A Newcomer's Guide to the

STFC Food Network+

STFC Food Network+

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Written by Sarah Bridle (SFN PI) and the STFC Food Network+ Champions:

Simon Pearson - SFN Champion for Sustainable Production
Sonal Choudhary - SFN Champion for Resilient Supply Chains
Christian Reynolds - SFN Champion for Improving Nutrition and Consumer Behaviours
Seb Oliver - SFN Champion for STFC Data Science
Stephen Serjeant - SFN Champion for STFC Technology
Sarah Rogers - SFN Champion for STFC Facilities

with inputs from Katherine Denby (CoI), Kieran Flanagan (CoI), Bruce Grieve (CoI), Jason Halford (CoI), Lenny Koh (CoI), Mark Reed (CoI) and Alison Fletcher (Project Manager) and STFC Food Network+ Members.

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Food is essential for civilisation - some say we are only nine meals from anarchy - and makes up a sizeable fraction of any economy. Yet our current farming systems are unsustainable and contribute significantly to climate change. Our food supply chains are global yet fragile and inefficient. We grow enough food to feed 12 billion – far in excess of the 7 billion population – yet more than 1 billion people are under fed. The projected 70% increase in demand for food by 2050, coupled with the increasing impacts of climate change on food production present a “perfect storm” of risk for the future. Interdisciplinary approaches can help understand and address these multiple challenges. The STFC Food Network+ connects one of the UK’s leading science communities directly into the challenge of creating sustainable food production systems. The opportunities are significant, we need new science to understand how we can drive sustainability across the global food supply chain as well as innovative technologies that generate economic, environmental and societal impact.

The Science and Technology Facilities Council (STFC) Food Network+ (SFN) brings together STFC researchers and facilities (see Box 1) with research and industry in the agri-food sector. The SFN is building an interdisciplinary community working to provide a sustainable, secure supply of safe, nutritious, and affordable high-quality food using less land, with reduced inputs, and in the context of global climate change and declining natural resources. The SFN is highlighting and developing key opportunities for the STFC community to make a meaningful contribution to the food system - from sustainable intensification, through building resilience in supply chains, to novel technologies to engage consumers and help change behaviour and improve nutrition. We do this by working together with existing experts in food and industry, and in collaboration with existing networks and centers.

Box 1: The Science and Technology Facilities Council (STFC)

The Science and Technology Facilities Council (STFC) is one of the 7 UK Research Councils, with an annual budget of around £600 million. It plays a role in underpinning the other research councils and has 5,122 unique users over 3,105 experiments, leading to 1,523 papers in 2015/16.

STFC funds the UK’s fundamental research into astro, particle and nuclear physics; this builds capability for large scale data science, for example to process petabytes of data with the Large Hadron Collider; it also develops precision technology, for example space instrumentation mass spectrometers used on the Rosetta comet mission.

