a label for a minor population set. If potassium is labelled on a food product, it must contribute 15% to the DRV (dietary reference values) according to EU labelling guidelines.

When tested by Kudos Blends, potassium bicarbonate within baked goods, including biscuits, cakes and bread, provided a darker colour/crumb compared to sodium bicarbonate due to its higher alkalinity. It is a great addition to biscuits to create a golden-brown colour, however could pose issues with increasing acrylamide formed during Maillard reaction.

UK government sodium reduction targets will be introduced slowly due to potential process challenges, allowing for natural adaptation of the palette to lower salt. Children have grown up with low salt foods, therefore expectations differ. Only a quarter of salt consumed is added to foods; it is not just industry that needs to participate in sodium reduction.

The evening was extremely informative, with great discussions on both the success of sodium reduction so far and the challenges still to come. The discussions ended, and networking pursued with an array of salty, savoury snacks – in moderation of course.
Meet the IFST team

Jon Poole Chief Executive
Jon’s prime role is to provide the leadership and direction for the executive team. He works closely with the Board to develop our overall strategic direction, translating this into actual delivery. Jon is responsible for external relations with many of our key supporters and collaborators. In addition, he oversees our publications, especially the International Journal of Food Science & Technology.

Andrew Gardner Operations Director
Andrew is responsible for helping the business run smoothly, from supporting the Finance Committee to overseeing our finances, premises, office facilities, services and IT. He manages our education and careers and our professional development team members and related activities.

John Bassett Scientific Policy Director
John is responsible for the development of our scientific policy positions and communication of these to stakeholders, including IFST members and government.

Natasha Medhurst Scientific Affairs Manager
Natasha’s principle focus is on scientific activities and affairs, contributing to the communication of our scientific voice. She is responsible for writing new scientific materials for our members and other interested parties as well as in response to external enquiries.

Delia Mertoiu Marketing and Business Development Manager
Delia is responsible for the coordination of our marketing activities. She develops promotional support materials and tools to enhance the awareness of our events and activities and works with external promotional support contractors on IFST marketing projects.

Kelly Ah Chin Kow Membership and Events Coordinator
Kelly joined the team at the beginning of August 2018. She is the main point of contact for our Branches, liaising with the regional committees to coordinate and support Branch activities and events as well as our LaunchPads.

Izabela Nair Communications Manager
Izabela is responsible for the coordination of our overall communication activities including e-comms, website content and social media. She is the first point of contact for media enquiries, promotes IFST’s key events and activities as well as records and edits videos.

John joined the team in October 2018 and is responsible for all of the Institute’s affairs relating to the teaching of food science and early careers (e.g. school initiatives on Love Food Love Science, university courses, apprenticeships and T-levels). She also supports the Student Group and New Professionals Group and is responsible for liaising with university contacts and representatives as well as student ambassadors.

Kiu joined the IFST team in October 2018 and is responsible for coordinating and actively managing the flow of applications for the Institute’s wide range of membership and other registration assessment processes via its network of trained assessors.

Ruth is responsible for ensuring that consistently high standards of assessment are maintained for the integrity of registers and their associated CPD standards.

Anjlee looks after our members by dealing with general enquiries and maintaining and updating member records including welcoming new members. Other areas of her work include dealing with queries related to renewals or joining, ensuring invoices and receipts are issued, and processing member related financial transactions.

The team is here to support you. If you have a question about your membership, wish to join one of our professional registers or would like to set up a Group Scheme at your organisation, email us at: info@ifst.org or call 020 7603 6316.
Recent highlights from IJFST

- Colonisation of lettuce by *Listeria monocytogenes*
  Foodborne illnesses involving ready-to-eat vegetables are increasing. Lettuce is the third most consumed fresh vegetable in the US, worth approximately $1.9 billion, making it the most valuable leafy crop.

  The colonisation of lettuce by *Listeria* has so far received limited attention in the scientific literature. *Listeria monocytogenes* has high mortality compared to other foodborne pathogens, such as *Salmonella*.

  This review summarises recent studies on the mechanisms of attachment and colonisation of *Listeria* on lettuce leaves. Various factors that affect colonisation of lettuce by *Listeria* are discussed, including the effects of washing, different radiation treatments and different cultivation systems on the recovery of *Listeria*.

  Strategies to minimise the colonisation of lettuce by *Listeria* to enhance food safety are proposed.

  Kyere et al., 2018, doi.org/10.1111/ijfs.13905

- Chitosan coating inhibits pathogens on catfish
  Antibacterial activity of high molecular weight water-soluble chitosan (800 kDa) was investigated against four Gram-negative (*Escherichia coli*, *Salmonella typhimurium*, *Vibrio cholerae* and *Vibrio parahaemolyticus*) and two Gram-positive (*Staphylococcus aureus* and *Listeria monocytogenes*) bacteria. Catfish fillets were surface-inoculated with these food-borne pathogens and coated with chitosan dissolved in aspartic acid (AS) or acetic acid (AC) solutions at different concentrations (1% or 3%). Samples were stored at 4°C for 8 days, except for those inoculated with *Vibrio* species (10°C for 6 days). Overall, the most effective coating treatment was the 3% chitosan in AS solution. Compared with the control, this treatment caused significant reductions in all pathogens tested and completely suppressed growth of *V. parahaemolyticus*.

  This study demonstrated that chitosan in AS solution could be used as an alternative antimicrobial coating for catfish fillets. Karsli et al., 2018, doi.org/10.1111/ijfs.13897

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First for food analysis
Border delays could cause congestion

Lorry traffic passing through Dover saw a record year for freight vehicles in 2017, up 0.4% on 2016, according to the figures issued by the port authority[1]. The figures show that Dover handled a record 2.6m freight vehicles in 2017, representing up to 17% of the UK’s trade in goods, worth up to an estimated £12.2bn last year. These statistics have fuelled concerns over delays and potential gridlock in Dover and other ports after Brexit.

More checks could cause major disruption not just to traffic, but to the supply chains for goods, from food to the motor industry.

Research has been carried out by a team from Imperial College London, through Imperial Consultants, to quantify the congestion impact on the M20/A20 of check time increase at Port of Dover and Eurotunnel (Folkestone) in a post-Brexit scenario. The study focused on a 40-mile segment of the M20/A20 motorway between Maidstone and Dover, with local access to Ashford and Folkestone.

Outbound lorries and passenger vehicles that use the ferry and tunnel to cross the Straight of Dover, as well as traffic with local origins and destinations were considered. Traffic simulations were conducted with assumptions regarding the check times at Dover and Eurotunnel for both current and post-Brexit scenarios. The impact of vehicle queuing at these locations was assessed in terms of queue length, travel time and disruption to local traffic.

Methods
The study area included the M20/A20 corridor between Maidstone (east of Junction 7, near Thurnham Lane) and Dover (Port of Dover), measuring 38.2 miles in length. The road network considered for the simulation included the A20 as an alternative route between Maidstone and Folkestone, local streets near Ashford, Folkestone and Dover and part of the A2 approaching Dover from the north (a potential route shift towards the M2/A2 corridor for Dover-bound traffic).

The simulation spanned a 24-hour period when performance indicators, including queue length and travel time, were calculated hourly. The base scenario (normal traffic operation) was sampled from working days in October 2017. The study considered both east- and west-bound traffic with local origins and destinations at Maidstone, Ashford, Eurotunnel, Folkestone and Dover. The traffic mix consisted of passenger vehicles, light goods vehicles and heavy goods vehicles. Taking into consideration different types of vehicles allowed more accurate modelling of traffic dynamics in free-flow, congested and queuing conditions, as they occupy different road space and have varying free-flow speeds.

State-of-the-art dynamic traffic assignment models and simulation platforms developed at Imperial College London were employed[2-5]. The dynamic traffic assignment model takes network characteristics (origin, destination, topology, link, node and path parameters) as well as time-varying origin-destination (OD) demand matrices as input. The algorithm assigns the OD demands within each hour to the corresponding set of feasible routes according to the dynamic user equilibrium principle[6-8]. The model captures the dynamic propagation of flow, queuing and vehicle spillback, while incorporating different mixes of traffic flows (e.g. passenger car, LGV, HGV).

To simulate the bottleneck effect at Dover and Eurotunnel, the study area included the

Ke Han, Daniel Graham and Washington Ochieng of Imperial College London report on their independent study, commissioned by the BBC’s Inside Out South East programme, to investigate the impact of increased check time for vehicles at the ports of Dover and Folkestone on highway congestion.

Dover handled a record 2.6m freight vehicles in 2017, representing up to 17% of the UK’s trade in goods.[1]

Table 1 Network performance indicators for different scenarios

<table>
<thead>
<tr>
<th>Check time at Eurotunnel</th>
<th>Check time at Dover</th>
<th>Length of queue* from Eurotunnel &amp; Dover (primary queues)</th>
<th>Peak hour travel time (Maidstone to Dover)</th>
<th>Combined queue* length in the network – including local traffic (secondary or reactionary queues)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 min (normal)</td>
<td>2 min (normal)</td>
<td>9.7 miles</td>
<td>2.1 hours</td>
<td>12.1 miles</td>
</tr>
<tr>
<td>3 min</td>
<td>3 min</td>
<td>19.8 miles</td>
<td>3.5 hours</td>
<td>26.9 miles</td>
</tr>
<tr>
<td>4 min</td>
<td>4 min</td>
<td>29.3 miles</td>
<td>4.8 hours</td>
<td>39.6 miles</td>
</tr>
</tbody>
</table>

* A queue in the network is defined to be a road segment with hourly average speed below 10km/h. The table only shows the network performance indicators during the most congested hour, typically in the afternoon peak. For the rest of the day the traffic deterioration is less dramatic.
caused by border checks, assumptions were made to calculate the corresponding bottleneck capacity (maximum number of vehicles that can go through in one hour). This allows the capture of the queue formation from these locations and their subsequent interaction with motorway and local traffic.

**Assumptions**
Under normal operational conditions at both Dover and Eurotunnel (before Brexit), the average time for a single vehicle to go through the checks is two minutes. Depending on the vehicle type, passport type and trip purpose, for which the data is quite scarce, the actual processes to go through may vary and the times taken are probabilistic. BBC *Inside Out South East* gathered information from the Union for Borders, Immigration and Customs and a Port of Dover study, which confirmed that the two-minute check time is a reasonable assumption for the current study.

Given that post-Brexit passport and custom checks are likely to bring extra delays at the borders, the study hypothesised that the check times at Dover and Eurotunnel are (A) two minutes on average (normal conditions), (B) three minutes on average (one minute additional delay to normal condition) and (C) four minutes on average (two minutes additional delay). These scenarios are not predictions of post-Brexit check times, as the outcome of the negotiation remains uncertain. Rather, they are hypothesised to understand the motorway congestion corresponding to different levels of border delays.

**Results**
To ensure the accuracy of the simulation model, the simulation results were validated for the normal check time scenario using existing data sources. The main simulation results for the three scenarios are summarised in Table 1.

Under the three scenarios considered, queues concentrated on local streets (secondary or reactionary queues) resulting from motorway deadlock can reach up to 2.4 miles, 7.1 miles, and 10.3 miles respectively.

In addition, live traffic updates were used to validate the spatial distribution of congestion predicted by the simulation. Figure 1 compares the actual traffic queues with the simulated ones during the afternoon peak (15:00-17:00). At 15:09, the queue emerging from Dover approaches Folkestone and minor queuing occurs around Eurotunnel, which is consistent across real-world and simulated traffic. At 16:33, the queue on the A20 towards Dover persists and the queue from Eurotunnel has expanded to cover the A20 between Junctions 11A and 12 as well as M20 between Junctions 11 and 11A. The same queuing pattern is observed in the simulation.

Based on the above validation in terms of daily traffic volume and peak traffic congestion, we conclude that the simulation model under normal operational conditions provides a reasonably accurate estimation of the real-world traffic on the M20/A20.

The findings of the study show that even one or two minutes of extra check times at the borders are accompanied by a dramatic increase of congestion on the motorways as well as local streets, with queues extending up to 30 miles from Dover/Eurotunnel towards Maidstone and travel time approaching five hours in peak times.

References and article available online at fstjournal.org/features/32-4/post-Brexit-border-delays

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Brexit and country of origin food labelling

There remain many unanswered questions and concerns about the implications for the food industry post Brexit. One particular issue gaining increasing attention is the call for clear labelling of food for consumers especially with respect to country to origin (COO). The UK farming and food industries recognise that labelling domestic production can provide an important marketing advantage in an extremely competitive retail environment. It is frequently claimed that UK consumers prefer meat from domestically produced animals. Recent consumer research in 2017 lends support to this assertion reporting that 67% of respondents would prefer to buy UK food. Also, 27% of respondents claimed they would buy more British produce even if imported food prices declined.

Calls for extending the coverage and scope of COO food labels for use by consumers post Brexit have also gained traction with policy makers. The parliamentary Food and Rural Affairs Committee in an extensive report on Brexit and food explicitly discussed the possibility of extending COO food labelling. In particular, the report advocated that the UK should extend the use of mandatory COO labelling to a greater array of food types including bacon, sausages and cheese. In response the UK Government acknowledged the proposals of the committee although there is no explanation or insight offered as to how the UK would change COO labelling or any other food labels in practice.

Professor Iain Fraser of the University of Kent considers the impact of country of origin labelling on UK farming and food production post Brexit.

The economic rationale for COO labels

Quite simply, the reason for identifying COO is to satisfy consumer demands for information about food. Consumers wish to know the origin of the food they are eating. However, origin is a credence attribute, that is an attribute that cannot be verified by the consumer even after the good has been experienced. Thus, the information must be provided prior to purchase so as to inform the purchase decision.

The economic argument as to whether or not COO information is supplied on a voluntary or mandatory basis should come down to costs and benefits. Available evidence is mixed when it comes to what consumers will pay (as opposed to value) for COO information. At the same time modifying food labels to include mandatory COO information is costly. Therefore, it remains unclear if the costs of providing COO information outweigh the benefits.

Of course, the balance between costs and benefits may well change as improvements in technology allow for cheaper, more rapid and reliable information to be collected and employed. Therefore, some of the technology solutions that are currently being proposed with regard to tracking food through supply chains (i.e. QR codes and blockchains) may offer possible technical as well as economic solutions.

Pilot trials and legislation

Importantly, the call for extending COO labelling is not restricted to the UK. There are currently several pilot COO trials being implemented within the EU.

These pilots are justified on the same basis as an extension of COO in the UK – consumers want (need) to know where their food is coming from. But what the pilot initiatives within the EU demonstrate is that implementation of COO labelling can quickly run into problems, especially with regard to the single market.

Take for example the case of Italy introducing mandatory COO labelling on pasta and rice packaging. The Italian legislation called for information on the primary ingredients, which also meant that the place of cultivation of the rice and wheat needed to be given. Although this information might be welcomed by consumers, the potential ramifications for international suppliers of rice and wheat to the Italian market are negative. Serious concerns have been expressed about how the implementation of the various pilot schemes can introduce trade distorting measures within supply chains and are potentially in breach of EU single market rules.

