Agri-food capabilities

A comprehensive guide to food and drink capabilities at the University of Nottingham

Contents

£1bn+
spend yearly on R&D in the food and drink sector

Global food and drink challenges

Reducing environmental impact

Creating new products to meet requirements for diet and health

Reduction in sugar, fat and calorie intake while maintaining consumer enjoyment

We will need **140,000 new recruits** in the sector by 2024... to feed an expected **70 million people** in the UK

One of the major global challenges is to feed an additional two billion people by 2050

Tackling over consumption – reducing the **causes of high blood pressure and Type-2 diabetes**

The UK agri-food industry

The Agri-food supply chain employs almost **4 million people**
Source: FDF

Consumer spending of **£203bn** on food, drink and catering
Source: DEFRA

Food and drink exports value more than **£20bn** in 2016
Source: DEFRA

Research excellence to transform the world

Foreword by Professor Dame Jessica Corner

Internationalisation is at the heart of everything we do as a University and as described by the Sunday Times, we are proud to be *"the embodiment of the modern international University."* We collaborate with institutions and businesses from around the world to address global challenge agendas and regard internationalisation as fundamental to our long term partnerships.

Our research brings together talented, passionate and dedicated people as they strive to make discoveries that have a real impact on lives and societies across the world.

Here at the University of Nottingham we have a long-standing reputation for transformative, world-class research. We are home to one of the largest groups of plant, crop, nutrition, animal, consumer and food science experts in the UK together with additional expertise on our campuses in China and Malaysia. Our pioneering, multidisciplinary and collaborative approaches deliver sustainable solutions to global food challenges.

We are poised to build on this reputation with an unprecedented investment in our research and people. This will further enhance our international standing as one of the UK's powerhouses for transformative research. We are expanding our prestigious research fellowship schemes and by attracting and retaining talent we will unlock potential and create teams and global networks with the collective power to transform lives.

We are continually improving our digital resources and infrastructure to match the scope of our research ambitions. Our commitment to world-class facilities underlines our passionate belief in supporting the discoveries that will secure a more sustainable and resilient future.

Our new Beacons of Excellence will build on our world-leading reputation in the fields of human rights, healthcare, agriculture and food, advanced materials and transport, biomanufacturing, and smart industries. All are driven by the need for sustainable solutions to key global challenges, and all are characterised by our transdisciplinary ethos. Working with our partners, these Beacons of Excellence support our goal of raising the profile of research at Nottingham.

One of our Beacons, "Future Food", addresses the challenge of feeding a growing population in a changing world. The programmes within this Beacon will leverage our capability across the whole food system from seed to digestion and will more specifically:

- increase food diversity by introducing new crops, materials and genetic variants to breeding programmes and agriculture
- enhance resilience by improving the yield and quality in the face of environmental challenges such as climate change
- improve nutrition by creating tasty healthier foods; support innovation in food manufacturing processes and consumer behavioural science; raise understanding of the choices made by consumers

By ensuring delivery of the appropriate technology to the farmer, food industry and consumer, our research will translate into solutions for the challenge of feeding the world in healthier and more sustainable ways.

Professor Dame Jessica Corner
Pro-Vice-Chancellor (Research and Knowledge Exchange)

University of Nottingham and the food and drink industry

As the largest manufacturing sector in the UK, food and drink has a fundamental role to play in boosting exports and encouraging a resource efficient and vibrant economy, maintaining our national competitiveness and protecting the UK's Food Security. We need to produce more from less and with reduced impact to meet growing global demand and the consequences of climate change.

Unlocking the full potential of what science can contribute to delivering sustainable growth to the largest manufacturing sector in the UK is a fundamental challenge. This capability document is structured to help the food and drink industry navigate and better access the University of Nottingham's expertise such that its industry-leading knowledge can be applied in helping to address challenges faced by the food and drink sector.

Here at the University of Nottingham we have a long-standing reputation for transformative, world-class research. The University, together with its campuses in China and Malaysia, offers one of the largest groups of plant, crop, nutrition, animal, consumer and food science experts in the UK. Our pioneering, multidisciplinary and collaborative approaches deliver sustainable solutions to global food challenges and the university is ideally placed scientifically, geographically and politically to undertake high-calibre multidisciplinary research from seed to digestion and find new ways of feeding a hungry planet. Our internationally acclaimed research is also focused on the sustainable provision of a safe and secure supply of nutritious food and as such the University of Nottingham has been awarded the Queen's Anniversary Prize for Higher & Further Education. This is in recognition of its cutting-edge research in global food security that helps feed the world's growing population – work which encompasses everything from growing more crops with less fertiliser, to improving the nutrition, safety and taste of food on the plate. The University's investment in food and drink related

expertise will continue to strengthen and further develop the capability of our science base for the future, while allowing cross-disciplinary projects to be undertaken throughout the breadth of the food system.

We also host the EPSRC Centre for Innovative Manufacturing in Food, and with our academic partners are developing the research agenda to ensure that the UK will be the most efficient converter of biomass to deliver safe food for a healthy nation with the lowest environmental impact. The major challenge faced is to future-proof today's supply chain to deal with tomorrow's finite resources, while developing flexible and scalable manufacturing solutions to address consumer requirements of low-cost, nutritionally balanced foods.

The UK food industry, in common with the global food production system, faces fundamental challenges including:

- reducing the industry's environmental impact
- meeting growing global demand
- producing more from less as pressure increases on resources
- mitigating the impacts of climate change
- reformulating and creating new products to meet diet and health requirements

Meeting the challenge to deliver the vision of an innovative, resilient, and resource efficient supply chain while manufacturing high quality, safe and nutritious food at affordable prices will require transformational, technological innovation from the ingredients used to the products made and how they are packaged and transported to customers and consumers.

UK food and drink sector **contributes**
£28.2bn
to the U.K. economy

Source: FDF

UK food and drink sector **employs**
420,000 people

Source: DEFRA

It supports a food chain which **generates**
£112bn GVA

Source: Industrial Strategy White Paper Nov 2017

A global university

We collaborate with institutions from around the world to address global challenges and regard internationalisation as fundamental to our long term partnerships, especially in global food security, energy and sustainability, and health.