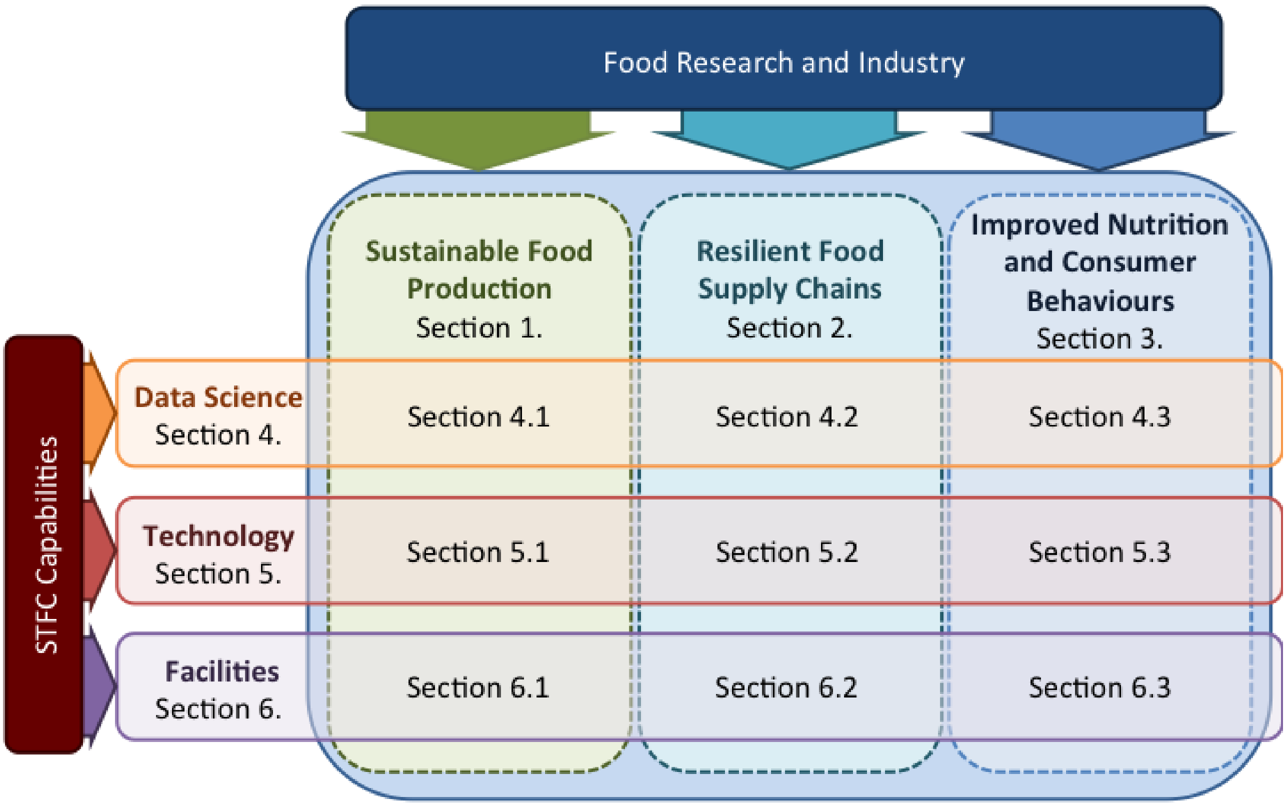
STFC provides access to the UK's world-leading, large-scale facilities across a range of physical and life sciences including Diamond Light Source, neutron imaging (ISIS) and the Central Laser Facility (CLF), as well as running a Scientific Computing Department which interfaces with industry through the Hartree Centre.

The SFN began in 2017, and during the next two years we would like to have instigated multiple successful new projects between STFC research and facilities and food research and industry, that would not have happened without the SFN. We would like the seed funding provided by the SFN to enable these projects to become self-sustaining beyond the SFN. We want the SFN to have built crossdisciplinary communities who understand the skill sets and challenges facing each other, and engage to solve agri-food problems.

To achieve these aims we are:

- Holding annual meetings designed to showcase work that our Network has helped facilitate and help develop new collaborations
- Interacting regularly with our members (at the time of writing >650 people
- Distributing this handbook through industry and university connections across the country
- Holding sandpits to develop collaborative scoping projects
- Offering funding for scoping studies <£8k per study
- Working closely with our Champions to penetrate the STFC physics and agri-food communities
- Spreading the word through our website www.stfcfoodnetwork.org

This document provides background information about food challenges aimed at newcomers, and an introduction to STFC capabilities aimed at food research and industry. It is structured around the following intersection diagram, providing basic information about each of the 3 Food and 3 STFC Themes, and then exploring the 9 ways that these intersect.



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1. Challenges of Sustainable Food Production

Current food production contributes over 20% of the world's total greenhouse gas emissions, uses 70% of the world's extracted water, occupies 35% of the ex-Antarctica land mass of the earth, and often reduces biodiversity and soil health. Specific challenges include: 1) Accurately identifying *yield gaps* - geographical regions where food production could be increased improved farming techniques. 2) Improving observations on individual farms to allow the *identification of pests and diseases*. 3) Realising the dream of *precision agriculture*, in which inputs such as water and fertilisers are applied as needed per plant or animal, which can allow less inputs to be used. 4) Reducing *soil degradation* by measuring soil health and identifying and deploying improved and novel farming practices such as robots to reduce soil compaction. Overall, to meet rising demand and respond to climate change we need to produce more food while decreasing its burden on the environment in terms of land use, soil degradation and reduced inputs including water and chemicals. The SFN is working with existing experts in this field including the four AgriTech Centers[1] and the Global Food Security Programme[2].