Another important example of how COO labelling has been used in an effort to extend consumer information and choice comes from the US. In 2008, legislation was introduced requiring food processors to incur additional costs in terms of information provision about the sources of meat in products. This change in how COO information was implemented, lead to an
extensive trade dispute in the WTO between the US and Canada and Mexico. The dispute was finally settled in favour of Canada and Mexico and subsequently the US withdrew the offending legislation.

What these examples demonstrate is that attempts to extend the scope of COO information to satisfy consumer demands for information can very quickly contravene international trade legislation or single market rules. Thus, these examples provide a timely reminder to the UK that even if there are demands from consumer groups to extend and potentially change COO labelling, there is a real possibility that these efforts could lead to unintended trade disputes. At the heart of this issue is the need to balance information provision for consumers without indirectly introducing trade restrictions that are in breach of international legislation.

**Agricultural policy post Brexit**

Finally, another important, emerging COO issue stems from how the recently proposed changes to UK agricultural policy post Brexit may impact the supply of domestically produced food stuffs. It is proposed in the recently published Agricultural Bill[3] that post Brexit farming will only receive government financial support in exchange for the production of public goods. This will mean a completely new allocation of funds to agriculture and is likely to have serious implications for the continued existence of certain UK farming sectors. This, plus changes in border tariff arrangements, may mean that food supply chains will be seriously impacted. In the post Brexit world, we will see if UK consumers are really prepared to support UK agricultural and food production.
Recent focus on the environmental impact of plastic packaging has drawn it onto centre stage in the debate on single-use items — a term many in the industry do not recognise. In most applications, plastic packaging already presents the most resource efficient way of preventing food waste, product waste and transporting goods. Nevertheless, the industry has responded by continuing to innovate its products to further reduce waste. Also, many producers have embraced the circular economy challenge to ensure even the most difficult functional packaging structure can be recycled.

**Single layer materials**

With many specifiers now focused on achieving the aims of the circular economy, it is inevitable that there has been a shift away from multiple material layers, where possible, to ensure ease of recycling and this has included a move to mono PET (polyethylene terephthalate) trays. This shift has been led by suppliers, including Klockner Pentaplast and Coveris to name just two. Now an increasing number of packer fillers and retailers see mono PET trays as the norm as opposed to the former PE/PET (polyethylene/polyethylene terephthalate) construction.

There have also been similar moves in the manufacture of flexible films, with RPC bpi protec’s new X-EnviroPouch stand-up pouch that is recyclable and comes with a good moisture and oxygen barrier. This is

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*Barry Turner of the British Plastics Federation reviews some of the most recent developments in plastic food packaging.*
already finding applications in the cereal and pet food market. The pouch can achieve an oxygen transmission rate of below 3cc/m²/day.

**Collaborations**
Polymer manufactures, major brands, converters, recyclers and waste management companies are all working together in industry-focused European initiatives. One example is Ceflex[1], which has nearly 100 stakeholders and encompasses government-led initiatives, such as Klöckner Pentaplast meat tray.
as the UK Plastics Pact; it is the first of its kind anywhere in Europe. Ceflex, which is focused on flexible applications of plastic packaging, includes leading polymer manufacturers, polymer converters and brands, such as Nestle, PepsiCo, P&G, Unilever and M&S, as well as recyclers and waste management companies.

The aim of Ceflex is to preserve the resource efficiency benefits of flexible films, while ensuring that best design principles preserve functional benefits and that flexible films are collected for recycling at end of life. Dow is already offering new film structures that fit with the aims and objectives of Ceflex. This sort of collaborative working will only intensify the rate of change and innovation and follows on from work started by Reflex (a collaborative project to improve the recyclability of flexible packaging)\(^2\) and PIRAP (Plastics Industry Recycling Action Plan)\(^3\) – both UK initiatives – to develop best practice in the design of plastic packaging and to ensure that it is collected and recycled.

As digital presses have continued to evolve, the industry now has the potential to offer short run packaging solutions. Ultimate Packaging and other companies have already stepped into this space, offering personalised packaging, for example a collaboration with

\[\text{Flow wraps with MAP and vacuum skin packaging are also starting to become more commonplace and the latter has been proven to reduce food waste from 12\% to 3\% for steak.}\]

KitKat printing digital personal images on the packaging. The principle has been extended to allow children to design their own flexible ‘lunch bags’.

\[\text{Composting}\]

In response to the need to provide circular economy solutions regardless of the size of the packaging medium or the complexity, RPC is offering coffee capsules that will industrially compost. Small items of packaging have always posed a problem to mechanical recycling, especially those with high levels of food waste. The Bebo B2nature™ material features a special multilayer sheet that incorporates an effective oxygen barrier to deliver a long ambient shelf life and maintain the aroma and quality of the coffee in the capsule, thus resulting in no degradation in function but at the same time offering another route to recovery at end of life.

Other areas of innovation have included the use of cellulose in conjunction with board for products and packaging more typically used in ‘on-the-go’ applications, such as sandwich packs. Although sandwich packing switched to board some time ago, in many applications it continued to use OPP (orientated polypropylene) film. Coveris has brought to market a number of plastic-free products featuring this construction, which are compostable.

Secretary of State for Business, Greg Clark, recently announced the winners of the UK innovation fund awards. One of the 11 winners securing part of a £4m fund, Skipping Rocks Lab in London, is developing alternative materials to be used for sauce sachets. The company is working on a scheme that would see single-use condiment sachets on takeaway counters made from seaweed. The material, which has successfully been trialled as an alternative to the plastic water bottle, biodegrades as fast as a piece of fruit and is said to be cheaper than conventional plastics. However, care will be needed to ensure such solutions, if successfully brought to market, do not encourage consumers to litter with impunity as products will just biodegrade!

Other similar developments include the use of bio materials in the manufacture of polymer, including the use by Dow of bio naphtha in the manufacture of LDPE (Low-density polyethylene) film for beverage cartons, collation shrink and other multilayer applications.

\[\text{Reducing food waste}\]

Efforts to ensure reduced food waste — a topic that some green campaigners seem to be all too willing to sacrifice in pursing their goal of reducing the use of plastic — have continued to receive attention. Examples include Ultimate Packaging’s Adapt MAP (modified atmosphere packaging), where companies can download live information about a crop’s journey to their factory to ensure the correct level of laser perforation to provide optimum food life. In another example, RPC’s X-Hance film prevents the greening of potatoes.

Flow wraps with MAP and vacuum skin packaging are also starting to become more commonplace and the latter has been proven to reduce food waste from 12\% to 3\% for steak. When you bear in mind the vastly higher resources required to put meat on our plates compared to the minute amount to produce the packaging, this is a ‘no brainer’ to those in the industry. Sealed Air has extended this concept with its Cryovac® Darfresh® Barrier Packaging, which claims to have reduced the amount of film required by up to 40\%.
Recycling plastic packaging

There has been a move to use significantly more recycled content in packaging and good examples include the PET tray market, where Klockner Pentaplast boasts up to 95% recycled content. Also, leading brands, such as Coca-Cola, have committed to increase the level of recycled content in their bottles to 50% with others in the bottled water market committed to go further still.

There are also exciting developments in the UK that offer the potential to make recycling of plastic packaging so much easier for the consumer, with the development of new chemical recycling plants. Once adopted at scale, this would enable UK householders to place plastic packaging in the recycling bin at kerbside, safe in the knowledge that it would be recycled by a combination of mechanical and chemical processes.

On-the-go applications of packaging have also come under scrutiny in terms of design to ensure components of the packaging, such as tear off pieces and caps, are less likely to be discarded. In fact, legislators in the EU have stepped into the space, calling for tethered caps to become the norm, which will be challenging due to the way bottles have been light-weighted, particularly in the neck area. Nevertheless, leading brands of bottled water have already started to adopt this for sizes typically associated with the on-the-go market and Highland Spring is working with cap manufacturers, such as RPC Massmould with its Secure Flip sports cap, to bring this innovation to market.

Other innovations in plastic recycling include moves by polymer manufacturers to introduce recycled content pre-blended with virgin feedstock for food packaging and the move by waste management companies to step in and buy plastic recyclers, for example resource management company Veolia has acquired the Dagenham Plastics Facility, which recycles milk bottles into HDPE (High-density polyethylene) pellets. These moves will ensure the building of efficient, joined-up plastic recycling plants in the UK, ensuring that the benefits of plastic as a material are maintained in a circular economy.

New packaging materials are continuously appearing in the UK marketplace. Aquapak now offers the possibility of using polymeric material in laminated structures — particularly those involving paper — which can be recycled. Marketed under the name Hydropol, the material is available at scale and can be used on a multitude of standard processing lines.

The industry continues to further boost its resource efficiency credentials by reducing the amount of polymer required to do a given job and a good example of this is in stretch film, where companies like Dow have reduced the amount of film per pallet by 50% over the last decade.

Figure 1 Chemical recycling process for plastic wastes

References and article available online at fstjournal.org/features/32-4/packaging-innovations

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Recycling plans for plastic

With public interest in the impacts of plastic leakage into the natural environment soaring, it becomes easy to lose sight of why plastics are used in the first place. As materials, plastics are light-weight, strong, versatile, cheap and hygienic, and so they have significant benefits for the packaging industry. Without plastics, it would be difficult for consumers to enjoy the sheer range of choice that exists in the market today. Plastics can also be instrumental in tackling food waste by increasing shelf life and have improved public health by keeping food and drinks free of contaminants [1].

While some argue that not all plastic packaging is necessary, it is certain that the way we treat plastics must change, particularly at the end of life. This change must occur across the whole value chain of plastics – for producers, converters, manufacturers and consumers – as plastics pollution becomes one of the most pressing environmental issues of our time. Marine ecosystems are now threatened by the amount of plastics in our oceans – as a direct result of plastics escaping into the natural world. The current production of plastics is also heavily dependent on non-renewable fossil fuels, providing further grounds for a rapid revision of behaviour to ensure the circular use of this valuable material.

Sustainability strategy

However, with such public scrutiny of plastics, it is easy to forget that the use of every material has its consequences and that companies must take a more holistic approach to the packaging of products. All materials have the potential to cause harm to the environment if handled incorrectly and not treated as part of a circular economy. The more sustainable use of plastics in packaging must be matched by considering the sustainability of other packaging materials, such as cardboard, aluminium and glass, something Coca-Cola European Partners (CCEP) has committed to in its ‘This is Forward’ Sustainability Action Plan [2], which was launched in November 2017.

Lisa Foster, Sustainable Packaging Manager at Coca-Cola European Partners, discusses the company’s approach to sustainable packaging and the future of plastics in packaging.

Recycling plastic packaging

CCEP’s overarching ambition is to collect all its packaging to ensure more is recycled and none ends up as litter or in the oceans. The company is working to invest and innovate to ensure that all its packaging is as sustainable as possible, regardless of the material used. This includes ensuring the recyclability of all packaging. Currently over 91% of the primary packaging produced by CCEP is 100% recyclable, which includes all our plastic bottles, glass bottles and cans [3]. Our ambition is to ensure all of our packaging is 100% recyclable by 2025.

Ensuring that packaging can be widely recycled by consumers is critical to supporting the circularity of the materials that manufacturers use. However, consumers expect packaging to have high levels of recycled content as well as being readily recyclable. With members of the UK Plastics Pact signing up to 30% recycled content in plastic packaging by 2025 [4], this may well become a reality, with an industry-wide shift expected over the next seven years.

CCEP has a history of using recycled content for its packaging. All our glass bottles and aluminium cans currently contain more than 50% recycled contents for plastic bottles. However, this figure increases to over 90% for certain products. Recycling plastic is further supported by the attempts of CCEP to use recycled material in its packaging, with over 91% of the primary packaging produced being 100% recyclable. This includes all our plastic bottles, glass bottles and cans.

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Improvements to collection systems, particularly for out of home environments, are needed to enhance capture of materials and to prevent leakage into the environment.

Economy as easy as possible, which requires input from many in the materials value chain. As it stands, there is much confusion around what can and cannot be recycled. Addressing this, CCEP now features messaging on the closures of more than 500m bottles every year with a ‘please recycle me’ message. We ensure our packs carry the On-Pack Recycling Label (OPRL) symbol to show they are widely recycled, and we ensure that our adverts carry a clear message about the recyclability and the need to recycle our packs.

Practical solutions
However, in order to make the future of plastics in packaging a reality, brands must do more than leverage their market prominence to shape behaviours. They must also make the circular economy as practical as possible – as laid down in the 2018 UK Plastics Pact, of which CCEP is a founding member. The targets of the UK Plastics Pact are very much in line with CCEP’s own ambitions around packaging.

At the University of Reading, for example, CCEP helped launch Coca-Cola Freestyle machines, where staff and students can purchase a refillable bottle, microchipped to make it recognisable on each use. The user can pre-load their bottle with credit so that they can easily and conveniently refill it with drinks; the credit on the bottle ensures that it will be reused. Today, many beverages are still dispensed using a disposable paper cup, so we continue to work with the University to try to understand what motivates and demotivates consumers from engaging with a refillable scheme.

Deposit return schemes
Recycling rates for common packaging formats, like glass bottles and jars, aluminium cans and plastic bottles, are relatively high. But improvements to collection systems, particularly for out of home environments, are needed to enhance capture of materials and to prevent leakage into the environment. This is why CCEP is championing new collection systems as part of its sustainable packaging strategy. CCEP recognises the role a well-designed Deposit Return Scheme (DRS) could play to remedy flat recycling rates and improve the quality of materials. Here, consumers would be asked to pay an additional charge on the cans and bottles they purchase, which is then refunded once the vessel is returned. Countries, such as Germany or Denmark, are successfully operating these schemes. A DRS in the UK has massive potential to shape the future of packaging, increase recycling rates and engage consumers in more sustainable practices – but this would require mass coordination between government, industries and consumers alike to provide an effective solution. Only with this kind of collaboration can we develop effective solutions to the problems posed by plastics waste.

Conclusions
We stand at a momentous crossroads. If we fail to effect rapid and immediate change, the damage done may become irreversible. We now have the rare opportunity to overhaul more widely our relationship with plastics and packaging, and implement a strategy that will preserve the world for future generations. Only by accounting for end-of-life disposal and its consequences. Only with correct disposal and its consequences.

References and article available online at fstjournal.org/features/32-4/plastic-packaging
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The future of packaging

Paul Jenkins, Managing Director of ThePackHub, looks at the latest packaging innovation trends and discusses how the last year has shaped the future of packaging.
Commercial packaging has been in use for hundreds of years. It is an important and often essential way to ensure that food products are fit for consumption. New packaging technologies have transformed how we consume products and helped to extend shelf lives significantly as well as improving the functionality of the products. Food companies are responding to increased consumer expectations for convenience and ease of use coupled with the challenges of the fast-growing e-commerce channel changing how we shop. This all leads to packaging having a pivotal role to ensure that these requirements are met. Packaging also has a very important communications role. It helps to portray brand values through structure and surface design as well as provide vital product information. The industry is under increasing pressure to defend its use of plastic and in many cases get rid of it entirely, with accusations of unnecessary and over-packaged products.