Our UK estate: left, the Trent Building, University Park, Nottingham Above, University of Nottingham Ningbo Campus (UNNC) and University of Nottingham Malaysia Campus (UNMC).

It is our vision to be recognised around the world for our signature contributions, especially in global food security, energy and sustainability, and health.

Our UK estate

The University of Nottingham is based on several locations, with our University Park Campus being the largest at 300 acres and is home to the Faculty of Engineering and various Schools such as Chemistry, Pharmacy, Manufacturing, and Psychology. It also includes state-of-the-art human imaging facilities and other related disciplines. This is further complimented by expertise in Life, Health and Medical Sciences with facilities at the University's Medical School Campus. Our Sutton Bonington Campus is home to the School of Biosciences and is today an internationally renowned centre for cutting-edge research in Animal Sciences, Food Sciences, Plant and Crop Sciences, Nutritional Sciences and Agricultural and Environmental Sciences. The School of Veterinary Medicine and Science (the UK's first new Vet School since the 1950s) is co-located with Biosciences, providing seamless multidisciplinary collaborations from soil to digestion. This provides the food and drink industry with easy access to some of the best expertise and facilities anywhere in the world.

Our international campuses

University of Nottingham Ningbo Campus (UNNC)

The University of Nottingham Ningbo Campus was the first foreign owned independent university campus established in mainland China in 2004. Research in China is embodied through our strategic partnership agreement with China Agricultural University (CAU) as its only UK strategic partner to develop joint research and study opportunities in Crop Science, Bioenergy, Nutrition, Veterinary Medicine and Animal Science. This places our partnership with CAU in a strong position to tackle together major global challenges related to food security and health.

University of Nottingham Malaysia Campus (UNMC)

This purpose-built campus at Semenyih, 30km south of Kuala Lumpur city centre co-hosts the Crops for the Future Research Centre Research Centre (CFFRC) – an exciting venture between the Government of Malaysia and the University of Nottingham. Opened in 2011, the centre is specifically designed to evaluate underutilised crops from all corners of the world.

Key initiatives

Industry, government and research communities are transforming the way they work together in delivering a shared agenda for sustainable growth across the whole supply chain from seed to digestion.

UK Government focus

The recently published Industrial Strategy White Paper sets out a long term plan to boost the productivity and earning power of people throughout the UK. The agri-food chain is featured in the strategy, through a commitment to establishing a new Food and Drink Industry Sector Council and through a new 'clean growth' grand challenge to develop cutting edge capabilities in agri-food chain innovation. The aim of which will be to put the UK at the forefront of advanced sustainable agriculture whilst transforming food production, from farm to fork, to deliver benefits to farmers, the environment and consumers and drive growth, jobs and exports.

For further information see www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future

The UK Government through the its Department for Environment Food & Rural Affairs (DEFRA) works with the food and drink industry to help the UK become one of the most innovative food nations in the world. Current focus is on a number of themes intended to increase competitiveness across the food chain:

- Attracting investment into the industry.
- Increasing productivity through innovation, research and development and sharing data.
- Boosting skills and apprenticeships to ensure that the industry has the confidence and capacity to meet the growing demand for British produce.
- Breaking down barriers to trade to enable food entrepreneurs to unleash their full potential and access new markets.
- Strengthening the British brand at home and abroad.

For further information see www.gov.uk/defra

University of Nottingham focus

Beacons of Excellence

Beacons of excellence will champion our field-leading research to tackle global food and drink challenges, characterised by our transdisciplinary ethos. They will drive significant inward investment in to our internationally renowned research areas and support our ambitious vision by increasing collaboration, strengthening networks and partnerships, attracting diverse funding, and raising the reputation of our world-changing research.

Future Food

Future Food addresses the challenge of feeding a growing world population, by providing sufficient quantities of nutritious, safe and palatable food.

Precision Imaging

From a pioneering idea within our Physics department 40 years ago, MRI is now used in 60 million clinical examinations world-wide annually.

Green Chemicals

We believe the next global industrial revolution will witness a step change in the creation of new manufacturing materials, with significant economic rewards for companies pushing the boundaries of biotechnology.

Smart Industrial Systems

In our new industrial age, smart factories will deliver highly personalised goods and services. This demands a profoundly new approach to how we create, manufacture and use products.

Rights Lab

With over 46 million people enslaved around the world today, there is a global political commitment to ending slavery by 2030. University of Nottingham are delivering the world's first large-scale research agenda for defeating slavery, placing Nottingham at the forefront of the UK's pledge to lead this global fight.

Industry focus

Industry focus is now on transforming the long-term health of the population by:

Making healthy foods more pleasurable and pleasurable foods healthier

Creating a more resilient, nutritious food supply better able to cope with external perturbations such as national demographics and climate change.

www.foodsectorprecompetitiveneeds.co.uk

Examples of the challenges for science and technology development are to enable:

- big data and modelling to support decision making throughout the supply chain
- enhancement of resilience by improving the yield and nutritional quality of crops
- enhancement of health through dietary diversification by adopting a 'Food Diversification' approach throughout the food system, taking a range of raw materials from primary production to manufacture of high quality, nutritious and sustainable food
- evaluation of the impact of sensory, economic and social factors in healthy food choice decisions and how these can help shape new food solutions
- a reduction in sugar, fat and calorie reduction while maintaining consumer enjoyment
- valorisation of side-stream materials to produce sustainable, high-value, nutritious food ingredients
- the creation of flexible and scalable manufacturing solutions for premiumisation and personalised nutrition

Priority areas wheel: A safe, secure food manufacturing supply chain — Food safety, Authenticity and traceability, Understanding changing behaviours/drivers; An innovative resilient food supply chain for 21st century populations — Next generation (integrated) retail, New and smarter ingredients, Smarter packaging, Health and wellbeing through diet; A resource efficient food manufacturing supply chain — Manufacturing of the future, Waste minimisation, Energy and water.