2. Challenges of Resilient Food Supply Chains

The aim of this theme is to address challenges within food supply networks from farm-to-fork. The resilience of the food supply chain can be defined as the "ability of a supply chain to *absorb* disturbances and *adapt* to return to its original state or *transform* to a new more desirable state after being disturbed". Some of the key challenges within this theme are issues related to: 1) *Environmental disasters*, which could impact different stages of the supply chain from production to logistics and distribution and thus, the supply of food. 2) *Traceability risk*, which includes supply chain transparency related to food quality, origin of food, fair contracts, compliance with sustainability standards, food fraud, bio-terrorism. 3) *Food loss and waste*, which include post-harvest loss at farm level and food waste (as well as nutrient loss) at various stages of the supply chain such as during processing, packaging, storage, distribution, retail and at consumption end. Food manufacturing already has a vibrant research and development programme and is well poised to take advantage of the possibilities the STFC Food Network+ has to offer. For example, Pepsico already used the US Advanced Light Source Beamline to carry out X-ray tomography of potato starch pellets to aid new product development[3].

3. Challenges in Improving Nutrition and Consumer Behaviours

The ultimate goal of a sustainable food system is to provide consumers with safe, nutritious, affordable, and appealing foods, whilst reducing waste and demands on land, energy and water. The consumer-side of the food system is paradoxical, with 800 million people hungry while 2 billion people are overweight. In addition, the global population is increasing by 80 million people a year. With people living longer, and a rising demand for more affluent lifestyles, demand is increasing for animal products and processed high-fat, high-sugar foods. This is not only is environmentally damaging, but is leading to an increase in non communicable diseases such as obesity and diabetes. Currently 24.9% of the UK population are obese and it is estimated that more than half the population could be obese by 2050. The NHS is currently spending over £1.5m an hour on diabetes and other conditions that relate to being overweight obese. At the same time, food poverty is on the rise in the UK. 8.4 million people (equivalent to the population of

[1] https://www.gov.uk/government/publications/centres-for-agricultural-innovation/centres-for-agricultural-innovation
[2] https://www.foodsecurity.ac.uk/
[3] https://als.lbl.gov/pepsico-explores-future-food-products-als/

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London) live in households that struggle to get enough to eat. In addition, less cooking is happening now than ever before due to the growing appeal of ready meals and food delivery solutions (such as Amazon, Just Eat etc).

4. The Potential of STFC Data Science to Contribute to Food Challenges

The STFC fundamental research in particle, astro and nuclear physics and space science drive powerful data science expertise. Furthermore the STFC Scientific Computing Department underpins the entire STFC remit and connects with industry through the Hartree Centre.

Astronomy and particle physics are archetypal "big data" research domains. Astronomers construct cameras with many hundreds of megapixels, collecting data from billions of stars and galaxies and make computer simulations of large sections of the Universe which require many millions of computer hours. Meanwhile the particle physicists' experiments at the Large Hadron Collider at CERN register 600 million particle collisions per second, collecting 1Gb of data per second. The plans for the future growth in these areas are huge, with planned CERN upgrades and new astronomical facilities like the the Large Synoptic Survey Telescope and the Square Kilometer Array, which will generate more than 100 times the global internet traffic. STFC scientists are driven to work at the boundaries of technology and to extract the maximum information to push the frontiers of scientific understanding in a highly competitive international arena.