Year of change
2018 has been the most significant year in the history of packaging. Never has the industry been under such scrutiny and faced such serious and difficult challenges. Almost every day, packaging is in the news and mostly for the wrong reasons. The airing of the BBC’s Blue Planet 2 programme created a step change in consumer attitudes to plastic packaging. David Attenborough’s excellent television series highlighted the effects of plastic debris in the ocean on marine creatures. The documentary series highlighted the amount of plastic entering our seas every year, which is estimated to be eight million tonnes. That is the equivalent of a truck dumping its full load every minute of every day. Plastic takes many years to break down leaving ever increasing amounts in the sea to potentially cause harm to wildlife. Plastic bags take 20 years to break down, plastic bottles 450 years. The Ellen MacArthur Foundation has claimed that by 2050, there will be more plastic in the oceans than fish, by weight. The accuracy of this statement might be challenged but there is no doubt of the seriousness of its implications. The Attenborough programme really resonated with the general public.

The documentary effectively precipitated a cascade of related events that have subsequently helped shape packaging’s present and future. This has included UK frozen food retailer Iceland pledging to ban plastic from its own label range by 2023 and a UK Plastic Pact with members, including leading brands, retailers and packaging suppliers, making a commitment to make all their packaging recyclable, reusable or compostable by 2025. Governments and local authorities around the world have also intervened with increased activity, such as pledges to ban single-use packaging like plastic straws and cutlery. A plastic-free shopping aisle has been introduced to an Ekoplaza store in Amsterdam, with the promise of many more rolled out in other locations. The refusal of the Chinese to continue to take the UK’s plastic recycling waste has only made matters worse. Plastic has become synonymous with all that is wrong about packaging.

The problem
It has been widely reported by the World Economic Forum that just 10 rivers, eight in Asia and two in Africa, are responsible for 90% of the plastic entering the oceans. Also about half the plastic polluting our seas is from fishing net waste. However, currently, most of the focus is on plastic packaging emanating from Europe and North America. The packaging industry has segmented itself into those companies that want nothing to do with plastic and those in many cases get rid of it entirely, with accusations of unnecessary and over-packaged products.

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that defend it as a versatile and useful material. After all, plastic packaging is so ubiquitous because it is so good functionally. It is lightweight, durable and versatile with excellent barrier properties.

**Compostable and biodegradable packaging**
Compostable packaging is a material that is biodegraded in a home composter or a commercial composting facility. It forms decayed organic substances that can be used as a fertiliser to benefit the soil. This can take a few months, but the process conditions and timescale can vary.

There are currently many compostable and biodegradable packaging solutions and ThePackHub has reported on hundreds in our Innovation Zone packaging database. These compostable materials can still deliver excellent barrier properties. The ideal applications are for snacks, confectionery and nuts, for example. The businesses adopting this technology so far tend to be small volume start-ups and challenger brands, because there is a cost disadvantage to switching to this material. Despite the pressures from society to improve their environmental credentials, the big brands have thus far not embraced these materials as a valid way to address the problems of plastic packaging. Materials that can only be industrially composted have higher heat requirement to break down. One of the challenges is the chicken or the egg scenario that not many homes have the facilities to compost and not enough local authorities in the UK have the facilities to industrially compost. No official figures are available, but the view of several experts is that compostable packaging is not being composted to its full potential by consumers.

**Bio-materials**
Materials such as sugar cane, coffee waste, olive oil, marble dust, tomato leaves, whey, shrimp, bamboo, pasta waste and more are being used to make packaging. The solutions tend to have a percentage of bio-material combined with virgin oil. The opportunity here is to reduce the amount of oil-based plastic in the production of the packaging. The introduction of these materials again tends to be from small players, challenger brands and start-ups. There can be an issue around the material’s recyclability. More research is necessary to substitute petroleum-based materials totally in the long term.

**Reusable packaging**
There has been a resurgence in the use of reusable packaging solutions over the last 12 months. The main opportunity has been in the beverage sector. There is plenty of scope here for improvement with more innovations now in the pipeline. We have seen how a small 5p charge on plastic bags has had a significant effect on the consumption of the product. The plastic carry bag market in the UK is reported to be just 10% of what it once was. This suggests that a small fee can have a substantial impact on consumption. Reusable cups are now encouraged in UK coffee retail outlets with an incentive of up to 25p off the price of the drink. Reusable transactions in some outlets remain at about 1%. This would suggest that paying a fee rather than getting a discount is a more powerful way to solicit a change in consumer behaviour.

**Increased recycling**
All industrialised countries have targets to increase the amount of packaging that they recycle across all materials. There is an EU target for Member States to recycle at least 50% of household waste by 2020 - the UK’s recycling rate was 45.2% in 2016. The UK recycling or recovery rate for packaging waste was 71.4% in 2016 compared to 64.7% in 2015. This exceeds the EU target to recycle or recover at least 60% of packaging waste.
packaging solutions are throwing up a range of opportunities for brands and retailers to better meet consumer needs. New technology is also providing solutions, such as NFC (Near Field Communications), which allow consumers to interact with packaging via their smart phones. This opens up an exciting new way to communicate and engage with the end user. Added functionality will continue to be a driver for change with solutions continuing to come to market that deliver a range of user benefits, such as easy open, resealability, better portability for on-the-go consumption, improved barrier properties etc.

The difference in the last year is that all new packaging briefs must consider sustainability at the forefront of their design. If not, the innovation will fail.

Conclusions

The packaging industry is at a crossroads but with a great opportunity to really make a difference. The industry is under scrutiny more than ever before. The rate of change is faster than it has ever been. We should expect even more activity from a sustainability point of view as well as more consumer rejection of packaging that is not perceived as environmentally friendly. We will also see more government and local authority intervention.

What is not changing fast enough is the amount of plastic entering our oceans. Tackling this problem will involve many stakeholders but the packaging industry has an important part to play.
Modified atmosphere packaging (MAP) is used as a means of preservation and is well known in the food industry as a method to extend the shelf-life of a range of different food products. It relates to the removal of atmospheric air, which is then replaced with alternative gases that are optimal to the product in order to provide the longest shelf-life whilst maintaining quality and safety. Changing the atmosphere in the headspace of a package can reduce biochemical changes, retard microbial growth and maintain organoleptic qualities whilst reducing the need for additives.

**Modified atmospheres**

A modified atmosphere can be produced in a number of ways. Passive modification is more commonly associated with fruits and vegetables by matching the respiration rate with the permeability of the film to create a favourable atmosphere. Gas packing can be used in combination with a vacuum (compensated vacuum) or just by gas flushing. Compensated vacuum firstly applies a vacuum to the pack to draw out the air and then the desired gas mixture is flushed into the pack.

Gas packing relies on a continuous stream of gas being injected into the pack to replace the air. The disadvantage of gas packing is the residual oxygen levels can be higher and therefore unsuitable for oxygen sensitive products. Compensated vacuum can be slower as it is a two-stage process, but the residual oxygen levels are usually lower.

The first recorded scientific study with modified atmospheres was conducted in 1821 by Jacques Etienne Berard, who found that the ripening of fruits could be delayed by removing oxygen. Advances with controlled atmosphere storage continued, initially with a number of studies on fresh fruit contained within a gas tight building relying on the respiration of the produce to generate a passive atmosphere.

Controlled atmosphere storage refers to bulk storage where the atmosphere is controlled and monitored. The first controlled atmosphere store was built in 1929 and a decade later over 200 units were in use. Controlled atmosphere storage progressed further for fruit and vegetables, enabling transportation by sea, making the export of a range of different products across the world possible. Controlled atmospheric storage is still used...
for this purpose and also for storing produce so it is available throughout the year.

Following Berard’s work, studies continued, mainly with meat and fish. These focused predominantly on the effects of carbon dioxide with results showing a dramatic increase in shelf-life compared to air. MAP made its debut in the retail industry in the 1970s, initially with meats and fish, and since then the market has rapidly grown to cover the majority of food groups.

The interaction between the gas and the food is critical and needs to be understood to select the correct gas mixture. Commonly a mixture of one, two or three gases, usually nitrogen, carbon dioxide or oxygen, are used. However there has been a lot of research looking at the potential benefits of other gases including carbon monoxide, argon and nitrous oxide. The gases used play an integral role in the finished pack.

Oxygen is usually removed from the pack, particularly with dried foods, ready cooked products and those with high fat contents to reduce oxidation and inhibit aerobic microbial growth. However, for some products the presence of oxygen can be beneficial. With red meat, oxygen helps develop the red colour and is used in high concentrations (70-80%) within the pack. In the presence of high levels of oxygen, purple myoglobin (in the meat) may be oxygenated to the red pigment oxymyoglobin, while at low oxygen levels, it can be oxidised to metmyoglobin, giving an undesirable brown colour.

Fresh produce requires oxygen to continue respiring. It also produces carbon dioxide as a by-product. During the modified atmosphere packing of fresh produce, the level of oxygen is usually reduced from that of atmospheric air (21%) to approximately 5% depending on the product. Reducing the oxygen slows the respiration of the produce, which can be high, as the cells try to repair themselves following the preparation processes of washing and cutting. This delays fermentation which can occur as the atmosphere becomes anaerobic.

Oxygen is often included with white fish as it can have a bleaching effect on the fish and also reduces drip.

Nitrogen is an inert gas and is often used to displace oxygen, particularly with products that are prone to oxidation. These products are often packed in 100% nitrogen. Nitrogen is also used as a filler gas to prevent pack collapse and offers some cushioning to the product.

Role of carbon dioxide
Carbon dioxide is normally included as an antimicrobial agent. It is often suggested that a minimum of 20% is required for it to have an effect, but there is little scientific data to back this. Carbon dioxide can be used in combination with oxygen with red meat, white fish and fresh produce but it is often used in combination with nitrogen to form an anaerobic environment to inhibit aerobic microorganisms.

Raw and cooked meats, fish, ready meals, combination products and bakery goods will all commonly be packed with a proportion of carbon dioxide. Carbon dioxide is more commonly used at levels between 25-40% apart from in bakery goods and some cheeses, where carbon dioxide can be used up to 100%.

Bakery goods can be packed in high levels of carbon dioxide to increase the mould-free shelf life. Studies have shown that with higher concentrations of carbon dioxide the mould free shelf-life (product specific) can be increased from days to weeks and months\(^2\). However, MAP will not prevent the inevitable staling of bakery goods although it may slow the rate.

Bulk packs of meat and poultry can also be packed in 100% carbon dioxide prior to being packed for retail.

Carbon dioxide is highly soluble in moisture and fats. Solubility of carbon dioxide in the water phase of the product produces carbonic acid, which can increase the acidity of the product resulting in a small drop in pH. Studies have shown that...
Intrinsic and extrinsic factors influence the solubility of carbon dioxide. These may include pH, water activity, fat type and content, gas to product ratio and temperature. The solubility of carbon dioxide increases as the temperature decreases, similarly the antimicrobial activity of carbon dioxide is higher at lower temperatures[39]. The change in pH may be beneficial with some products, but not if it causes an undesirable taint.

The concentration of dissolved carbon dioxide in the water phase of the food is thought to help with the inhibition of microorganisms. Gram negative microorganisms, such as *Pseudomonas*, are more sensitive to carbon dioxide compared to Gram positive organisms. Lactic acid bacteria are the least sensitive to carbon dioxide[40] and growth can be stimulated by the presence of carbon dioxide[39].

Due to solubility, high levels of carbon dioxide can cause pack collapse, therefore nitrogen is often included to prevent this. High levels of carbon dioxide can also cause damage to plant and muscle tissues, discoloration and excessive drip.

One aspect of MAP, which is often overlooked, is the gas to product ratio. This can often be confused with the composition of gas rather than the volume of gas added to the pack. It is particularly important with carbon dioxide, which is absorbed into the product to get enough gas into the pack for it to have an effect.

Depending on the product, it is normally recommended that a 2:1 gas to product ratio is used. However, this can result in a large seemingly empty headspace and manufacturers can be criticised for using too much material.

**Carbon dioxide shortage**

Carbon dioxide is usually recovered as a by-product from the production of hydrogen or ammonia used in the manufacture of fertilisers. It is captured and then sold on to different industries.

The summer of 2018 saw a shortage of carbon dioxide, which affected several industries, bringing to light the importance and benefits of the gas.

Several ammonia plants were shut down for maintenance and, although it is not unusual for plants to close in the summer, a higher that usual number of plants closed at the same time. The food industry was not given sufficient time to react and prepare for the shortage with only 1-2 weeks’ notice being provided by the gas suppliers that stocks of carbon dioxide would be short or delayed.

Since the carbon dioxide shortage occurred during the football World Cup and an extremely hot summer, the media was largely focused on the shortage of beer and carbonated drinks. However, behind the scenes, food manufacturers were seriously affected too. Well-established gas mixes providing extended shelf life to a range of products including ready meals, bakery goods, meat and poultry were in jeopardy. With imminent shortages of carbon dioxide, industry was faced with packing its products with reduced levels of carbon dioxide or in atmospheric air with no carbon dioxide.

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**Plastics challenge**

Modified atmosphere packing will continue to be used as a means of preservation within the food industry. For ‘clean’ products that require a longer shelf life, modified atmosphere is an ideal solution, however concern over the excessive use of plastics in packaging is something we need to consider for the future.

The food industry has faced significant criticism for its use of plastics and this is driving the development of alternative materials. Although there are many options to explore, there are specific food groups for which this will be more technically challenging.

Products packed in a modified atmosphere require the materials to have specific barrier properties and maintain seal integrity for the duration of the shelf-life of the product or the modified atmosphere will be lost. This not only relates to chilled foods but many ambient products. Many snack products, such as crisps, which have been targeted by anti-plastic groups, rely on nitrogen flushing to provide a longer shelf life and to maintain the quality of the snack, slowing rancidity, which can result in off flavours. If the food industry is going to continue to supply and develop the vast range of products consumers are currently used to, then new materials must provide the same properties to ensure the quality and safety of the product is maintained.
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**SUPPORTING THE FUTURE OF FOOD**

The shortage of new talent to fill skilled roles in the food sector is a critical issue. A key focus for the Institute is therefore encouraging and supporting the future generation of food scientists and technologists. We have developed, often in collaboration with others, a wide range of activities and events.
Good work, CHAPs

Dr David George describes the role of CHAP (Crop Health and Protection) in driving forward the agri-tech revolution.

According to a 2016 Defra report (British Food and farming at a glance) the value of UK agricultural production is estimated to be over £25bn, accounting for 70% of UK land use and employing nearly half a billion people. Growing demand from this sector for sustainable produce with reduced chemical inputs and environmental impact puts increasing strain on arable and horticultural production.

There is a need to produce more and more food, with fewer and fewer inputs, from fixed field sizes. The current political and legislative environment is also placing significant stresses on our food production sector. Future farmer support systems, supply chains and access to plant protection and production products are all unclear in a post-Brexit Britain.