Download a copy of the precompetitive landscape booklet, as developed by Knowledge Transfer Network (KTN), National Technology Platform for Food (NTP) and the Food and Drink Federation (FDF). **www.fdf.org.uk/events/Pre-comp-Food-Booklet-Final.pdf**

Nottingham's research capability matrix

Key themes

- **Primary production**
- **Post-harvest**
- **New ingredients and development**
- **Food engineering and processing**
- **Behaviour, consumer health and clinical applications**

The capability matrix not only identifies the University of Nottingham's expertise across the whole supply chain but also where it sits within the 10 key pre-competitive research areas, as illustrated on pages 10 to 15.

The individual matrix cells indicate just some of the relevant key research capabilities offered by the University. These are discussed in further detail in the categories listed alphabetically, where you can find out more about the academics and their teams carrying out the world-leading research in these areas.

The expertise is colour coded which allows for ease of identification and is referenced to the A-Z categories detailed within the main document, from page 16 onwards.

Top 10 global research areas	Key research capabilities		Key research capabilities		
	Primary production	Post-harvest	New ingredients and development	Food engineering and processing	Behaviour, consumer health and clinical applications
1. Food safety	▪ Animal Infection and Immunity ▪ Animal Science ▪ Centre for Dairy Science Innovation ▪ Diagnostics and Therapeutics Group ▪ Future Food Beacon ▪ Microbiology and Food Safety ▪ Veterinary Science	▪ Centre for Dairy Science Innovation ▪ Future Food Beacon ▪ Microbiology and Food Safety	▪ Food, Water, Waste ▪ Future Food Beacon	▪ Food Process Engineering ▪ Future Food Beacon ▪ Microwave Process Engineering ▪ Microbiology and Food Safety	▪ Future Food Beacon ▪ Nutrition, Diet and Health
2. Authenticity and traceability	▪ Corporate Social Responsibility ▪ Future Food Beacon	▪ Corporate Social Responsibility ▪ Future Food Beacon	▪ Corporate Social Responsibility ▪ Food, Water, Waste ▪ Future Food Beacon	▪ Corporate Social Responsibility ▪ Food Process Engineering ▪ Future Food Beacon	▪ Corporate Social Responsibility ▪ Future Food Beacon
3. Understanding purchase drivers and changing behaviours	▪ Future Food Beacon ▪ Rural and Environmental Science	▪ Future Food Beacon	▪ Future Food Beacon ▪ Human Factors in Manufacturing ▪ Nutrition, Diet and Health	▪ Future Food Beacon	▪ Brewing ▪ Corporate Social Responsibility ▪ Future Food Beacon ▪ Human Factors in User Behaviour and Diet ▪ Nutrition, Diet and Health ▪ Resource Efficiency ▪ Sensory Science
4. Next generation retail	▪ Future Food Beacon	▪ Crops for the Future Research Centre ▪ Future Food Beacon	▪ Future Food Beacon	▪ Future Food Beacon ▪ Microwave Process Engineering ▪ Innovative Manufacturing in Food	▪ Digital Economy Research ▪ Future Food Beacon ▪ Human Factors in User Behaviour and Diet
5. New and smarter ingredients	▪ Chemical Sciences ▪ Crops for the Future Research Centre ▪ Edible Oils and Fats ▪ Future Food Beacon ▪ Model Plants	▪ Future Food Beacon	▪ Biomaterials: Products, Properties and Processing ▪ Bioproducts ▪ Biotechnology ▪ Brewing ▪ Chemical Sciences ▪ Crops for the Future Research Centre ▪ Edible Oils and Fats ▪ Flavour Analysis ▪ Food Process Engineering, Water and Waste ▪ Future Food Beacon ▪ Granular Material Behaviour ▪ Industrial and Biomedical Macromolecules ▪ Microbiology and Food Safety ▪ Nutrition, Diet and Health ▪ Sustainable Proteins ▪ Synthetic Biology	▪ Bioenergy ▪ Biomaterials: Products, Properties and Processing ▪ Food Process Engineering ▪ Future Food Beacon ▪ Granular Material Behaviour ▪ Innovative Manufacturing in Food	▪ Nutrition, Diet and Health ▪ Sensory Science
6. Smarter packaging			▪ Chemical Sciences ▪ GLiCAN	▪ Microwave Process Engineering ▪ GLiCAN ▪ Surface and Nanoscale Analysis of Food and Packaging Materials	▪ Surface and Nanoscale Analysis of Food and Packaging Materials