To extract the important information from these vast data sets STFC scientists bring expertise in e.g. archiving and handling datasets with extremely large volumes and rates, building software (and hardware) for processing and calibrating raw data from new and bespoke instruments, image processing and signal analysis, object detection, object classification, and applying machine learning, and related techniques, for classification and regression. In order to use the extracted data to address the fundamental research questions and to understand the confidence they can put on the conclusions they make, they are always pushing the boundaries in the application of statistics e.g. exploiting Bayesian inference methodologies for the estimation of model parameter estimation, building complex statistical models through hierarchical probabilistic modelling, and selecting the best models that are just-complex-enough to explain the data, exploiting Bayesian evidence techniques. STFC scientists are always pushing the limits of these data analysis methods to e.g. make more complex models with thousands of parameters, combining more complex data sets, and having to provide faster algorithms to do the calculations on finite computational resources. In developing physical models of the processes they are studying, STFC scientists will also push the limits of computational solutions to complex mathematical models e.g. in the hydro-dynamical modelling of the evolution of galaxies in the Universe with computational models requiring the simulations of billions of particles of gas and dark matter.

The STFC fundamental research fields also attract some of the most numerate and computationally skilled scientists. These are people who are able to access a vast "toolkit" of methods originating from mathematics, computer science or other disciplines and are experienced in applying (and adapting) these methods to real research problems and fully understand their strengths, weaknesses and appropriateness for the task.

4.1 The Potential of STFC Data Science to Contribute to Sustainable Food Production

Agriculture generates a wide variety of data types. From arable farm management data on crop type, sowing density and fertilizer and pesticide application rates, to robot, drone or satellite imaging of plants over the season; from livestock and aquaculture genetic information, feed rates and yield, to imaging data inside sheds or across outdoor farms. This data would ideally all be tagged, shared and combined with environmental information including weather, in a way that would allow cause and effect to be understood and then applied in future seasons, tailored to the needs of each organism. However, this dream is still some way from being realised.

There is a technical and societal challenge of collecting all this information in a way that respects the ownership of the individual farmers, but that allows scientific advances in understanding and returns the benefits of this new understanding to both the farmers themselves and the public and/or industry who funded the research. Data sharing practice has undergone a transformation in astronomy in the past twenty years, from small proprietary datasets owned by single research groups, to large surveys that are obliged to make their data available after a set period of time in an accessible way. This has required additional resources, but has allowed a new generation of ground-breaking research to be done by people who were not involved in the data collection. Perhaps some STFC experience could be useful in mapping out a culture shift in agriculture data management.

Earth observation satellite data from Sentinel and other missions provide information at optical to infrared and radio wavelengths and length scales of a few meters. These can be combined to provide information on plant biophysical parameters, soil moisture, vegetation type and plant stress indicators. Soil moisture is typically estimated at a spatial resolution of 2km, yet farmers need to understand its variability over a few meters. Although their telescopes point up rather than down, astronomers routinely deal with similar types of satellite and ground-based imaging data. The techniques astronomers use to combine data of different resolutions and wavelengths to infer the physical properties of galaxies may thus be directly applicable to earth observations. Machine-learning and citizen science methods for the classification and statistical characterisation of astronomical or earth observations might also be analogous.
STFC data science may also be useful for improving aquaculture and fisheries, for example by monitoring growth in murky conditions or monitoring illegal fishing activities.

Box 2: STFC Newton Agri-tech Programme in China

The STFC Newton Agri-tech Programme is a £12 million initiative over the period of 5 years, to use the UK's expertise in remote sensing, data processing, modelling and simulation in the area of agricultural technology to work with and aid the Chinese farming community (PI: Hugh Mortimer, RAL Space).

It funds the STFC Agritech in China: Newton Network+ which coordinates networking activities and helps identify new priorities (PI: John Crawford, Rothamsted).

The STFC Newton Agri-tech Programme also funds 5 large flagship projects, including one on synthesis of remote sensing and novel ground truth sensors to develop high resolution soil moisture forecasts in China and the UK, using fast neutron detectors of scattered cosmic rays (PI: Simon Pearson, Lincoln).