CHAP (Crop Health and Protection) at Sand Hutton near York, one of the Government’s four Agri-Tech Centres supported by Innovate UK, has been charged with the task of finding scientific and technological solutions to the practical problems facing growers. We bring together leading scientists, farmers, advisors, innovators and businesses to understand industry challenges, drive research and innovation and develop and trial solutions to transform crop systems. Our aim is to translate and promote these solutions for market adoption and so improve crop productivity.

Two of the most significant challenges to UK food production are pest and disease control and limitations on available land for crop production.

Pest management

Where pest management is concerned, novel chemistry, biological control and biopesticides are beginning to phase out conventional chemical insecticides in many areas, though such approaches are arguably less well developed to target plant pathogens. Growth of the biostimulants sector has also been progressing rapidly of late, due to the benefits that can result from producing a healthy, happy plant with an innate ability to respond to, or
even tolerate, pest and disease attack. Though often highly effective, such biologically-based products and crop production programmes are typically more sensitive to external influences (such as temperature, humidity and UV exposure) than synthetic chemicals. As a result they require more considered approaches to demonstrate their efficacy during the development and demonstration phases. Biopesticides, for example, include a wide range of product types – from living microbial organisms to botanical plant extracts – all of which have varying and inherent ‘needs’ that must be met if they are to work well in practice.

To ensure product-tailored, robust, reliable and fully repeatable approaches can be developed and deployed using these new products and practices, CHAP has invested in an ‘Advanced Glasshouse Facility’ (AGF), based at Stockbridge Technology Centre (STC) in North Yorkshire, a site with more than 50 years’ experience in running applied trials for the crop protection industry. With a flexible design and multiple enhancements, CHAP’s AGF is not just a glasshouse, it is also home to a fully replicated suite of sixty deep-water hydroponic tanks, available for either crop or aquatic ecotoxicology work, and precision field and hand-held sprayers to allow optimal product testing both indoors and outdoors. Perhaps most importantly of all, the AGF is supported by STC’s in-house expertise to design methodologies to ensure that effective new products that could be of benefit to the industry do not slip through the cracks of conventional testing protocols.

**Environmental impact testing**

Another exciting new CHAP facility that has recently been officially opened is the E-Flows mesocosm, an Edge of Field Waterbody Safety Assessment Facility at Sand Hutton. As plant protection products are developed and registered, there is a requirement to ensure they are safe when they reach bodies of water and aquatic environments. The E-Flows mesocosm is a ground-breaking project encompassing 2.7 hectares of land and is the first truly, flow through, field scale mesocosm facility in Europe. The E-Flows consists of 60 realistic streams up to 2m wide and 10m metres long, each with its own continuous supply of water. This facility provides a large scale, controlled system to examine the environmental impacts of plant protection products for higher tier regulatory risk assessment, as well as other research projects assessing the effects of plant protection products on lowland aquatic habitats. The majority of mesocosm facilities already available are either static, or they simply recirculate water. This is not representative of what actually happens in the field, where fresh water is constantly flowing in streams and ditches, and where chemicals are naturally broken down. To overcome this, the E-Flows mesocosm is
supplied with a continuous flow-through of aged, fresh water; the flow in the test units is closely controlled.

Plant breeding and polyculture
In addition to new product development, there is increasing interest in other avenues, such as plant breeding and polyculture, which aim to sustainably increase yields returned from finite agricultural and horticultural land. Though by no means a novel technique, polyculture – the growing of more than one crop together - could address multiple challenges being faced by the arable and horticultural sectors. These include erosion control, reduction in surface water pollution, addition of soil organic matter, improved soil structure and tilth, fixing of atmospheric nitrogen, recycling of unused soil nitrogen, greater soil productivity, increased soil biodiversity and improved pest, disease and weed control.

Research indicates that polyculture utilising flowering plants can promote on-farm pollinator conservation, which if delivered over large field areas could greatly increase the conservation potential of UK crop production, adding to the valuable work farmers and growers are already doing in this area with measures such as flowering field margins. Such a significant shift away from our traditional monocultural methods of crop production could offer multiple gains, but would require a complete step change in our approach to food production that could only be justified from a farm-business perspective if the benefits outweigh the costs. Despite the benefits of polyculture demonstrated to date, commercial uptake in UK arable farming has remained low due to concerns over production conflicts and practical difficulties in the management of polycultural systems.

CHAP can help here too by providing access to modern machinery that is being utilised in multiple European projects at STC to validate and demonstrate farm-friendly approaches to maintaining cereal yields whilst cropping into permanent ‘living mulches’ of clover. State of the art strip-tillage machinery is of particular importance to demonstrating compatibility of living mulches to modern arable production, allowing crops and clover to be simultaneously sown into cultivated bands in a single machinery pass. CHAPs Baertschi Oekosem ROTOR Strip Tiller, coupled to precision agricultural technology, has the ability to achieve just this, and the CHAP and STC team are aiming to demonstrate that it can revolutionise drilling into permanent ground cover, overcoming past and present constraints of polycultural approaches to realise more sustainable, more profitable, mixed species production models.

Measuring crop health
CHAP has a globally unique Soil and Crop Health facility. Operating at pilot scale (<1m² → 20m²), the facility can dynamically simulate the interrelationships between soil health, water use and biotic factors (pathogens and weeds) in the production of diverse agricultural commodities, whilst controlling the many environmental variables that influence crop yields and ultimately gross margins for farmers. The facility recreates every stage of the production process from ‘field to fork’, from cultivation (from intensive through to no-till systems), drilling, plant establishment, crop development to harvest and post-harvest. Uniquely, the facility can operate over multiple cropping cycles and is not season dependent thanks to the integration of a glasshouse.

Supported by funding through Agri-EPi, this glasshouse is equipped with state of the art sensors monitoring and controlling crop and soil health at pilot-scale above ground (RGB camera, FLIR IR Camera, Laser scanner, PRI photochemical reflectance sensor) and below ground (mini-rhizotron cameras, handheld hyperspectral sensors to collect soil moisture information, moisture sensors, temperature sensors and a weighing platform for water usage). Cranfield University’s long track record and expertise in applied soil science adds further value to the Soil and Crop Health facility. This ensures translational research with tangible, positive outcomes for industry.

Availability of arable land
For some crops, modern technology is beginning to overcome issues of restricted land availability. Vertical farming systems have been developed on a small scale in the UK and Europe over the last decade. Crops are grown on tiers of stacked production benches in fully enclosed ‘Controlled Environment Facilities’ (CEF) and lit by LEDs that deliver controlled wavelengths and intensities of light.

In addition to obvious efficiencies in terms of the amount of crop that can be produced per unit of land area, other benefits of this production model include year-round and optimised cropping cycles, decoupling of food availability and climate, and sustainability gains driven through minimised waste and use of renewable energy.

Large-scale commercialisation of vertical CEF has already been established in some countries, e.g. USA and Japan, and is now under development in the UK, focusing on key horticultural crops, such as salads and herbs. These larger scale operation models, however, will need to compete more effectively with standard crop production practices, both in terms of volume and price points, meaning that efficiency savings will be critical to ensure economic viability.
Though significant opportunity exists to deliver efficiency savings in large scale CEF systems, for example in terms of light selection, sensor integration, automation and plant breeding/varietal selection, extensive work in this area has yet to be undertaken in Europe, largely due to the lack of commercially representative research facilities able to undertake such projects. Similarly, evaluating pertinent pest and disease risks, and options for effective management in these systems has yet to be fully addressed in commercial production models.

Recognising the importance of CEF to the future of food security and sustainability in the UK, CHAP has recently completed construction of the UK’s ‘Vertical Farming Development Centre’, allowing research and demonstration projects in this field to be conducted in Europe for the first time.

The facility consists of two identical climate-controlled 120m² growing rooms, split over four tiers, allowing comparison of current vertical farming ‘best practise’ against optimised models driven by integration of innovations, such as those mentioned above. The facility also houses a germination room and cold store, allowing for work covering all stages of crop production pre-farm-gate. Based at STC, also home to the LED4Crops Facility, where research on CEF has been ongoing for almost a decade, this CHAP venture combines the UK’s leading expertise in LED-driven cropping and CEF.

**Information flow**

Effective translation of new approaches to crop management and two-way conversations with the crop production sector are key to CHAP’s mission. CHAP’s ‘mobile laboratories’ have been busy up and down the country, interacting with state of the art conferencing and training capabilities, which have been put in place at key Technology Translation sites, such as STC and Cockle Park (Newcastle University). These help to ensure that knowledge can flow both ways, shortening the 10-15 year lag phase between new solutions being developed through research and being realised commercially on farmers’ fields or in growers’ glasshouses.
Introduction
Over millennia humans have established a particular relationship with the species they categorise as pests and it is a distinctly anthropocentric relationship. Pests threaten the quality of human life and existence, and in this lies the justification for their control and eradication as a common good benefiting humans as individuals and society as a whole. Farmers, more than most people, understand the importance of controlling pests because they present a constant threat to crops, farmed animals, stored materials, processed food products and premises.

To illustrate, the FAO (Food and Agriculture Organisation) estimates that the potential world crop yield is reduced by between 20 and 40% by pests and diseases[1]. Therefore pest control in food production is vitally important, but it presents particular challenges in relation to effective and safe methods of use, environmental protection and ecological effects.

This article presents a snapshot of pest control in agriculture by application of pesticides. It is a topic of great importance and one about which a vast literature exists, addressing the wider benefits of pesticides in the context of humans and the environment[2] as well as research of a very specific nature.

Historical perspective
Pests compete with human beings for the resources necessary for survival and in some instances people are the resource. Early farmers would have sought the means to control agricultural pests and people generally would have innovated solutions to more personal problems, such as fleas and body lice. Pyrethrum, derived from the flower heads of Chrysanthemum (Chrysanthemum cinerarifolium and Chrysanthemum coccineum), was used as an early form of insecticide and is still in use today. Toxic compounds based on mercury and arsenic were used to combat infestation by the body louse, Pediculus humanus humanus, and head louse, Pediculus humanus capitis. Sulphur compounds were also used to control insects and mites in domestic and agricultural situations. Some 3,500 years ago the Chinese introduced the use of botanical compounds as insecticidal seed treatments and around the same time the ancient Egyptians used cats to control rodents threatening stored grains. In 1200 BCE the Chinese were utilising biological methods of pest control with predatory ants eliminating beetles and their larvae.

The human need to control pests clearly stretches back into history, but scientific pest control and specifically the protection of agricultural produce has progressed most rapidly over the last century and a half, as a consequence of advances in industrial chemistry. As urban populations grew during the 19th century, demands on rural food production increased. Watson records the history of the development of pesticides and the pesticide industry explaining, for example, that many compounds used as early, non-selective pesticides, such as copper acetarsenate, or Paris Green, a toxic dye, were by-products of industrial processes. Other substances used as pesticides included compounds of arsenic, mercury and sulphur as well as nicotine and hydrogen cyanide. Clearly such pesticides were as potentially lethal to those who used them as to the pests they were intended to destroy. During the early 20th century a number of notable industrial chemical companies identified the market opportunities that an increasingly mechanised and industrial agriculture offered. These companies were transformed into agro-chemical businesses serving agriculture, first in economically developed countries in Europe and North America, but also other parts of the world as the century’s Green Revolution gathered pace.

It is interesting to note that some of the leading agro-chemical companies of the 20th century developed their expertise in pesticide chemistry as manufacturers of chemical warfare agents. Organophosphorus compounds, for example, act on the nervous system of mammals and insects inhibiting irreversibly the enzyme acetylcholinesterase. This causes the neurotransmitter acetylcholine to overload the nervous systems of affected organisms with constant
transmission of signals between motor neurons, resulting in eventual death. The nerve agent Novichok, a topic of international news in 2018, is an organophosphate-based compound. Other examples include Tabun, based on insecticide development by the German chemical company, I.G. Farben in 1936, and VX, a nerve agent developed at Britain’s Porton Down defence laboratory in the 1950s and based on the organophosphorus insecticide, Amiton.

**Modern pest control**

In relation to modern pest control, Watson[3] defines the period 1930 to 1973 as the Productivist Period, during which many functionally valuable pesticides came into use. The foundations of today’s monoculture agriculture were formed during this time, as engineering and seed companies recognised the commercial opportunities to be gained by collaborating with agro-chemical companies in the intensification of agriculture and food production. Innovations in engineering, plant breeding, fertilisers and pesticides were aligned to support farmers in the challenges they faced, not least in pest control.

Farmers who are engaged in crop production seek to control mainly invasive plant species (weeds), insects, nematodes and the fungal diseases of crops as well as rodents, other small mammals and birds. Those involved in animal production face similar problems when growing e.g. fodder crops, but they also need to control insect and parasitic pests of farmed animals as well as disease-causing microorganisms. The benefits of pest control are primarily increased crop and animal yields with associated increases in harvested product (crops and animals), improved product quality and the control of invasive species. Additionally, the use of pesticides (and drugs) in animal production brings improvements in animal welfare by the alleviation and elimination of animal suffering.

Agricultural pests require treatment with specific pesticides, which are classified according to the pests they eliminate. In the context of British farms this generally means herbicides, insecticides, nematicides, fungicides, bactericides and rodenticides.

**Herbicides**

Herbicides, also known as weed-killers, can be conveniently divided into two groups: selective and non-selective herbicides. They are also defined according to stage of use in the crop cycle: preplanting, pre-emergence, post-emergence and established stands. Different herbicides have different modes of action (MOAs). Some disrupt cell division and are generally used for pre-emergence applications with germinating seeds, while those that disrupt photosynthesis are used post-emergence. Herbicides that target specific enzymes are designed to treat different plant species, from grasses to broad leaved weeds; and are used on established plants, for instance to prepare ground for cultivation and/or seed drilling.

Selective herbicides are formulated such that they are effective against weeds growing among a given crop, e.g. broad leaved weeds or grasses growing alongside maize and pulses. The organic compound 2,4-D (2,4-Dichlorophenoxyacetic acid) functions as a systemic herbicide. It is absorbed into plants where, as a synthetic auxin (growth hormone), it stimulates uncontrolled growth resulting in death. It leaves cereals and grasses unaffected. As a herbicidal compound, it is the active ingredient in many proprietary products and has been used as a defoliant since the 1940s. During the Vietnam war, 2,4-D was weaponised along with 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid) as ‘Agent Orange’ in the USA’s herbicidal warfare programme. Unfortunately Agent Orange was contaminated with dioxins, now linked to abnormally high incidences of cancer, such as leukemia and non-Hodgkin lymphoma, as well as birth defects among the Vietnamese people.

Non-selective herbicides are formulated to kill both grasses and broad leaved weeds. Two examples are, paraquat (N,N’-dimethyl-4,4’-bipyridinium dichloride) and glyphosate (N-phosphonomethyl-glycine). Paraquat obstructs photosynthesis and was used widely for many decades as a very effective non-selective foliar contact herbicide. However, it is extremely toxic to humans and other mammals and has been banned in the EU since 2007, as well as in other countries. Glyphosate, in contrast, is the most widely used herbicide in the world with some market research agencies projecting sales of US$8.5b by 2020. It is as an extremely effective herbicide, favoured by British farmers as a means of controlling blackgrass (Alopecurus myosuroides) and as a desiccant on cereals before harvest, although herbicide resistance is appearing in blackgrass[4]. Matthews[5] provides a detailed review of pesticides and their use, noting that many newer products have...
Insect pests are a common problem for farmers, however insecticides risk harming beneficial insect pollinators such as bumble bees.