Top 10 global research areas	Key research capabilities		Key research capabilities		
	Primary production	**Post-harvest**	**New ingredients and development**	**Food engineering and processing**	**Behaviour, consumer health and clinical applications**
7. Health and wellbeing through diet	■ Animal Science ■ Centre for Dairy Science Innovation ■ Future Food Beacon ■ Nutrition, Diet and Health ■ Plant Integrative Biology	■ Centre for Dairy Science Innovation ■ Future Food Beacon ■ Post-harvest Biotechnology	■ Chemical Sciences ■ Future Food Beacon ■ GLiCAN ■ Microbiology and Food Safety ■ Nutrition, Diet and Health ■ Sustainable Proteins ■ Synthetic Biology	■ Future Food Beacon ■ GLiCAN ■ Innovative Manufacturing in Food	■ Biomaterials: Products, Properties and Processing ■ Bioproducts ■ Digestive Physiology and Pathology ■ Future Food Beacon ■ In-body Imaging of Food and Drink ■ Microbiology and Food Safety ■ Nutrition, Diet and Health
8. Manufacturing of the future	■ Agriculture Machine Drives ■ Animal Nutrition ■ Animal Science ■ Centre for Dairy Science Innovation ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ Genomics ■ Model Plants ■ Plant Integrative Biology ■ Veterinary Science	■ Animal Nutrition ■ Animal Science ■ Centre for Dairy Science Innovation ■ Food, Water, Waste ■ Future Food Beacon ■ Veterinary Science	■ Bioenergy ■ Biomaterials: Products, Properties and Processing ■ Chemical Sciences ■ Food Process Engineering ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ GLiCAN ■ Human Factors in Manufacturing ■ Sustainable Proteins	■ Advanced Manufacturing ■ Agriculture Machine Drives ■ Bioenergy ■ Biomaterials: Products, Properties and Processing ■ Biotechnology ■ Brewing ■ Chemical Sciences ■ Food and Biomaterials Rheology ■ Food Process Engineering ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ GLiCAN ■ Granular Material Behaviour ■ Microwave Process Engineering ■ Innovative Manufacturing in Food ■ Microbiology and Food Safety ■ Resource Efficiency	
9. Waste minimisation	■ Adaptive Bioprocessing ■ Animal Science ■ Brewing ■ Centre for Dairy Science Innovation ■ Chemical Sciences ■ Corporate Social Responsibility ■ Crops for the Future Research Centre ■ Food, Water, Waste ■ Future Food Beacon ■ Geospatial Positioning for Farming, Precision Agriculture and Global Food Security ■ Plant and Crop Science ■ Resource Efficiency ■ Sustainable Crops ■ University Farm ■ Whole Systems Analysis	■ Adaptive Bioprocessing ■ Bioenergy ■ Brewing ■ Centre for Dairy Science Innovation ■ Chemical Sciences ■ Corporate Social Responsibility ■ Food Process Engineering, Water and Waste ■ Future Food Beacon ■ Post-harvest Biotechnology ■ Resource Efficiency ■ Synthetic Biology ■ University Farm	■ Chemical Sciences ■ Corporate Social Responsibility ■ Food Process Engineering ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ GLiCAN ■ Resource Efficiency	■ Brewing ■ Chemical Sciences ■ Corporate Social Responsibility ■ Food Process Engineering ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ GLiCAN ■ Microwave Process Engineering ■ Innovative Manufacturing in Food ■ Resource Efficiency	■ Corporate Social Responsibility ■ Future Food Beacon ■ Nutrition, Diet and Health ■ Resource Efficiency
10. Energy and water	■ Adaptive Bioprocessing ■ Brewing ■ Chemical Sciences ■ Crops for the Future Research Centre ■ Energy Efficiency ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ Geomechanics ■ Model Plants ■ Plant and Crop Science ■ Plant Integrative Biology ■ Resource Efficiency ■ Rural and Environmental Science ■ Sustainable Crops ■ University Farm ■ Whole Systems Analysis	■ Adaptive Bioprocessing ■ Brewing ■ Chemical Sciences ■ Energy Efficiency ■ Food, Water, Waste ■ Future Food Beacon ■ Post-harvest Biotechnology ■ Resource Efficiency ■ Rural and Environmental Science ■ University Farm	■ Chemical Sciences ■ Energy Efficiency ■ Food Process Engineering ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ Resource Efficiency	■ Chemical Sciences ■ Energy Efficiency ■ Food Process Engineering ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ Microwave Process Engineering ■ Innovative Manufacturing in Food ■ Resource Efficiency	■ Brewing ■ Energy Efficiency ■ Food, Water and Waste Research Group ■ Future Food Beacon ■ Resource Efficiency

Additional University expertise	Key research capabilities		Key research capabilities		
	Primary production	**Post-harvest**	**New ingredients and development**	**Food engineering and processing**	**Behaviour, consumer health and clinical applications**
Measurement and analytics	■ Animal Population Health and Welfare ■ Big Data ■ Biosensors ■ Chemical Sciences ■ Geomechanics ■ Mathematical Modelling ■ Nanoscience ■ Plant Integrative Biology ■ 3D Imaging through X-rays (MicroCT)	■ Analytical Biosciences ■ Big Data ■ Biosensors ■ Chemical Sciences ■ Mathematical Modelling ■ Nanoscience ■ 3D Imaging through X-rays (MicroCT)	■ Analytical Biosciences ■ Chemical Sciences ■ Industrial and Biomedical Macromolecules ■ Mathematical Modelling ■ Nanoscience ■ 3D Imaging through X-rays (MicroCT)	■ Analytical Biosciences ■ Biosensors ■ Chemical Sciences ■ Food and Biomaterials Rheology ■ Microwave Process Engineering ■ Mathematical Modelling ■ Nanoscience ■ 3D Imaging through X-rays (MicroCT)	■ Big Data ■ Chemical Sciences ■ Magnetic Resonance Imaging ■ Mathematical Modelling ■ Nanoscience ■ Nutrition, Diet and Health ■ 3D Imaging through X-rays (MicroCT)
Ethics	■ Corporate Social Responsibility ■ Food and Agricultural Ethics	■ Corporate Social Responsibility ■ Food and Agricultural Ethics	■ Corporate Social Responsibility ■ Food and Agricultural Ethics	■ Corporate Social Responsibility ■ Food and Agricultural Ethics	■ Corporate Social Responsibility ■ Food and Agricultural Ethics ■ Nutrition, Diet and Health
Politics, policy and economics	■ Animal Science ■ Global Food Security ■ Resource Efficiency ■ Rural Business Research ■ Rural and Environmental Science ■ University Farm	■ Resource Efficiency ■ Rural and Environmental Science ■ University Farm	■ Resource Efficiency	■ Resource Efficiency	■ Resource Efficiency
Innovation and facilitation	■ Animal Science ■ Digital Economy Research ■ Geospatial Positioning for Farming, Precision Agriculture and Global Food Security ■ Geospatial Science ■ Reproductive Biology ■ Rural and Environmental Science	■ Animal Science ■ Digital Economy Research ■ Geospatial Science ■ Innovation Support for Business ■ Rural and Environmental Science	■ Digital Economy Research ■ Geospatial Science ■ Innovation Support for Business	■ Digital Economy Research ■ Geospatial Science ■ Innovation Support for Business	■ Digital Economy Research ■ Geospatial Science ■ Innovation Support for Business
Education and training	■ Animal Science ■ BBSRC Agrifood Training Partnership (AFTP) ■ BBSRC Doctoral Training Partnership ■ Chemical Sciences ■ Continuing Professional Development ■ European Arabidopsis Stock Centre	■ Animal Science ■ BBSRC Agrifood Training Partnership (AFTP) ■ BBSRC Doctoral Training Partnership ■ Chemical Sciences ■ Continuing Professional Development	■ BBSRC Agrifood Training Partnership (AFTP) ■ BBSRC Doctoral Training Partnership ■ Chemical Sciences ■ Continuing Professional Development	■ BBSRC Agrifood Training Partnership (AFTP) ■ BBSRC Doctoral Training Partnership ■ Chemical Sciences ■ Continuing Professional Development	■ BBSRC Agrifood Training Partnership (AFTP) ■ BBSRC Doctoral Training Partnership ■ Chemical Sciences ■ Continuing Professional Development ■ Nutrition, Diet and Health