4.2 The Potential of STFC Data Science to Resilient Food Supply Chains

The food supply chain contains large and heterogeneous datasets and would ideally carry data taken on-farm through to the products on supermarket shelves. The supply chain can contain many steps from farm to fork, with multiple ingredients and farms feeding through into each item sold. To tackle the multiple resilience risks described earlier it would be desirable to model the whole production system, checking the modelling against data where possible, and then test the impact of environmental and other shocks. This is the type of approach necessary for understanding astrophysics data where only a limited number of observations can be taken. The complex data would ideally be assimilated in a coherent way, including details of processing and packaging and waste that occurred along the supply chain. Experience from particle physics research on data protocols, structures and standards could be helpful for this. In this new connected world there is a rich source of additional data, from customers, complaints, social media, Internet of Things and smartphone devices. The complex mathematical modelling of the supply chain, requiring consistency with these data, might also benefit from expertise of the theoretical physicists. Better models could then be used to provide a better outcome for all.

4.3 The Potential of STFC Data Science to Contribute to Improving Nutrition and Consumer Behaviours

STFC data science capabilities could provide innovative solutions to some major consumer-side food challenges around nutrition and measuring of consumption. Currently there is much uncertainty around what people actually eat on a day to day basis, which is problematic for current diet and health policy. We can measure what people purchase, and we can estimate what is eaten and wasted using survey methods such as food diary surveys, through photo records or diet tracking apps. However, these estimations are known to be inaccurate by around 30%. STFC data science solutions could harmonise these many different data sets to create a more accurate understanding of the UK diet.

STFC expertise in machine-learning and classification of images could also be used to identify the food on photos of plates and in fridges and shelves, cataloguing their contents and assessing what is being stored and eaten. This could connect with the Internet of Things to keep track of foods coming in and out of the home, making sure that food never runs out, nor is wasted. STFC data modelling, machine learning, and satellite mapping could also be used to track food throughout the urban environment and help predict how best to transport food (and surplus food), and when food should be in stores. This could extend to examining the UK's urban food security via mapping allotments and other urban farming; or mapping where the best and closest take-away is (and also calculate optimal driver delivery route). STFC data processing and machine learning could also be used in conjunction with a citizen science campaign to create personalised nutrition and dietary advice for each participant. STFC modelling skills could be used to model the mechanistic functions of nutrition in the human body could look at the transformation (cell structure) of proteins, sugars, fats and carbohydrates.

5. The Potential of STFC Technology to Contribute to Food Challenges

STFC develops new technology as needed for its programmes, including gravitational wave detectors, LHC and underground dark matter particle detectors, and telescopes. The STFC UK Astronomy Technology Center (ATC) in Edinburgh designs and builds instrumentation for many of the world's leading telescopes .

Space instrumentation has many constraints that drive innovations which may be useful for spin-outs to the food sector. It must be *robust*, because it must survive accelerations of several *g* and survive the ultra-hard vacuum and hard radiation environment of space. It also has to be *compact*, because physical space is almost always at a premium in spacecraft. Similarly there are drivers for *low mass* and *low electrical power*. These make for portable robust technology for potential application in the food sector, with many applications to food security, food supply chains, food provenance, the quality of food and water, etc.

Examples include: 1) Gas Chromatography / Mass Spectrometry (GC-MS) and variants were developed in space instruments and have already been applied to detecting TB, detecting cancer, monitoring air quality in submarines, and are potentially applicable to detecting complex molecules in the food sector (e.g. furan, ethyl carbamate, chloropropanols, acrylamide, PAHs, PBDEs and PCBs, polybrominated biphenels, bisphenol A, phthalate esters, pesticides, triazole, fungicide simeconazole, pyrethroids, BTEXs, toluene and other residual solvents, moisture damage, sugar compounds). 2) Terahertz technology (THz), both active and passive, has already spun out from the space sector to airport security, non-ionizing, with high opacity for metals and sensitive to polar liquids (e.g. to measure moisture content). It is well-suited to finding contaminants in dry food streams, and active imaging could e.g. count seeds in fruit. Costs are dropping quickly. 3) Infrared and ultraviolet spectroscopy, are already being spun out from the space sector as hand-held robust devices to detect leaks in the petrochemical industry and to measure water quality by measuring the dissolved organic carbon.