Insecticides

A wide range of compounds have been and are used as insecticides. Natural insecticides include pyrethrums, nicotine and neem. Synthetic insecticides include organochlorides, such as DDT (Dichlorodiphenyltrichloroethane), organophosphates and carbamates, neonicotinoids and pyrethroids. Different insecticides have different modes of action. For example, DDT interferes with the function of cellular sodium channels; organophosphates interfere with the function of acetylcholinesterase.

As the agricultural use of organochlorine and organophosphate pesticides increased as a consequence of the 20th century’s Green Revolution, concerns were raised about effects on human and animal health. Rachel Carson[9] drew attention to the hazards inherent in the use of pesticides and particularly DDT, which began to focus the attention of public health authorities on the nature and effects of these substances. Studies of global wildlife in the 1960s and 1970s revealed bioaccumulation in body tissues and biomagnification in the biological food chain of various toxic compounds of industrial origin, such as PCBs (polychlorinated biphenyls) and some widely used pesticides. DDT proved to be an environmentally persistent organic pollutant detected in the tissues of many wildlife species, resulting in it being banned or restricted in many countries. It is very effective against the malaria carrying Anopheles mosquito and use is permitted in some countries.

The use of pesticides on food crops involves the intentional application of toxic substances to materials destined for human consumption. Caution must therefore be taken with regard to the toxicity of pesticides, rates of application and the persistence of residues within the environment and on the foodstuffs to which they are applied. In this respect, farmers are provided with explicit recommendations regarding use and application rates in order to ensure that at the time of harvest, Maximum Residue Levels (MRLs) are not exceeded. Even so, history has shown that pesticides that once were presumed to be safe for use were subsequently discovered not to be. Dieldrin, for instance, an organochlorine insecticide used commonly in the mid-20th century, was banned by the Stockholm Convention on Persistent Organic Pollutants. It proved to be carcinogenic, an endocrine disruptor and harmful to the nervous system of humans, among other effects, and does not readily degrade, remaining active in the environment for many years.

More recently controversy has arisen in relation to a class of systemic agricultural insecticides resembling nicotine, termed neonicotinoids, which have proven very effective insecticides, for example, in the prophylactic protection of autumn-sown oilseed rape (Brassica napus L.). However, Whitehorn et al[12] report harm to bumble bee colonies caused by neonicotinoids and similar findings have been obtained by other workers. Consensus on the effects of neonicotinoids is though incomplete as others have been unable to draw definitive conclusions[12]. Concern about the effects of neonicotinoids on insect pollinators, including Apis mellifera, the honey bee, has led to the banning of three in the class, imidacloprid, clothianidin and thiamethoxam, for outdoor use in the UK by the end of 2018. Other neonicotinoids, such as thiacloprid, are still permitted.

Conclusion

Pesticides are an important tool in the agricultural production of food. However, they are not without controversy, because of associated possible harms to the environment, wild biodiversity and human beings. As a topic, the use of pesticides in agriculture is complex: scientifically, politically and morally. Part two of this article will consider the other main classes of pesticides – fungicides, nematicides and rodenticides – together with policy perspectives and a view of the future encompassing alternatives to pesticides, precision farming and the ethical aspects of pesticide use. ■
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Blockchain or bust for the food industry?
There has recently been a wave of enthusiasm for applying Blockchain technology in the food sector. This article aims to clarify many of the questions surrounding Blockchain technologies, in particular:

is Blockchain the future for the food industry and therefore does my company need a Blockchain?

Traceability has been achieved for many years using systems that connect core business processes with strategic management of product and supply chain data, namely Enterprise Resource Planning (ERP) platforms. Companies must determine what Blockchains can offer that is different from existing ERP systems and what is the value of using them. Working within a secure cloud platform is mainstream today but this was not the case five years ago.

While ERP systems have significant benefits that can be realised, they are often very expensive to implement, with the cost of implementation linked to the operational complexity. The full costs can range broadly from £150,000 to £1,000,000+ and therefore are prohibitive for many SMEs, which make up 96% of the UK Food industry.
The changing world of cloud and ERP systems

Cloud-based ERP systems are well developed in retail, with Amazon providing the world’s second largest service alongside Microsoft and Google. However, these big market share companies are not used in many parts of the world, for example, the Alibaba platform is often described as the ‘Amazon of China’. This industry is moving fast and market positioning could change even by the time this article is printed.

Indeed, the cloud or real-time transaction arena is populated by several smaller companies, which are the ‘disrupters’ in this fast-evolving retail space[1].

In this arena, Blockchain technologies are seen as having a disruptive effect. Disruptive providers have emerged from the digital currency sector, where there is a requirement to ensure all vendors and buyers know what is paid and received. The alternative is no guarantees on transactions, contracts or due diligence. Blockchain technology can provide this by linking business transactions to verifiable sources of capital. They ‘chain’ these ‘blocks’ of information so that trust within the transaction can be established. Currencies, such as Bitcoin, have no central banking mechanism of underwriting risk and Blockchains have provided this endorsement of trust. Until recently there has been little consideration of a potential link between Blockchains and Fast Moving Consumer Goods (FMCG). However, by the end of 2018, the investment in food-related Blockchain technologies and platforms will easily have eclipsed investment in developing any other food sector technologies. This is unprecedented - there is much talk of what Blockchain can do and it is in our interest to be ready to respond as its potential applications will herald a paradigm shift, enabled by the other facets of the 4th Industrial revolution.

A global food system based on trust

The global food supply chain has become highly complex and often lacks transparency and trust.

The emergence of consumer interest in food provenance and authenticity – in response to food crises, such as the Horsegate scandal in Europe in 2013 – has made transparency essential for any brand, whether a large global or local food provider[2]. The larger cloud platform providers, such as IBM, which now reports that over half its revenues are from cloud services, are also lining up Blockchain technologies for the food system. The IBM platform is Food Trust[3] and it has demonstrated the Walmart tracking of mangoes to their source in just over two seconds, where it previously took a week.

These high-profile cases send nervous ripples out to business and regulators alike. But the IBM-Walmart tie-up has proved that a use-case driven Blockchain is a must-have for a product safety recall. In fact, Walmart’s VP of Food Safety, Frank Yiannas, is critical of regulatory requirements for 1-up/1-down traceability, noting that Blockchain eliminates the delays caused by regulatory compliance to an outdated requirement.

There is no doubt that these examples provide a step change in transparency with an improved window on supply chains that provides revolutionary traceability. It is the ability to follow the movement of a food through the supply chain, that makes Blockchains so appealing and if a data carrier (barcode or a suitable, as yet, untested alternative) can provide a link to a product’s history and location data for the origin of materials and parts after delivery, it becomes even more incisive.

Increasingly, supply chain actors want to know the history of feed, ingredients and foods across the supply chain. The problem arises when this information is created and owned by different actors across different organisations and countries. The scaling of the simple producer-to-manufacturer-to-retailer supply chain becomes more complex as the amount of data associated with it increases. This forces a formalising of data quality so that systems still work together for transactional business across
Industry-driven supply chain data and information standards are critical to ensure a common language across supply chains. More importantly, they enable seamless interoperability between disparate technologies. This is where Blockchain systems offer unique characteristics by comparison with ERPs. Blockchains can communicate efficiently across all enterprise management systems and, in some cases, legacy problems are eliminated. The IBM and Microsoft Blockchain platforms are GS1-compliant and utilise the joint GS1/ISO standard for interoperability called EPCIS. A Blockchain that is EPCIS enabled is a key differentiator because it can ‘talk’ to other GS1-enabled Blockchains and GS1-enabled traceability systems. A Slovenian company, Origin Trail, provides a Blockchain-neutral middleware or data protocol that is 100% aligned with GS1 and helps companies to quickly establish themselves as industry standards compliant and interoperable.

Standards-based solutions provide the answer to the question of whether you need a Blockchain or can utilise other existing traceability systems that provide supply chain transparency through their usage of GS1/EPCIS. The decision may lie in the complexity of the supply chain and how ‘deeply’ a manufacturer or producer can control its products. It is quite common for a brand owner to lose sight of its products when it is using multiple distributors, resellers or retailers. The need for Blockchain technologies Scaling food supply data is critical in supply chains with multiple exchange partners and where data exchange protocols vary between partners resulting in data being managed differently. GS1 standards enabled Blockchains can cut through this chaotic situation because they provide a method of uniform data input (master data, transactional data and event data) and transfer, which will identify, share and defragment the data siloes. A GS1-enabled Blockchain can provide a line of sight through a supply chain that is not blocked by different transfer protocols and data standards.

Risk reduction strategies within the global food supply chain are focusing on reducing waste, improving product recall effectiveness, reducing natural resource usage and greenhouse gas emissions etc. The indications are that Blockchains may also have a role in supporting these strategies. However, the ultimate focus must be on reducing the risk of harm to consumers and improving overall customer trust in the food industry. This is often lost in the maelstrom of issues that are associated with framing risks and futureproofing a company by undertaking foresight plans.

Recall actions and processes Where Blockchain technology will be most useful is still uncertain, but food recall deserves specific mention because it is often associated with complexity in tracking forward and tracing backward in an urgent recall situation. As lives may depend on the speed of execution, Blockchain technology has the ability to improve the traceability and accountability as well as reducing the risks related to human health and safety. In doing so, it can significantly reduce the risk of a costly, multi-week recall process to determine the source and location of contaminated inventories. The key benefits are that it reduces the time required to trace raw material components and products from days to seconds. Typically British Retail Consortium (BRC) certificated businesses must achieve traceability within 4 hours – a Blockchain can achieve this in seconds but without the intensive labour element.

Food recalls typically occur because of mislabelling (in particular mislabelling of allergens, which must be notified on-pack with nutritional declarations)[4], process mishaps with foreign objects entering the product, human error or poor hygiene and food safety standards compliance. It has been estimated that the actual cost of a recall can reach several


**Data, inspection and Blockchains**

Blockchain technology can improve data interoperability across and between supply chains, but the communication and actions associated with these transfers remain critical. Blockchain will not be able to change responses and actions as these remain at the heart of developing competitive advantage in any food business. In short, Blockchain is a ‘carrier’ of information, it does not ‘define’ the content.

In a supply chain fully embracing Blockchain, appropriate data can be accessed by any member of the chain. This would significantly reduce the need to work down or up the chain to get relevant product or raw material information. It would allow the particular link to obtain the required data without resources being deployed by the other links to answer the data request. This benefits all members of the supply chain and saves resources that would otherwise have been tied up passing messages up and down the chain.

Fast delivery of data is not sufficient to solve supply chain problems; processes need to be in place to provide change in response to data. GS1 barcodes, for example, are scanned more than six billion times every day and the GS1 Standards-based technology can rapidly trace back to the producer and forward if a data carrier (barcode) is in place. There are cloud platforms that use GS1 standards, such as in South Korea, where the regulators can send an urgent product safety notification to all retailers and within 30 minutes, all point-of-sale transactions related to the unsafe product are blocked, protecting the consumer and the brand. This ‘stop-sale’ process is then followed quickly by the formal product recall process.

Regulations are critical in this space and where recall is associated with protection of consumer safety, the regulator is likely to be actively involved. Regulations and indeed supplier contracts are in place to control risk and are based on ‘mistrust’. In the ‘Regulation Mediated Transparency’ model (Figure 1), regulation and supplier contracts aim to cut risk to the minimum.

An alternative model is voluntary based trust building strategies and this is where Blockchain and related technologies can provide a significant leap forward from a regulatory compliance and contracts enforcement position. In this model, strategic transparency and identification-based trust can be leveraged through education and bi-directional sharing of information with the supply base (technology-mediated transparency) [6]. For example, a retailer can assure its suppliers that the data shared on the Blockchain would enhance product velocity, increase sales and reduce the risk of harm to consumers. This theoretical model provides a framework in which it is easier to understand how technologies can reduce the information asymmetry across the supply chain and cultivate a whole new level of trust and transparency, potentially all the way to the consumer. However, this is a double-edged sword – such access to data could have unintended consequences, e.g. assisting consumers in boycotting companies, countries or continents if populist rhetoric encourages a buy local/national sentiment.

Caution is necessary if Blockchains claim to solve issues of food authenticity and provenance and to ensure product safety, because the only practical and legal way of ensuring these is by inspection, audit and analysis.

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Figure 1
Diagram shows how trust transactions can differ in supply chains and why this is so important to developing transparency and traceability [6].
Vulnerabilities and threats are identified in food defence planning and digital traceability enables implementation of actions.

or data beyond direct transaction information is likely to become more important if not essential for food and drink products. 'Human input' will still be necessary for the foreseeable future as part of the data collection process and therefore the risk of transcription error onto the Blockchain or deliberate fraud is still possible. Other emerging technologies, such as Internet of Things (IoT), devices and sensors, could transmit real-time data and mitigate the risk of human error or fraud. However, the vast majority of food businesses still utilise spreadsheets or manual processes for their management of such information and therefore industry wide adoption of a 'higher tech' approach is likely to take a long time unless regulatory pressure is applied.

Blockchain also permits 'Watchers' or 'Sentinels' to be deployed. These are smart algorithms/codes that sift through significant data looking for patterns and trends and permitting management by exception. For example, in a cold chain a 'Watcher' could be looking for signs of chill chain failure and alert the supply chain to an elevated risk for the batch of food affected. Or the Watcher could highlight reduced sales for a certain product SKU (Stock Keeping Unit), and perhaps also link to other SKU’s that contain the same ingredients, enabling further investigation of a potential quality issue. Such ‘sales rate issue flagging’ could even be utilised to help prevent retailers and food service operations from a ‘stock out’ (unexpectedly running out of product), if EPOS data is linked up to the Blockchain.

Certification legacies

The food industry has developed certifications that use a Chain of Custody to determine provenance and fairness. This goes beyond transparency of one-up and one-down in supply chains because the Chain of Custody is cumulative across a supply chain. The approach has been used, for example, by the sustainable Roundtable for Sustainable Palm Oil and Roundtable for Sustainable Soy
tm. This insight into how food certifications have developed might provide a significant application for Blockchain technologies because it is likely that they will strengthen the integrity associated with such certifications because transparency is improved across supply chains. Another example is provided by the measurement of GMO contamination of soy bean crops, which revealed that the supply chain for soy beans is rarely GM soy bean free. It is not known how GMO soy beans enter the supply chain during pressing and milling, but Blockchain could help to resolve this if it is supported by existing forensic analysis of supply chains[9].

Furthermore, the GMO issue has become increasingly important for consumers in the USA and feed supply chains globally. The issue of slave labour is equally controversial and Blockchain could track payments for work associated with specific people and identifiers, such as biometric data. This would still require inspection so the requirement for forensic analysis and audit remains. However, Blockchain will provide robustness in determining where data comes from; the verification of that data remains an important part of delivering integrity.