A to Z of food and drink expertise

Adaptive Bioprocessing

Key contact: Rachel Gomes

Economic incentives are encouraging new approaches to manage manufacturing resources and treat wastes, enabling reuse, recovery of value products and possible safe release into the environment of waste products. Processes where bio-sourced feedstocks or catalysts are used are of particular interest as this is where inherent variability of the bio-input increases the system complexity.

Key research expertise includes: product analysis (including metabolite profiling) to inform process development and optimisation, understanding the impact of biomass variation on natural product's extraction and processing, using process considerations to inform feedstock development, diversifying to the biorefinery concept and obtaining value from waste streams (chemical and energy products).

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Advanced Manufacturing

Key contact: Svetan Ratchev

The Institute for Advanced Manufacturing (IfAM) encompasses a multidisciplinary team of established academics in their respective fields in the UK and at our campuses in Malaysia and China. This provides the foundation needed for research and world-leading facilities to encourage the development of new technologies and systems for production of high-value products within the manufacturing sector.

IfAM is dedicated to supporting UK manufacturing to revitalise the British economy through innovation and collaboration. The research portfolio at the institute presents a unique and holistic approach to manufacturing.

Current research is concerned with developing new technologies and systems for cost efficient, knowledge intensive, high value and environmentally friendly production. IfAM addresses the full product lifecycle from development through to manufacture, usage and disposal.

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Analytical Biosciences

Nottingham's Centre for Analytical Bioscience (School of Pharmacy)

Key contact: David Barrett

Researchers in this Centre apply advanced analytical approaches to investigate complex biological and pharmaceutical problems. Current studies involve the need to analyse multi-component mixtures of molecules in human, mammalian, bacterial, plant or food samples. A major area of investigation is the role of biological metabolites in important biological processes and disease states, particularly using metabolomics.
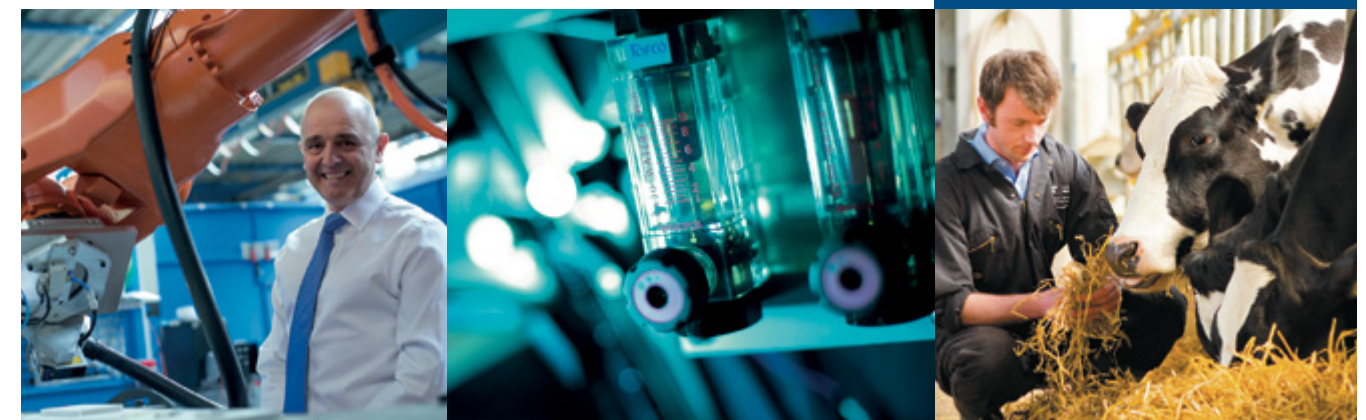
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Animal Infectious Diseases

Key contact: Janet Daly, James Leigh

Research on disease caused by bacteria, parasites, prions and viruses in companion and livestock animals and wildlife species is conducted within the School of Veterinary Medicine and Science. The aim of our research is to understand interactions between pathogens and their hosts to develop disease-preventive measures (vaccines and other therapeutics) and improved diagnostics. Technologies including genomics, transcriptional analysis, proteomics and metabolomics, imaging and epitope identification using next-generation phage display are employed. 'One Virology,' which encompasses researchers from the Schools of Biosciences and Life Sciences and Veterinary Medicine and Science, has four research themes: chronic and persistent infections, emerging and re-emerging viruses, mechanisms of resistance to infection, and molecular epidemiology and disease modelling.

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Pictured opposite: canning in the Food Processing Hall. Below left to right: Svetan Ratchev with an ABB robot system, the Kern 5-Axis micro-milling machine and dairy cattle on the University Farm.

Reproduction

The physiology of reproduction, particularly improving or regulating fertility, is mostly on domestic mammalian species, but we relate findings to human and animal medicine. We study the pituitary-ovarian-uterine axis, including oocyte development, folliculogenesis, ovulation, formation of the corpus luteum, maternal recognition of pregnancy, conceptus development and the impact of assisted reproductive technologies (ART) in the long term health of animals.