Beyond space instrumentation, STFC develops a wide range of technology from spin-outs from facilities research, to experience with blockchain and Internet of Things technology. For example, STFC cryogenics expertise supports the next generation of particle accelerators and cryogenically-cooled instruments for telescopes, underpinned by STFC experience of superconducting radio frequency cavities.

5.1 The Potential of STFC Technology to Contribute to Sustainable Food Production

STFC could contribute to novel detectors and sensors that provide new physical, chemical and biological insights into food, soils and agri food systems. For example, STFC are developing novel hyperspectral cameras for deployment on satellites, miniature versions may be deployable on the ground to monitor crops or to measure the freshness and quality of foods. STFC pioneered detectors working across much wider regions of the spectrum, for example terahertz imaging is now being developed to measure the internal properties of food in real time.

Box 3. AgriRover[4]

The AgriRover prototype shown here was built this year by RAL Space and outfitted for autonomous agricultural monitoring duties by SMeSTech Strathclyde. It is a testbed for mobility, navigation, and sensing technologies to enable unsupervised and autonomous operation in monitoring farms. Some technologies are derived from the development of rovers and satellites for use in space, others are based on cutting-edge sensing and processing methods on Earth.

[4] For more information see https://www.ralspace.stfc.ac.uk/Pages/Agri-rover-project.aspx and http://agribot.dmem.strath.ac.uk/

Novel robotic and autonomous systems too could be used to monitor fields and sense the environment. STFC have world leading capabilities in autonomous systems and robotics and have developed significant elements of the technology being deployed on Exomars, the European Space Agency's robotic system that will explore Mars. For example, the hardware and software developed for Exomars could be used to explore the Earth, in particular robotic technology designed to survive some of the more challenging environments that may be encountered in agriculture systems.

Robust low-mass and low-power GC-MS instrumentation, and its variants, have been developed for multiple space missions. This expertise in detecting complex molecules can be deployed to many areas of sustainable food production, including the detection of pesticides and other contaminants as well as measures of food quality.

5.2 The Potential of STFC Technology to Resilient Food Supply Chains

STFC cryogenics and temperature monitoring could be used to help solve the food loss risks discussed in Section 2 by increasing the efficiency and/or use of cooling in the food supply chain. For example, most problems in the banana supply chain have been found to be due to temperature fluctuations in transport. More non-destructive testing techniques are needed for monitoring food quality along the journey from farm to fork, for food sorting and efficient rejection of unusable items. STFC experience could provide valuable additional tools, from ultraviolet, optical, infrared and terahertz imaging and spectroscopy to GC-MS, and techniques such as hyperspectral imaging and offset Raman spectroscopy (see Box 2). STFC could also contribute in applying blockchain experience address the food traceability risk by increasing the transparency of the food supply chain, potentially leading to a reduction in food fraud and allowing more effective recalls in the case of accidental contamination.

5.3 The Potential of STFC Technology to Contribute to Improving Nutrition and Consumer Behaviours

STFC technology is uniquely placed to tackle some of the biggest consumer-side food challenges around nutrition and consumption. STFC materials imaging capability (with EPSRC functional materials) may be useful to help design better ways for people to cook (pan coatings, better ovens, more energy efficient ovens, stoves and fridges), all helping to get food to the consumer faster and hotter. This could also extend to new packaging innovations (and atmosphere and vacuum controlled environments) and irradiation techniques to help extend shelf life, prevent food waste, and keep food fresher, and healthier for longer. Likewise STFC cryogenics technology could have a major impact on food waste, with translation of cryogenic research resulting in better fridges and freezers. STFC hydroponics knowledge could also be applied to the consumer market and urban farming.

STFC infrared and ultraviolet spectroscopy could be linked to food databases to enable handheld scanning for food quality, or food safety. This same technology, and GC-MS technology and related detectors, could also be used on 'prick/stick tests' of people's blood or urine to identify low levels of nutrients. Another STFC-relevant technology, and an application of STFC data mining expertise, is internet connected devices (e.g. smart bins, smart fridges etc.) that could e.g. reduce food waste.