Blockchain can also help drive forward the sustainability agenda by helping to track and calculate CO₂ emissions, energy and water consumption and wastage levels.

Conclusions

Blockchain technologies provide potential to defragment supply chain data and show promise in enhancing the transparency of data streams from food supply chains. This is particularly useful where supply is built across several partners and nations and where large amounts of data can become redundant because they are not acted on or are simply lost. Blockchains could become an important addition to existing supply chain management systems that provide food integrity. There is a growing requirement for data carriers (barcodes) to have digital links to descriptive content regarding labour, authenticity and sustainability. It is already apparent that the use of Blockchains can dramatically improve the speed of action in, for example, a product safety recall. With continued enhancements, Blockchains will be of greatest use for food retailers and service providers operating internationally.

The existing use of ERP’s and product certifications will not become redundant because there remains a requirement for effective analysis of all claims of food integrity or food credence, such as organic. This requirement holds even if artificial intelligence and machine learning protocols are used to identify threats and vulnerabilities in supply chains. These ERPs could become Blockchain ready because only supply chains that are ‘Blockchained’ will experience the added benefits. The final part of the Blockchain approach is determining how much transparency is required by consumers. How consumers will interact with Blockchain applications has yet to be determined.

References and article available online at fstjournal.org/features/32-4/blockchain

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Sniffing out contaminants

A key component of the EU and WHO strategy to promote a healthy diet includes sufficient intake of fresh fruit and vegetables\(^{[1]}\) with a daily recommended dose of 400g. Recently, the consumption of ready to eat salads and fruit salads has been rising in Europe, the USA and elsewhere. These products help to provide readily accessible sources of fruit and vegetables in the home and on the move. However, both traditional fresh fruit and vegetables and minimally processed products can harbour human pathogens. Minimally processed foods are particularly vulnerable compared to fully processed foods, as they do not typically include a kill step to eliminate the presence of microorganisms, as this would also affect their nutritional value. Furthermore, due to the processing steps that include trimming, peeling and cutting and then a wide distribution of the product, opportunities for propagating any contaminants entering the supply chain are increased\(^{[2]}\). A key priority for the industry therefore is early detection of contaminants in the supply chain and a thorough investigation of any contamination found to determine the source. Processes can then be improved to reduce occurrence of contamination to a minimum.

**Pathogens associated with fresh fruit and vegetables**

The principal pathogens of concern in the safety of fresh fruit and vegetables are *Escherichia coli*, especially the most virulent strains, such as O157, *Salmonella* serovars, and *Listeria monocytogenes*\(^{[3]}\). *Listeria* presents particular problems because it is able to grow even at the low temperatures used in the supply chain for minimally processed foods\(^{[4]}\). *L. monocytogenes* is the etiological agent of foodborne listeriosis, which annually results in hundreds of illnesses, hospitalisations and deaths worldwide. Prevalence in fresh fruits and vegetables has been reported to vary from 0.04% to 36.8%\(^{[5]}\) depending upon a variety of factors including agricultural practices and logistics conditions\(^{[6]}\).

Over the last decade several outbreaks of listeriosis have been reported, the most pronounced of which were in the USA (the multi-state 2011 cantaloupe and lettuce outbreaks), the 2017-18 South African outbreak (polony processed meat sausage) and in Europe the multi-country 2018 frozen corn outbreak. In the first case, a total of 231 hospitalisations and 48 deaths were reported\(^{[7]}\), while in the South African outbreak, 216 deaths, including at least 92 children, have been recorded to date\(^{[8]}\). The European outbreak resulted in 47 hospitalisations and nine deaths\(^{[9]}\). These highlight the importance of fast and reliable detection of the pathogen.

**Detection of Listeria**

Presence of the pathogen and its population size depends upon the hygienic conditions during production, processing and distribution as well as the intrinsic characteristics of the product (pH, water activity, presence of antimicrobial substances etc.). In the majority of cases, the population of the bacterium may not exceed a few cells per 25g of product. Furthermore, due to the aforementioned intrinsic properties of the commodity or its processing, another dominant microbial population may be present at numbers several orders of magnitude higher. Strategies that have been developed to detect *Listeria* more efficiently include the use of selective enrichment media, immunoassay techniques and molecular methods. These techniques can be used to detect *Listeria* at different stages of the supply chain, from the raw material to the final product. However, the detection of *Listeria* in fresh fruit and vegetables remains challenging due to the low population sizes and the presence of interfering microbial populations.

Spiros Paramithiotis, Natasha Spadafora, Carsten Muller, Eleftherios H. Drosinos and Hilary Rogers look at current methods and future prospects for detecting *Listeria* in fresh fruit and vegetables.
Listeria monocytogenes
LISTERIA DETECTION

Figure 1 Overview of different strategies for the detection of Listeria monocytogenes in fresh fruit and vegetables with estimated times for each step

Figure 2 VOC collection and analysis for assessing quality and safety of fresh fruit and vegetables. VOC samples are collected onto SafeLok thermal desorption (TD) tubes packed with Tenax TA and SulfilCarb sorbents using an EasyVOC™ pump (Markes International Ltd). Typically 200ml to 1L of headspace are collected. Tubes can be safely transported to the laboratory where VOCs are desorbed using thermal desorption and analysed by gas chromatography (GC) to provide spectral data. Time of flight mass spectrometry (TOF-MS) is then used to identify the VOCs based on comparison to databases such as NIST. Statistical analysis using R software and based on PerMANOVA and CAP allows discrimination amongst different samples.

Shelf-life experiments

Remote sampling kit

Transport

Statistical analysis

Spectral data and RI

TD-GC-TOF-MS

employed for detection of Listeria monocytogenes are summarised in Figure 1. The classical approach aims to detect the pathogen itself. For that purpose, two enrichment steps are necessary to allow the pathogen to regain viability and/or culturability and increase in numbers while at the same time suppressing the rest of the microbial populations. Then, presence is assessed through cultivation on selective solid media and confirmation tests on colonies exhibiting a typical appearance according to the medium used[11]. This is the reference method and no additional skills are required for its execution and interpretation apart from a microbiological background. On the other hand, a conclusive result may be reached only after 6-7 days. This is a time-frame that exceeds the shelf-life of many fresh cut fruits and vegetables and is a particular problem for the fresh cut industry where products may only transit at the processing site for 1-2 days.

**Rapid detection methods**

To reduce the time frame, development of alternative strategies that may allow faster detection of listeria has been extensively researched. Indeed, a wide variety of methods have been proposed based either on the detection of nucleic acid sequences, mostly DNA, or protein epitopes usually residing on the cell surface, both of which need to be specific for the pathogen.

In the first case, many protocols based on quantitative and qualitative polymerase chain reaction (PCR) formats, loop-mediated isothermal amplification (LAMP), fluorescence in situ hybridisation (FISH) and strand exchange amplification (SEA) have been developed[12]. Similarly, the detection of protein epitopes through a wide variety of ELISA protocols has been reported[13].

For all the DNA or protein based assays, the detection protocol itself requires less than a day; however selective enrichment is also necessary for the reasons already mentioned. Alternatively and/or additionally, separation and/or concentration of the nucleic acid extraction (1-2 h)
Separation/concentration of nucleic acids (1-2 h)
Detection step (PCR, qPCR, LAMP, SEA etc) (1-6 h)

Sample

Primary enrichment (24 h)
Secondary enrichment (24 h)
Growth on selective media (24-48 h)
Subculturing of ‘typical’ colonies and confirmation tests (24-48 h)

Sample

Primary preparation (eg lyophilization) (12-16 h)
Pathogen release from the matrix (1-7 h)
Detection step (ELISA) (16-20 h)

Sample

Total 4-6 days

Total 29-43 h

Total 3-10 h

classical approach

protein epitope-based detection

nucleic acid-based detection

**Figure 1** Overview of different strategies for the detection of Listeria monocytogenes in fresh fruit and vegetables with estimated times for each step.
target cells may be necessary in order to remove interfering molecules and concomitantly improve target detectability as well as method sensitivity and specificity. However, the addition of such steps increases the time required for the analysis, as well as the complexity and the level of expertise required. At the same time, the sensitivity and specificity of these methods are inferior to the reference method, mostly due to primer specificity in nucleic acid detection and cross reactivity between the antibodies and other plant material in protein detection.

**Measuring VOCs to detect Listeria**

Analysis of volatile organic compounds (VOCs) provides an alternative option for detection of *Listeria*, which would not require selective enrichment. An advantage of VOCs is that they can be collected in a non-destructive way directly from the product and their analysis is rapid (Figure 2). Thus in principle, batches of product could be analysed routinely for changes in VOCs indicative of contamination with human pathogens.

The profile of volatile organic compounds (VOC) alters during the shelf-life of fresh cut products[14, 15] at least in part due to the growth of spoilage microflora. This can be detected for example as off-odours late in shelf life of bagged salads. However, using objective instrument-based assessment of the VOCs, very subtle changes in profile can be detected and used to assess quality of the product. Although bacteria such as *L. monocytogenes* are not considered spoilage bacteria, they can multiply on the surface of fruit and vegetables, producing a range of VOCs including alcohols, amines, esters, hydrocarbons, and ketones[16]. Detection of bacteria other than *Listeria* using VOCs has been reported in a range of products including mango fruit, tinned tomatoes and strawberry. In most of this work, detection used gas chromatography mass spectrometry (GC-MS) using solid phase micro extraction (SPME) or electronic noses. In some cases, specific compounds could be associated with the specific microorganism, however these associations are often not completely robust when analysed across different matrices or conditions. Even subtle changes in the relative abundance of a common set of VOCs could be used to detect the presence of human pathogens and indeed may be more robust and specific[17].

Detection of *L. monocytogenes* using VOCs on cantaloupe melon at levels lower than 1 log CFU/g was reported recently by the current authors[18] (Figure 3). The study used a combination of VOC collection on thermal desorption tubes with analysis on GC-MS and a time-of-flight MS (TD-GC-TOF-MS). This approach provides a platform that combines quick, simple and stable sampling of VOCs on site with a much more sensitive detection than other forms of mass spectrometry. In addition, the detection of *Listeria* was based initially on differences detected between complete VOC profiles using multivariate statistical methods, such as PerMANOVA and CAP for analysis. Further statistical evaluation of profiles (WCNA) enabled identification of a panel of VOCs that discriminated between contaminated and uncontaminated melon samples. The methodology required six hours incubation for enrichment of VOCs and one hour analysis time, much faster than current culture-based approaches. This time-frame falls within the required needs of the processing industry and is comparable to DNA and protein-based methods discussed above.

One of the most difficult problems for the industry is false-negative results. Contaminants can be missed due to the difficulty of sampling product batches exhaustively when the microorganisms are present at very low levels. VOC analysis may be able to help with this by enabling detection from larger pooled product batches although further research is needed to verify the robustness of the technique at the industry scale. Furthermore, the method could be used to calibrate other detection methods e.g. PTV-MS, SWIFT-MS, FAIM or eNoses. These can all be used onsite without the need to transport samples and offer much cheaper alternatives to the investment in a TD-GC-TOF-MS system. Moreover, they could be calibrated to detect changes in overall quality of the product as well as the presence of microorganisms thus adding value for the industry and the consumer.

Thus, VOC analysis could be a useful new approach to add to the tool box for contaminant detection, complementing existing analytical techniques. It can provide valuable independent extra confirmation of results based on other rapid detection methods to help to ensure that consumption of fresh fruit and vegetables is safe. This will ensure that we can continue to eat our daily 400g of fresh fruit and vegetables, known to protect against a range of important long-term conditions, such as cancer, diabetes, and cardiovascular disease, without the fear of exposure to foodborne pathogens.

Figure 3 Melon cubes were sprayed with a culture of *L. monocytogenes* at 6, 3 and < 1 CFU/g, and then stored at 4°C for seven days to simulate the shelf life of fresh cut melon. Melon cubes were then transferred to 37°C for 6 hours and headspace collected onto TD tubes. Tubes were desorbed on a TD100 (Markes International) instrument and VOCs were separated and identified using TD-GC-TOF-MS. Analysis of the whole VOC profile for each inoculation level clearly separates even the lowest level of cfus from the uninoculated control.

### References and article available online at fstjournal.org/features/32-4/listeria-detection

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Global meat consumption is rising annually as the human population grows and affluence increases. Sterling Crew examines the environmental impact of this trend and looks at strategies for addressing sustainability in food consumption and agriculture.

### Meat consumption

Paleontological evidence indicates that meat constituted a substantial proportion of the diet of even the earliest humans and that we have hunted and killed animals for meat since prehistoric times. With civilisation came the domestication of animals, which eventually led to the use of livestock in meat production on an industrial scale.

### Dietary choices

The amount of meat in our diet differs significantly amongst individuals, across cultures and worldwide. Meat is a good source of energy and some essential nutrients, including protein, essential amino acids and micronutrients, such as iron, zinc, selenium, riboflavin and vitamin B12. It is however possible to obtain a sufficient intake of these nutrients without eating meat if a wide variety of other foods is consumed. The NHS advises that with good planning and understanding of what makes up a healthy balanced vegan diet, it should be possible to obtain all the essential nutrients without consuming meat, dairy or eggs.[1]

Across Britain, an increasing number of consumers have become vegans, vegetarians and flexitarians and others are just eating less meat. Table 1. This is largely driven by concerns about health, animal welfare, ethics, religious dietary laws and environmental impact. Research conducted in 2016 by the Vegan Society estimated that there were around 540,000 vegans in Great Britain – 3.6 times as many as there were in 2006[2]. People are spending more money on vegan products and plant based diets are trending online. In January 2018, more than 168,000 people pledged to go vegan under the Veganuary campaign. The variety and quality of food choices to flexitarians, vegetarians and vegans in the UK has improved dramatically in recent years. The appeal of vegetarian and vegan products shows no sign of declining and after a recent dip, the retail market is now expected to grow to £658m by 2021[3].

Most people living outside the Western economies already tend to eat more plant based diets for reasons of economy because they simply cannot afford to eat meat. However, global meat production has increased rapidly over the past 50 years with total production having grown 4-5 fold since 1961[4]. One third of the average global consumption of meat is pork, a third is poultry, a fifth is beef and the remainder is from sheep, goats and other animals.