Development

The team are investigating the developmental mechanisms involved in generation of pluripotent cells. Our aim is to understand the molecular basis of pluripotency, and use the strategies employed by the embryo to recapitulate these events in laboratory conditions that will enable the manipulation of somatic cells. We use pig embryonic stem cells to serve as a valuable model for gene targeting and for the generation of animal models of human disease. We use chicken embryos as a model system for studying development by examining growth factor signalling in muscle development, microRNAs in myogenesis, origins of adipose tissue, and regulation of limb muscle formation.

Epigenetics

Ongoing research is addressing how maternal nutrition can programme foetal development and adult health via heritable epigenetic changes to DNA methylation. In addition to mammalian work, the honeybee is used as a model organism. Changes in the activity of honeybee genes have been linked to one of the recently banned neonicotinoids that may affect energy metabolism and the stability of developmental processes that could augment the impact of additional stressors such as pests, disease and bad weather and influence bee health.

Neuroscience

Our research goals are increasing the understanding of pain systems, how they are modulated following injury/inflammation and how best to treat pain. The group are founder members of the Arthritis Research UK Pain Centre (Nottingham) established to increase the understanding of arthritis pain mechanisms and its treatment.

Bioethics

Our team is amongst the few international groups of researchers who focus on animal, agricultural and food ethics. The research being conducted is on integrated biotechnology assessment and policy-making; development of ethical tools; ethical dimensions of the human use of animals, making science public and the role of stakeholder engagement.

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Pictured opposite: Lely Astronaut robotic milking machine. Right: inside the dairy shed, University farm.

Animal Nutrition

Key contacts: John Brameld, Phil Garnsworthy, Tim Parr, Andy Salter

Livestock Nutrition
(Animal Sciences Division, School of Biosciences)

Research includes all aspects of the animal production chain from evaluation of feed raw materials, through responses to nutrition in terms of animal performance, fertility and health, to enhancement of milk and meat quality. Emphasis is on dairy and beef cattle, sheep, pigs and poultry. A major objective is to improve feed efficiency in livestock production systems whilst reducing their environmental impact and improving product quality.

Meat Science
(Nutritional Sciences Division, School of Biosciences)

As a result of better agricultural and food processing methods and improved public health, the world's population has reached seven billion and anticipated to reach nine billion by 2050.

This projected population increase will involve an additional annual consumption of 200 million metric tons of meat. Research in this area includes: molecular aspects of protein and enzyme biochemistry with particular relevance to muscle structure and function in farm species; the function of the calcium-activated proteases in muscle growth and in meat tenderness in pigs and in ruminants; identification of SNP's of relevance to meat quality and growth; the potential role of other proteolytic enzymes in the development of tender meat and the effect of modifying the composition of feed to enhance tenderisation and thereby meat quality.

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Animal Science

Animal Sciences Division, School of Biosciences

Key contacts: Phil Garnsworthy, Cormac O'Shea, Kevin Sinclair

The Animal Sciences Division has an international reputation for research in animal nutrition, development, reproduction and biotechnology. Research in Animal Science focuses in six primary areas:

Animal production

Our focus is on major livestock species by studying feed efficiency and sustainability in animal systems, nutritional strategies for enhancing dairy cow fertility, nutritional value of dietary raw materials, environmental impact of methane emissions, effects of exposure to environmental chemicals on development of the foetal hypothalamic-pituitary-gonadal axis and product quality – e.g. modifying fatty acid profile of milk – through changes to diets.

Animal Population Health and Welfare

Key contacts: Paul Barrow, Malcolm Cobb, Gary England, Martin Green

A number of projects are examining how early environment – and interactions with the genome – may influence susceptibility to non-communicable disease such as obesity, metabolic syndrome and hyper-tension. Nutrition is the predominant environmental variable that is manipulated. Species groups investigated include: companion animals; production and performance animals; laboratory animals; zoo, wildlife and exotics. Expertise includes: epidemiology and statistical biology; study design and epidemiological modelling, bioinformatics, molecular epidemiology, evidence-based veterinary medicine and laboratory diagnostics.

Big Data

Informatics, Intelligent Modelling and Analysis and Nottingham Geospatial Institute and the Advanced Data Analysis Centre

**Key contacts: Ian Dryden, Richard Emes**

The availability of very large data sets, together with smart technology, is enabling advances in information technology applied to the food sector including: geospatial mapping for smart agriculture; geospatial risk assessment re: species and pests; genetic trait diversity in animal and crop breeding; crop selection and climate change analysis, and smart sensing devices.

The Advanced Data Analysis Centre (ADAC) was established in 2012 in the University of Nottingham to provide a vital infrastructure service to undertake advanced data analysis in multi-disciplinary contexts, without requiring fundamental research into the data analysis itself. ADAC offers skilled data analysis expertise, across the entire portfolio of academic subject areas and application context, which can be utilised by anyone within the University. It is increasingly the case that the data being generated by research projects in all academic areas within the University is growing in size and complexity, and that the requirements for appropriate analysis of this data are becoming more sophisticated.

The remit of ADAC is to analyse such complex and large data sets assembled by University researchers. 'Complex data' is specified as being beyond the normal comfort-zone of the researchers possessing the data; it is recognised that academics from various disciplines possess differing skill levels and ADAC provides services as required by the client end-users. ADAC has found significant demand from within the domain of food and drink and in particular responding to requests to assist with large genetic datasets from various food sources – such as rice, barley and tomato plants.