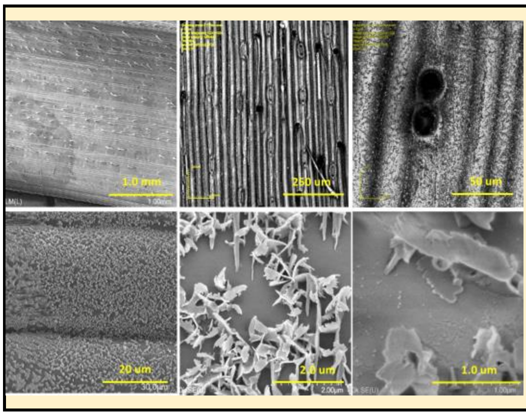
6. The Potential of STFC Facilities to Contribute to Food Challenges

The Science and Technology Facilities Council (STFC) is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide. The council has responsibility to ensure that the UK scientific community has access to the large facilities that will enable it to perform high quality, world leading research now and in the future. These facilities include:

- Central Laser Facility (CLF)[5] which provides world class laser facilities from advanced, compact tuneable lasers which can pinpoint individual particles to high power laser installations that recreate the conditions inside stars
- ISIS, the UK's Neutron and Muon Facility[6]. Neutrons and muons provide detailed information on the structure and dynamics of materials on the scale of atoms and molecules across a very wide range of science areas from condensed matter science to archaeometry.
- Diamond Light Source[7], the UK's national synchrotron. It works like a giant microscope, harnessing the power of electrons to produce bright light that can be used to study a wide range of science such as new medicines to innovative engineering.

6.1 The Potential of STFC Facilities to Contribute to Sustainable Food Production

STFC facilities can be used to provide new structural insights at multiple stages of the food production process. Neutrons have great potential for food research because, unlike X-rays, they can travel through metals but see water. The response of plants to pathogens can be investigated, to understand the mechanism for expression of antimicrobial proteins. So far, mono and bi-layer models have been studied using neutron reflectivity to explore how single amino-acid residue substitutions affect a protein's ability to penetrate lipid membranes[8]. (See also Box 4.) Treatment of animal and human diseases could be improved using new understanding of how bacteria interact. For example, neutron scattering has been used to understand how E. coli bacteria, often associated with food poisoning, kill each other by inserting colicins into the hydrophobic membrane[9]. The insolubility of cellulose in water has been studied using the SANDALS instrument at ISIS by looking at the interactions of water with cellobiose, finding that a hydrogen bond is formed between two sugar molecules in cellobiose[10].



Box 4: Studying surfactants on leaves using ISIS[11]

The impact of pesticides on leaf health has been studied using ISIS neutron imaging of pesticide surfactants penetrating a model for the waxy surface of a wheat leaf membrane.

Left: Microscopic images of the adaxial (top) surface of a 2 week old wheat leaf. Credit: Elias Pambou, University of Manchester, Dr Gordon Bell and Dr Jill Foundling, Syngenta

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[5] http://www.stfc.ac.uk/research/lasers-and-plasma-physics/central-laser-facility/
[6] http://www.stfc.ac.uk/research/our-science-facilities/isis/
[7] http://www.diamond.ac.uk/Home/About.html#
[8] https://www.isis.stfc.ac.uk/Pages/Exploring-membrane-activity-of-plant-seed-defence-proteins.aspx
[9] https://www.isis.stfc.ac.uk/Pages/Ecoli-packs-a-punch.aspx
[10] https://www.isis.stfc.ac.uk/Pages/Watering-the-plants--neutron-insights-into-cellulose.aspx
[11] For more information see https://www.isis.stfc.ac.uk/Pages/Neutrons-could-reveal-how-pesticides-protect-crops.aspx http://rsif.royalsocietypublishing.org/content/13/120/20160396

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6.2 The Potential of STFC Facilities to Resilient Food Supply Chains