This increased meat consumption is due to the rise of the middle classes in emerging economies, such as China and East Asia. For a large proportion of the global population, the price of meat today relative to their average income is now less than it has ever been. This brings with it a steady increase in meat consumption where once more sustainable plant based diets were followed. India is not reflecting this trend – probably because of the long tradition of vegetarianism amongst its religious communities. A review by the United Nations FAO (Food

### Types of plant based dietary patterns

<table>
<thead>
<tr>
<th>Vegetarians</th>
<th>Do not eat meat, poultry or seafood.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegans</td>
<td>Do not eat meat, poultry, fish or any products derived from animals, including eggs, dairy products and gelatine.</td>
</tr>
<tr>
<td>Lacto-ovo vegetarians</td>
<td>Do not eat meat, poultry or fish, but do eat eggs and dairy products.</td>
</tr>
<tr>
<td>Lacto vegetarians</td>
<td>Eat no meat, poultry, fish or eggs, but do consume dairy products.</td>
</tr>
<tr>
<td>Ovo vegetarians</td>
<td>Eat no meat, poultry, fish or dairy products, but do eat eggs</td>
</tr>
<tr>
<td>Partial vegetarians</td>
<td>Avoid meat but may eat fish (pesco-vegetarian, pescatarian) or poultry (pollo-vegetarian).</td>
</tr>
<tr>
<td>Flexitarians</td>
<td>Primarily vegetarian diet but occasionally eat meat, poultry or seafood.</td>
</tr>
</tbody>
</table>
MEAT CONSUMPTION
and Agriculture Organisation), in 2012 projected an increase of 76% in the total quantity of meat produced by mid-century[8].

This shift is underscored by the current biomass of mammals on the planet, which is made up of 60% livestock, mostly cattle and pigs, 36% humans and 4% wild animals[2]. This is also true for wild and domesticated birds, for which the biomass of domesticated poultry (dominated by chickens) is about threefold higher than that of wild birds. By 2050 there will be an extra two billion mouths to feed and increasing consumption of animal products will bring new challenges to global agriculture.

**Environmental impact**

According to the FAO report Livestock’s Long Shadow[1], meat production is one of the most important ways in which humans affect the environment. It assessed the full impact of livestock on environmental problems along with potential technical and policy approaches to mitigation and concluded that meat products are one of the largest contributors to greenhouse gases, air and water pollution, land degradation, energy and water use, deforestation and loss of biodiversity.

Feeding grain to livestock to produce meat, instead of feeding it directly to humans, involves a large energy loss making animal agriculture more resource intensive than other forms of food production. This is because meat produces more emissions per unit of energy compared to plant based foods, due to energy loss at each trophic level. Livestock production accounts for 70% of all agricultural land and 30% of the land surface of the planet[3]. It is estimated that the amount of water required for a meat diet is twice as much as that needed for a vegetarian diet.

A plant based diet cuts the use of land by 76% and halves the greenhouse gases and other sources of pollution that are caused by food production. The FAO report[3] concludes that livestock is responsible for 18% of greenhouse gas emissions. It reflects the growing consensus amongst the scientific community that meat production is extremely resource intensive and that dietary change towards plant based eating habits could significantly reduce agricultural land loading. It is evident that urgent action is required to address the current state of affairs.

**Recent developments**

October 2018 saw the publication of two important environmental impact reports, both of which generated global media attention. The first was the influential Intergovernmental Panel on Climate Change (IPCC) report ‘Global Warming of 1.5°C – a special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty’[10]. The 1.5 °C target was set by the United Nations Framework Convention on Climate Change Paris Agreement of 2015[10]. The report concludes that rapid changes must take place in four key parts of society: energy generation, land use, cities and industry. It highlights the contribution made by agricultural practices and dietary choices and comments that, while current trends are in the opposite direction, eating less meat and dairy is important.

The second report was published on the 10th October 2018 in Nature entitled ‘Options for keeping the food system within environmental limits’[11]. The report concludes that the food system has a number of significant environmental impacts, including being a major driver of climate change, depleting freshwater and creating pollution through excessive use of nitrogen and phosphorus.

Using a global food systems model, the study found that between 2010 and 2050 the environmental effects of the food system could increase by 50-90% reaching levels that are beyond the global boundaries that define a safe operating space for humanity, unless technological changes or dedicated mitigation measures are introduced.

The authors analysed the options for reducing the environmental effects of the food system, including dietary changes towards healthier and more plant based diets, improvements in technology and reductions in food waste, and found that no single measure was enough to keep these effects within the global boundaries. They recommended a synergistic combination of measures to address environmental impacts, including a flexitarian diet to halve emissions from livestock. This would mean the average person needs to eat 75% less beef, 90% less pork and half the number of eggs, while tripling consumption of beans and pulses and quadrupling nuts and seeds.

The authors concluded that animal production systems require a more intensive and environmentally damaging mode of production than that needed for plant based food. The study also found that halving the amount of food lost to waste would reduce the environmental impacts of agriculture by 16%.

**The challenge**

Clearly, a significant reduction in meat consumption is necessary to help to mitigate climate change. However, the issue of eating less meat is very complex. The trade in livestock and related food products is a significant component of the economies of many rural communities and countries. Livestock and its associated processing industries provide employment for large numbers of people. Eating meat is a pleasurable experience for consumers and it is an important source of nutrients.

Meat consumption has strong embedded personal and cultural associations. It often has symbolic meaning and important social functions. Food choices are by their very nature personal and behavioral and dietary change can be difficult to achieve.

Some cultures live in environments where meat is the only available sustainable food resource, for example the Inuit people of the Arctic. There is also a risk that people, especially the young and old, would suffer from a greater number of deficiencies in essential nutrients. There is even an argument that millions...
of undernourished people in poor nations need to eat more meat and dairy foods. There is still a lot of controversy over the data concerning the effects of livestock on the environment and its interpretation, depending on the vested interests.

Food science may well help to contribute a technological solution. Plant based meat substitutes could be one of the planet’s most critical future food technologies. Producing a palatable acceptable meat alternative for consumers would not only reduce environmental degradation but also contribute to improving health and making food more affordable. This is the food scientist’s Holy Grail. An example of this type of innovative alternative meat technology is Quorn. Launched in 1985, Quorn is made from mycoprotein from the soil mould Fusarium venenatum strain PTA-2684, which is grown by fermentation. It is sold as an ingredient and as a meat substitute in meals.

If the retreat from meat is to be encouraged, there needs to be an understanding of the socioeconomic and environmental factors at play to nudge a dietary change. It is encouraging that there is evidence for this working in some of the richer developed countries, where numbers of citizens choosing vegetarian and vegan diets are increasing. We already have a legal requirement under a European Directive to label all appliances with energy efficiency and this could be extended by using environmental labelling on foods to nudge behaviour in the same way as nutritional indicators are currently used. This could incentivise food businesses to act more sustainably, enable the consumer to make more informed choices on sustainable eating and encourage improved policymaking.

A recent study undertaken by scientists at the University of Oxford has calculated that in 2020 there will be 2.4m deaths attributable to red and processed meat consumption, as well as $285bn in costs related to healthcare[12, 13]. They found that red meat would need to be 20% more expensive and processed meat, such as bacon, sausages and jerky, would need to be more than double its current price to account for these health costs. The research suggests that if the optimum health taxes were introduced, the consumption of processed meat would decline by about two portions per week in high-income countries and by 16% globally.

Taxing food in this way raises obvious questions over its political acceptability and its effectiveness. Taxing plastic carrier bags has seen a significant reduction in their use. Public health taxation has been applied successfully to help reduce the consumption of alcohol and tobacco smoking. The fuel levy has been used as an ecotax to promote ecological sustainability. Taxes on transportation have been shown to be an effective tool to reduce pollution, conserve energy and help reduce global warming. The jury is still out on the sugar tax on soft drinks, although it has encouraged manufacturers to reformulate food products to reduce sugar content.

Conclusions
Dietary change could play a significant role as part of a strategy to ensure future food security for a growing world population while mitigating environmental challenges associated with agricultural production. Even modest reductions in meat consumption in industrialised societies would substantially reduce the burden on natural resources and help to contain the environmental impacts of agriculture.

In November 2017, over 15,000 scientists signed a warning letter to humanity calling for a drastic reduction in per capita meat consumption. If the world wants to limit climate change, water scarcity and pollution, then we all need to embrace diets containing less meat. The current global growing demand for meat is simply unsustainable. Strategies for sustainability must address dietary change to ensure food security for future populations, while addressing the environmental challenges associated with agricultural production. We are the first generation to know that we are damaging our planet by increasing meat consumption and maybe the last that can do anything about it.

In 2020 there will be 2.4m deaths attributable to red and processed meat consumption, as well as $285bn in costs related to healthcare.
The influence of scientific research is evident in all aspects of modern life, and the relationship between science and society is becoming increasingly complex.

Scientific and technological developments in the agri-food sector are affected and shaped by politics and public opinion, as well as moral and cultural values. Science can be mistrusted; discussions about risks are often politicised and values can sometimes create a barrier to accepting scientific evidence.

Some citizens take great interest in the work of scientific organisations and in policy making. There is a legitimate expectation that different views should be listened to and that the development of policies should be based on science and evidence and should involve transparent participation by anyone with an interest.

One example is the ongoing debate around pesticides, which arouses strong feelings on all sides. More than 1.3 million Europeans signed a petition demanding that glyphosate, one of the most commonly used herbicides in the world, be banned on the grounds that it posed ‘a serious threat to human health’ and that ‘its negative impacts on the environment and biodiversity are clearly documented’. The debate has highlighted increased expectations from public bodies regarding transparency and participation.

Another polarised discussion has been focused on Bisphenol A (BPA), a chemical used to harden plastic, which is found in a number of products, such as plastic drinking containers and food cans. In animal studies, BPA imitates the effects of oestrogen. This has generated questions about whether animal studies are relevant to humans, and some scientists and consumers suggest that human exposure to BPA should be reduced.

The European Commission and other EU bodies are willing to listen to citizens’ views and concerns on scientific, technological and policy developments. More can be done, but many initiatives are underway. For example, the European Commission recently submitted a proposal to the Council and the Parliament, to improve the transparency of scientific studies used in the risk assessment of food and food products.

The European Commission’s proposal on transparency
Under this proposal, citizens would have greater access to the information submitted to EFSA for the risk assessment of products to be used in the agri-food chain.

The Commission’s proposal represents a good opportunity to adapt the EU’s General Food Law, which is now 15 years old, to today’s needs. The proposal includes:
- All studies and documents

Barbara Gallani, Head of Communication Engagement and Cooperation department at the European Food Safety Authority (EFSA), explains its current initiatives to improve openness and transparency by promoting stakeholder participation in its activities.

“..."
Scientists and science communicators need to be more aware of how context, language and cognitive biases can influence the communication process.

Assessed by EFSA and included in already published scientific opinions.

**Engagement with stakeholders**
EFSA listens to the views of outside parties and fosters active and constructive engagement with its stakeholders. Many stakeholder groups have a close interest in EFSA’s work – from the food industry to environmental and consumer groups.

EFSA maintains a list of registered stakeholders and proactively seeks their input and encourages exchange of views. All registered stakeholders meet once a year at EFSA’s Stakeholder Forum.

A successful example in this regard is the establishment of the EU Bee Partnership, designed to improve data sharing on bee health. The partnership was the key outcome of a symposium organised by EFSA as part of last year’s Bee Week. Since then, a stakeholder group representing beekeepers, farmers, NGOs, veterinarians, academia, industry, producers and scientists has been working to agree the terms of reference that will guide the work of the partnership.

**Making data available**
The Authority publishes its data wherever possible as part of its commitment to widening its evidence base and maximising access to its data. Many of these datasets are already publicly available on the Knowledge Junction open repository – including data on foodborne zoonotic diseases, antibiotic resistance and the presence of chemicals in food.

EFSA manages a huge amount of data on pathogens, chemicals and other hazards in the food chain in its Data Warehouse. Much of this data has been made available to the public through web reporting tools, such as tables, reports, graphs, maps and dashboards. An example is an interactive data visualisation tool showing resistance of animals and humans to antimicrobials and bacteria found in food.

The Data Warehouse also hosts OpenFoodTox, a compilation of toxicological information on every chemical assessed by EFSA and included in already published scientific opinions.

**Science and society**
Public controversies about science are now openly debated, often without expert mediation. Scientists and science communicators need to be more aware of how context, language and cognitive biases can influence the communication process.

**Expertise of the future**
In the coming years, organisations, agencies and public service in general will face major challenges, such as budgetary cuts and growing societal demands. More needs to be done to improve cooperation, communication and sharing of expertise.

Input from the conference and the proposal that followed the EU citizens’ initiative will provide useful insights to help shape the EFSA strategy for 2021–2027. ‘Collaboration, multidisciplinary science and engagement are the key factors for success,’ according to EFSA’s Executive Director.

Exciting times lie ahead.
Productivity framework

A highly diverse industrial sector short of human capital

The agriculture, food and drink industry contributes more to the UK economy per annum than that of the automotive and aerospace industries combined. In 2017, food and drink businesses alone had a turnover of £196bn and generated over £10bn per annum for HM Treasury, with exports exceeding £22bn, 60% of which were traded with the EU.[5]

Sustaining the agriculture, food and drink industries requires human capital. Current estimates calculate that the agrifood supply chain employs approaching 4m people of whom over 10% are within the food and drink sector.[2] The sector has built a reputation for being economically resilient, producing high quality goods, making an average annual investment of over £350m in research and development (R&D) and bringing around 16,000 new products to market every year.[3] Despite the high profile of some major food and drink manufacturers and retailers, over 96% of food businesses are classified as SMEs. These smaller enterprises are particularly concentrated in regions of low employment and productivity, such as the South West of England, Wales and rural parts of Scotland[4]. The diversity of companies in the sector, both in terms of portfolio and size, enables people to pursue a range of career pathways. Furthermore, in a billion-pound industry there is as much need for financial, legal and sales expertise as there is for product development, production and technical processing skills.

Despite being the largest manufacturing community in the UK, the agrifood sector has seen the size of its workforce fall during a period of rapid technological advances. Pressures on costs and margins, off-shoring and globalisation, extensive merger and acquisition activity and growth in market power of major retailers, have all contributed to this decline. Between 2000 and 2007 over 80,000 jobs were lost, which equates to a 16% drop in employment levels.[5] However, the value of the sector continues to expand and it is predicted that there will be an increasing need for individuals with the skills to become managers, senior officials, professionals and skilled technical experts.[6] The 2017 Nesta report The Future of Skills:

Employment in 2030 indicated that the food preparation and hospitality occupations are likely to show the largest growth of any industry in the UK (>70%).[7] The authors associate this with the increased presence of ‘differentiated products’ e.g. artisan goods and services, such as roasting, butchery, bartending, that have become increasingly valued by consumers.[8]

The food and drink industry has identified that it will need over 140,000 new recruits by 2024[9], plus a further 595,000 in agriculture to replace those retiring or leaving the sector for other reasons[10]. There is a particular shortage of experience in food engineering, food science, crop technology, engineering and automation, and management, with higher-level skills shortages across the sector. Agrifood currently has one of the lowest take-up of apprenticeships and tends to be more reluctant to invest in formal staff training and development compared with other sectors. Agrifood currently has one of the lowest take-up of apprenticeships and tends to be more reluctant to invest in formal staff training and development compared with other sectors. The Food and Drink Federation has pledged to triple apprenticeships within the food and drink industry by 2020 to address the staff shortages experienced by companies at all levels[10].