ADAC also provides training in data analysis, assistance in preparation of academic publications and funding proposals, and consultancy services to industrial partners. By providing a permanent central data analysis service across the University, ADAC is able to supply data analysis on a bespoke basis to individual projects without restriction on quantity or duration of analysis required, obviating the potential problem of attempting to appoint short-term data analyst posts.
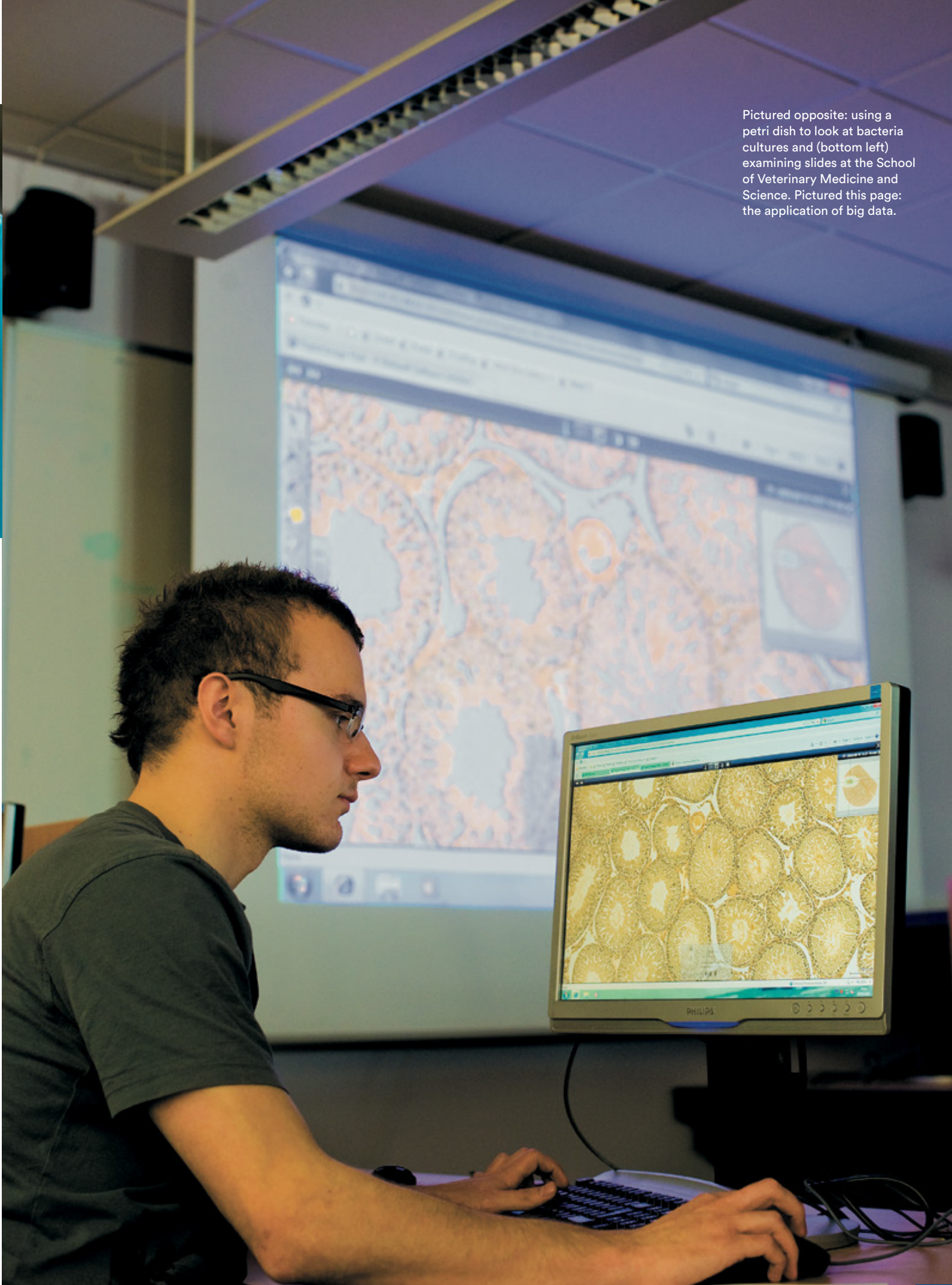
Bioenergy

Bioethanol
Key contact: David Cook, Louise Dynes

Our expertise includes brewing science and microbial physiology, the breeding of improved crop strains that can promote optimal biofuel production and the science and technology of fuel utilization. Our team are developing a co-ordinated multi-disciplinary study of biofuel generation from brewers spent grains between scientists at the University and five industrial partners. In addition, our Food and Biofuel Innovation Centre has an area dedicated to biofuel and has equipment to develop new and efficient ways to turn waste and non-food agricultural products (for example wood and straw) into alcohol for use as fuel.

Biobutanol
Synthetic Biology Research Centre
Key contact: Nigel Minton

One of the research areas in the Synthetic Biology Research Centre is on the generation of liquid transportation fuels and other chemical commodities from renewables using microbial fermentation. Professor Minton's research is especially relevant to the production of second generation biofuels, and in particular biobutanol. This is being achieved through the application of advanced gene technologies to improve both the yield of fuel by the process organism, as well as enhancing its ability to degrade lignocellulose.

Biomaterials: Products, Properties and Processing

Key contacts: Tim Foster, Jo Gould, Chung Lim Law, Bettina Wolf

Understanding how food microstructure evolves during processing from ingredient to product and how it affects in-use characteristics plays an important role in the design of healthy safe-to-eat foods with good sensory properties. Our expertise encompasses processing and analysis of low moisture to high moisture products as well as lipid based foods such as spreads and chocolate. Our processing and property analysis suite is available for use and includes thermomechanical extrusion, comminution, spray drying, retorting, thermal analysis techniques, spectroscopies, rheology, texture analysis, interfacial tension, particle size and wet chemistry. Research is conducted into the interplay between food or animal feed and the digestive system with respect to microstructure deconstruction following ingestion and its impact on sensory properties, energy and nutrient uptake – which in some instances is desired to be delayed. Microstructure design expertise includes interfaces in foam, emulsion and suspension based products; emulsions, suspensions and starch based products through processing with or without shear understanding hydration and plasticisation.

The Food Structure research theme performs fundamental and applied research into the creation, evaluation and understanding of the structure of foods, pharmaceutical systems and biomaterials. The main expertise of the Group is the creation and characterisation of biopolymer-based structures over a range of water contents, from solutions and gels to low moisture glassy systems, although more recently, it has developed substantial expertise in sugar and fat based confectionery systems and emulsions.