STFC Facilities can be used to better understand food during the processing and transport stages[12]. From real-time behaviour of nucleation and crystallization in fats, behaviour and structural characterisation of soft solids to phase behaviour in emulsions, suspensions and gels. This can inform introduction of emulsifiers and complex structures for reducing fat or sugar content in products, and help determine the suitability of novel more sustainable ingredients. Facilities imaging can help to optimise processing conditions to minimise energy and waste and help monitor chemical and structural changes during processing to optimise product behaviour. For example, bubble formation in breads and cakes have been studied using X-rays to understand the impact of different ingredient formulations. Particle sizes in milk and yoghurt have been studied using the SESANS neutron instrument in real-time, to understand implications for shelf-life. Flow and characterisation of powders and liquid systems can be monitored in real-time, as can friction, wear and lubrication in components.

6.3 The Potential of STFC Facilities to Contribute to Improving Nutrition and Consumer Behaviours

STFC Facilities are uniquely placed to investigate food and nutrition at a new level of detail. The Diamond Light Source could be used to study the mechanistic aspects of human nutrition, in the human body and in food products generally. Using the Diamond Light Source and ISIS, transformations (cell structure) of proteins, sugars, fats and carbohydrates could all be analysed with greater precision. This nutritional analysis could enable us to identify new superfoods and methods of nutritional analysis. The STFC analysis could then be harnessed with STFC technologies (programmable matter/nano-robotics) to re-engineer how food is organised and assembled at a molecular level. This could be a major game changer for plant based proteins that taste and feel like meat, creating new types of foods without of allergens (free-from gluten etc), and for product reformulation (higher fiber and lower sugar). STFC Facilities offer the potential to find new methods for foreign body detection, detecting the presence and distribution of trace elements and contaminants (e.g. Box 5), including chemical fingerprinting. Techniques developed at the Central Laser Facility, including spatially offset Raman spectroscopy, have be used to detect chemical signatures through containers, e.g. to detect counterfeit alcohol[13]. STFC Facilities can now be deployed to optimise new foods and perhaps find ways to manufacture more healthy foods that have higher nutritional value as well as reduced fat content.

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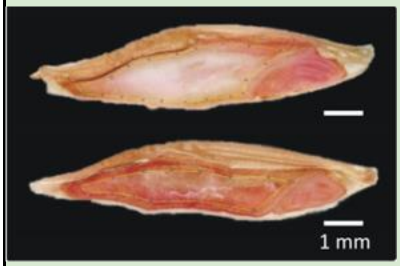
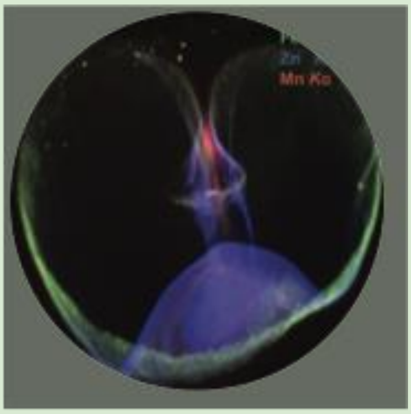
[12] http://www.diamond.ac.uk/industry/Industry-Research-using-Diamond-Synchrotron-Facilities/Food-research-using-Diamond-synchrotron.html

[13] https://www.nature.com/articles/s41598-017-12263-0

Box 5: Elemental mapping of barley



Diamond's I18 beamline was used to measure the X-ray fluorescence spectra of zinc and other elements across 70 µm-thick sections of grains from the engineered and normal barley plants.



The analysis revealed a major redistribution of zinc in the engineered grains, with up to 30% more zinc accumulating in the endosperm of these plants.[14] This has important implications for consumer nutrition when outer layers are removed in milling.

Please visit our website www.stfcfoodnetwork.org to join our mailing list and find out more.

[14] For more information see http://dx.doi.org/10.1111/pbi.12749
http://www.diamond.ac.uk/Science/Research/Highlights/2017/zinc-barley.html
http://www.diamond.ac.uk/industry/Case-Studies/Case-Study-Wheat-Grain-Mapping-XRF-XAS-Rothamsted.html

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