The Industrial Strategy and its challenges for the agrifood sector

The 2017 Industrial Strategy White Paper states that by

Careers

Carol Wagstaff, Fiona Kendrick, Colin Dennis, Phil Hollington, Tim Hess, John Brameld, Mitch Crook, Michael Wilkinson, Jerry Roberts, Craig Farrell and Barbara Mason look at skills shortages and careers pathways in the agrifood industry.
2030 the Government aims for: ‘the UK to be the most innovative country in the world’ with businesses ‘investing in R&D and the skills needed in a changing work environment to maximise the rewards and benefits innovation can bring to everyone in the UK’[11]. This is a particularly welcome aspiration for a sector that is short of skilled workers and which needs innovation in order to adopt technologies that will enable the intensification of production, a reduction of the environmental footprint of the industry and a replacement of some jobs with engineering solutions. However, much as it would appear that the Government should be pushing on an open door, the Future of Skills & Lifelong Learning Foresight Report (2017) indicates that the availability of training does not correlate with engagement. The Report describes this as implying ‘that education providers are not offering, or students are not selecting, the courses that match with employers’ skills needs, and that future skill needs are not being fully anticipated’[12]. Businesses are not able to recruit new staff with the necessary skills straight from the education system. Employers therefore need to recognize the broader impact of skills shortages on their business. A 2015 survey of 6,469 employers reproduced in the Foresight Report revealed that the majority recognised the impact of skills shortages in the business on other employees, but few were aware of the consequences on the ability of the business to develop new products or services or to introduce technological change (Figure 1).

The Foresight Report further notes the need for workers to continue training throughout their careers in order to keep up with technological changes and market influences. However, despite most companies recognising that they are experiencing a skills shortage, work-based training has been in decline since 2001. Employer investment in training in England fell by 14.5% in real terms between 2005 and 2011[14]. A survey of 30,721 employees (Office for National Statistics, 2017) shows that training in the early part of careers is more likely to be undertaken by men, whereas women are more likely to pursue training as they get older (Figure 2). When the data are expressed in percentage terms, they reveal a steady decline in the percentage of employees of either sex who undertook training as age increased (Figure 3).

The Industrial Strategy Challenge Fund, spearheaded by UKRI, includes specific challenges on Healthy Ageing and Transforming Food Production securing opportunities for academic-industrial collaboration to bring the latest research ideas into the real commercial world. However, unless suitable training is provided to ensure that workers have the skills and understanding to implement new ideas, the investment will not bring the practical outcomes desired by the Government. The Government has already invested £80m in four Centres of Agricultural Innovation, the first of which (Agrimetrics) was launched in October 2015. It is imperative that the agriculture, food and drink industries engage with these centres so that government investment benefits the sector. The aim of the centres is to increase UK productivity; increased dialogue with industry stakeholders is critical to ensure that the centres remain relevant and develop tools and technologies that are fit for purpose.

**Skills: a key priority for the Food and Drink Sector Council**

Established in January 2018, the Food and Drink Sector Council is a formal industry partnership with government created to...
improve the productivity and sustainability of the UK food and drink supply chain. The Food and Drink Sector Council represents the whole of the food chain from farming and manufacturing, to retail, hospitality and logistics. It provides the gateway for government into the food industry to address the big challenges and opportunities in areas, such as raising productivity, reducing the environmental impact of the industry, improving public health and creating new employment opportunities across the UK.

One of the Council’s key priorities is workforce and skills. Under the leadership of Nestlé UK & Ireland Chair and Sector Council member, Dame Fiona Kendrick, a Workforce and Skills Group has been set up to create some industry-led actions – that government can fully support – to secure a world-class, skilled workforce and this should help the UK food and drink supply chain transition into a post-Brexit world. The Workforce and Skills Group is currently focusing on:

- Future workforce and skills needs of the UK food chain, which will be evidenced by a research project
- Apprenticeships
- Image of the sector
- Up-skilling the workforce.

**Career perceptions of the sector and training opportunities**

One area of focus for the Workforce and Skills group is the image of the food chain and the perception of the industry – something that has often arisen as a challenge. Overall, the sector is not perceived as attractive to young people – despite the fact that it is well paid with excellent career opportunities and high earning potential. When a sample of UK undergraduates were asked about their perceptions of the agriculture, food and drink industries, their awareness of the sector as a whole was extremely poor; they regarded it as an unattractive career option using terms such as ‘low paid; low skilled; dirty; long hours; shift work; stuck in a factory; and driving a tractor’. The reality is that the sector provides high-flying career options that are extremely transferable, requiring people with management, finance, marketing, sales and creative skills to sit alongside technical knowledge of the sector and the products it generates. The food and drink industry needs to work with government to capitalise on opportunities to inform schools and students about the careers available.

Although the GCSE in Food Technology that is available in England and Wales is popular, it is not always taught from the scientific perspective desired by those within the industry and schools have a limited understanding of career paths available to students who are interested in food science. This is compounded by the A Level in Food Technology being discontinued in 2018, although Scotland offers an Advanced Higher level qualification in Health and Food Technology, which is split into two units: Food for Health and Food Science, Production and Manufacturing. Whilst the inclusion of health in the subject will encourage uptake from a broader cohort, there is remarkably little science in the course description, which does not encourage students who are interested in core sciences to consider the food industry as a career path. There is huge potential to include food and agricultural real-world examples in mainstream STEM subjects, such as biology, chemistry and mathematics, but, to date, the opportunity has not been seized on the talent pipeline emerging from schools.

When a sample of UK undergraduates were asked about their perceptions of the agriculture, food and drink industries, their awareness of the sector as a whole was extremely poor.
farming industry due to a sharp decline in the European workforce coming to the UK\textsuperscript{[16]}, a view further supported by a BEIS (Business, Energy and Industrial Strategy) Select Committee report a month later\textsuperscript{[19]}. A range of training organisations already operate within the sector, sometimes underpinned by formal qualifications, sometimes designed to be taken as Continuous Professional Development (Figure 4). At present there is reasonable progression to level 5 (mid-BSc), either by taking qualifications through land based colleges or courses at providers, such as Campden BRI/Leatherhead Food Research. A gap then exists between level 5 and the current postgraduate offering provided by the AgriFood Training Partnership (AFTP), with few options available in the Level 6 (BSc) space. Degree apprenticeships, at both Level 6 and Level 7, may plug this gap but there are currently limited options for the agrifood sector and apprenticeships, particularly at the higher levels, do not suit the needs of all companies. Almost half of businesses that employ apprentices feel that the levy needs reform to provide more flexibility in how the funds set aside are used\textsuperscript{[20]}. Training providers also need to consider the mode of training delivery in addition to content and timing, as people increasingly look to study online to enable them to combine this with other commitments.

The Sector Council’s Workforce and Skills Group is investigating why some parts of the food chain are successful in using apprenticeships, while others struggle. In particular, the group is exploring solutions to the key barriers businesses face in trying to make better use of apprenticeships.

**The AgriFood Training Partnership as a model for delivering enhanced skills to the sector**

The AFTP model has already demonstrated its ability to attract and train part time, work-based learners using a blended learning approach that fits well with employer and employee needs. It receives funding from the Biotechnology and Biological Sciences Research Council (BBSRC) to provide participants with postgraduate level training from Continuous Professional Development (CPD) at Level 7 to Professional Doctorate (Level 8). Qualifications are validated through a consortium of UK universities (Aberystwyth University, Bangor University, Cranfield University, Harper Adams University, The University of Nottingham and The University of Reading) that are globally recognised for their teaching and research in agriculture, food and nutrition. The AFTP runs Industrial Advisory Groups addressing Food and Nutrition, Livestock and Forages, Environment and Sustainability and Crops and Fresh Produce. These groups are heavily populated by relevant representatives from

![Crop protection workshop, above,](image-url)
each sector and seek to guide new developments within the partnership and ensure that existing courses remain relevant and focused on the industry’s own perception of its needs.

The consortium’s existing links with industry, particularly where lower-level apprenticeships are delivered, enables an innovation culture to be embedded into business through increasing staff skills and leadership at Level 7. Facilitating the AFTP consortium to develop platforms for delivering postgraduate level Degree Apprenticeships will assist in professionalising the agrifood industry and removing barriers to career progression that exist in areas where university education is not the norm for school leavers. Additionally, the AFTP enables participants to dip into its portfolio without pursuing qualifications, with all CPD endorsed by the Institute of Food Science and Technology, plus other specialist bodies as appropriate e.g. Association for Nutrition, DairyPro, BASIS. The quality and need for training platforms, such as the AFTP, was recently endorsed by Iain Ferguson, Co-Chair of the Food and Drink Sector Council: ‘[The AFTP] have a central role to play [...] the way that you’re already working with six or maybe even seven universities right across the chain is exactly the same model that we’re trying to build in the Food and Drink Sector Council’. Businesses have reported that dissemination of the learning by individual employees, who have undertaken AFTP training, results in enhanced professional practice, development and adoption of new manufacturing processes or technologies with a subsequent benefit to the bottom line of the business.

**New directions for the agrifood sector**

The sector needs to improve its ability to portray the career potential that it offers. Other sectors, such as engineering and IT, have employees possessing a wide range of skills that are applicable to agriculture and food, yet there is almost no movement between sectors.

More graduates need to enter the sector with the right kinds of qualifications i.e. science, maths and engineering subjects. Some excellent resources are available for schools, such as the Tasty Food Careers document, but the awareness of opportunities amongst career departments remains inadequate, despite the efforts of the National Skills Academy for Food and Drink.

More agriculture, food and drink companies need to have a clearly defined staff learning and development policy - presently only 40% of those in Wales have one, whereas in Ireland the state has taken a more proactive stance towards facilitating lifelong learning through SOLAS (State Organisation with responsibility for funding, planning and co-ordinating Further Education and Training in Ireland). The Career Traineeship initiative has been developed by SOLAS in collaboration with Education and Training Boards (ETBs) and enterprise. Work-based learning, primarily at NFQ levels 4 and 5, is used as the main mode of delivery and is currently being piloted with the hospitality and engineering sectors, with the involvement of seven ETBs. Networks of employers have been created to facilitate partnerships with ETBs to identify training needs, design the training programmes, recruit learners and deliver the training on and off the job. Throughout the UK there is a need for business to work increasingly collaboratively with training providers to design course curriculums so that businesses get people straight out of training who have the specific, and sometimes bespoke, skills they need.

The provision of skills training in SMEs is recognised to be worse than it is in large organisations. SME managers tend to recruit externally if they need a new skill rather than encouraging employees to take ‘time out’ to receive appropriate training. SMEs often lack the financial flexibility to invest in staff training and are either unaware of opportunities to access funding support, or perceive the process as too time consuming. The opportunities for smaller organisations to access funding for existing staff development need to be simplified with the benefits of such training being more clearly articulated by the providers.

Local Enterprise Partnerships (LEPs) are the lynchpin of recognising the needs for skills investment for their regions. LEPs, such as the Midlands Engine, Heart of the South West and The Marches, are well positioned geographically to serve key agrifood areas. Dialogue about training needs should be encouraged over a broader range of business types and sizes, with clear pathways for skills and staff development identified as a result.

Business leaders need to be more aware of the ‘training paradox’, where investing in training makes people marketable commodities that are likely to move on. However, people who have a company investing in their future feel ‘looked after’ and are more likely to stay, thus bringing enhanced benefit to their employer. This is a far healthier situation than ignoring staff development, which can only result in a static business and untrained employees. Apprenticeships can enhance both technical and management/leadership skills. Most food companies considering level 7 apprenticeships have expressed a need for enhanced management...
Conclusions
The food system is changing across the UK, Europe and indeed worldwide. Consumers demand different products and different production standards compared to times gone by. Lifestyles are changing so that technology is embedded within consumers’ daily lives; values, such as the cultural and ethical origins of food, are becoming more important.

Questions remain as to whether the industry is ready to adapt to this changing food system and how workers will acquire the necessary skills and competencies. The agrifood industry is characterised by its diversity, in terms of products grown or made, employee numbers and scope of the supply chain from ultra-local to truly global. Therefore, a one-size-fits-all solution is unlikely to be successful. That the sector is facing a shortage in staff numbers and staff skills is an undeniable truth. How it reacts to this situation remains to be seen, but the solutions will involve a wide range of training opportunities, revolutionary technological innovations and leadership at the highest level to enable businesses to invest in people and grow their productivity.

Figure 5 College Development Network (CDN), Scotland. Achievements in the first four years 2013-17[1][6]

More collaboration is required between business, training providers and schools to make career opportunities clear and to enable a structured pathway into the area.
The first thing to say about David Watson’s book on agricultural pesticides is that it is a fascinating and absorbing read. The second thing to say is that the title does not fully reflect the subject matter and breadth of the work, or the undoubted scholarship upon which it is based.

Politics and policy in relation to pesticides in agriculture are explored, so are corporate perspectives in relation to the development of the global pesticides industry. But the book is much more than its title suggests: it is essentially a history of the development of the global agricultural pesticides industry, providing a valuable insight into the creation of an influential industry and its numerous products. Names of the companies that have built the pesticides industry leap from the pages, such as Bayer, BASF, Ciba-Geigy, Dow, DuPont, ICI, Monsanto, Rhone Poulenc and Syngenta. They are names that will be familiar to farmers as well as others whose interests lie in industrial chemistry, which is why this book will find a readership that extends well beyond those specifically involved in agriculture.

Pesticides and agriculture: Profit, politics and policy will be of immediate interest to anyone involved in production agriculture, agricultural education or agricultural research. As a resource for academics and those teaching agriculture, as well as students studying the topic, there are few comparable publications and certainly few that have been so well researched. In fact the detail and comprehensiveness of the book are two of its most impressive features, communicating a truly scholarly achievement. Beyond the readership identified above, the book should also be of interest to those who work in sectors allied to or associated with agriculture, such as horticulture, agricultural engineering and environmental sciences, as well as educated lay readers and policy makers involved in matters relating to farming and agricultural pesticides.

The index of this 403-page book could be more detailed and comprehensive to facilitate access to the contents. The work is packed with information - a rapid reading followed by a slower reading is recommended for maximum benefit. The effort will be well worthwhile, as Dr Watson has assembled a large amount of knowledge drawn from multiple sources to make it easy for the reader to gain a broad understanding of the factors that have brought into being the agricultural pesticides industry upon which much of today’s industrialised food system is based.

The structure of the book has been thoughtfully designed to reflect different historical periods, with each assigned to a chapter. For instance, the 20th century period that created the foundation of the modern industry is classified as the Productivist Period (1930-1973), while later in the book the challenge of sustainable agriculture and the pesticide industry’s response is dealt with in the chapter, Sustainability Paradigm (1974-2017), bringing the story up-to-date. The book clearly achieves its aim of communicating understanding of the development of the agricultural pesticides industry, and the political and policy factors that have affected it. In this latter respect the chapter on Post Productivism (1974-2017) is particularly relevant.

As a publication from the Burleigh Dodds shelves, the book is extremely well produced as a high quality educational/reference book with negligible typographical errors. It is completely legible and Dr Watson’s writing style is entirely comprehensible. As a window into the history and development of the agricultural pesticides industry, I cannot recommend this book highly enough. It has been a joy to review.
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