One of the strengths of the group is its extensive interaction with industry. This involves companies of different sizes (from SMEs to large multinationals) from different sectors (ingredients, food manufacturing, process equipment, analytical equipment, etc.). The Food Structure group also collaborates extensively internationally, most recently through the European Polysaccharide Network of Excellence which is committed to integrating polysaccharide research across the European Union. The group already has first class equipment for the physical characterisation of foods, ingredients and other biomaterials (see facilities) and this will be further strengthened through access to techniques residing with other partners in the Network.

Key contact: Rachel Gomes

Economic incentives are encouraging new approaches to manage manufacturing resources and treat wastes to enable reuse, recovery of value products and/or safe release into the environment. Processes where bio-sourced feedstocks or catalysts are used are of particular interest, where inherent variability of the bio-input increases the system complexity. Key research expertise includes: product analysis (including metabolite profiling) to inform process development and optimisation, understanding the impact of biomass variation on natural products extraction and processing, using process considerations to inform feedstock development, diversifying to the biorefinery concept, and obtaining value from waste streams (chemical and energy products).

Key contact: Chung Lim Law

The Food and Bioproduct Processing Centre is a joint UK/Malaysian campus venture, and focuses on processing foods and bioproducts including fruits and vegetables (salak, ciku, chempedak, durian, jackfruit, kiwi and papaya); herbal products (ganoderma and misai juching); agricultural products (paddy and cocoa beans); biopolymers such as alginate as well as high value products such as edible bird's nests. The Centre is currently collaborating in: assisting a noodle company, exploring new beauty and healthcare products derived from edible bird's nests; assisting the Ministry of Health in formulating guidelines on the safety and quality of edible bird's nests.

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Bioproducts

Key contact: Anna Croft

Our general expertise is in biological oxidation and prevention. Oxidation can result in the accumulation of free radicals in the body which can cause adverse effects on lipids, proteins and DNA. Food components, such as phenolic compounds, act as antioxidants which can reduce free radical intermediates. Understanding antioxidation mechanisms of naturally occurring polyphenols (e.g. in Irish seaweed) and complementary combinations (polyphenol-proteins) is important in food formulation and in improving nutraceutical capacity. The team also specialise in the use of ionic liquids for extracting natural bioactives.

Biosensors

Key contact: Serhiy Korposh

The team is involved in the development of fibre optic chemical sensors with a functionalised sensitive layer to detect specific chemical compounds in liquids and in air. Specific applications of the work include detecting indoor/outdoor air contaminants, measuring bulk refractive index change of a liquid sample in real time, and in monitoring chemical and bio compound binding reactions and deposition.

Pictured: testing the temperature resilience of Rice Plants in the Rice Growth Room, Plant Sciences, Sutton Bonington.

Biotechnology

Key contacts: Ian Connerton, David Cook, Chris Dodds, Paul Dyer, Tim Foster, Rupert Fray, David Gray, Phil Hill, Jon Hobman, Nigel Minton, Chris Powell, Cath Rees, John Robinson, Graham Seymour, Gill Stephens

The work at the University of Nottingham in the area of biotechnology spans faculty structures but is focused on the state-of-the-art developments in understanding the genetic origins of behaviours and functional materials produced from plants and microorganisms. Such developments will be valuable in the pursuit of creating value-added materials from natural resources. Past work has focused on the area of second generation biofuels created from fermentation of materials from lignocellulosic origin, but this is being expanded into the production of valuable materials and chemicals from yeast and bacterial fermentations, and the use of plant genetics and breeding programmes for plants as chemical factories. Work also focuses on the development of novel ways to control and detect bacterial pathogens, creating new diagnostics and therapeutics.

Brewing

Key contacts: David Cook, Chris Powell, David Quain, Rod White

The University of Nottingham is a centre of excellence for brewing technologies delivering outstanding value, research and teaching to the brewing industry through internationally recognised excellence. Our scientists work with the brewing industry to meet the challenges of the 21st century; researching novel process developments targeted towards increased sustainability, efficient resource usage and minimising waste or effluents. The approach is truly multi-disciplinary, providing new solutions by bringing together expertise in crop science, malting, brewing, sensory and consumer science, engineering, novel materials and environmental science.

Based in the Bioenergy and Brewing Science Building, the centre houses brewing science laboratories which contain their own mini experimental brewery and also have access to international brewer SABMiller's pilot plant which is co-located in the building. SABMiller uses its pilot plant to develop its own products and for research into the brewing process.

Pictured: the live fermentation of bacteria consuming carbon monoxide - Life Sciences, BioEnergy. Right: Brewing Science laboratory, Sutton Bonington campus.

Centre for Dairy Science Innovation

Key contacts: Martin Green, Phil Garnsworthy, James Leigh, Jean Margerison

The Centre for Dairy Science Innovation (CDSI) builds on the University of Nottingham's existing strengths in this area and brings together existing expertise in Dairy Science, Dairy Herd Health and Welfare and Dairy Food Science. CDSI was formed in spring 2016 as part of the national "Centre for Innovation Excellence in Livestock" (CIEL), one of four UK Centres of Agricultural Innovation created by funding from Innovate UK. The formation of CDSI sees a substantial investment in the dairy facilities at the Sutton Bonington Campus, considerably expanding and redeveloping the existing research unit, creating internationally leading dairy science research facilities.

The new facilities will encompass three principal components, a nutritional research unit, a flexible housing unit and a Category 2 containment unit. The nutritional research facilities will allow nutritional studies with up to 100 individually-fed high-yielding dairy cows (dry and lactating) and heifers to test nutritional products, concepts and systems. Dietary treatments can include a variety of forages, compounds and straights. Animal responses will include milk production and composition, feed intake and live-weight change, but can be extended to measures such as blood metabolites and hormones, rumen function, digestibility, greenhouse gas emissions, reproduction and health indicators, feeding behaviour and milk fatty acid profile.

Green and sustainable technologies developed in School of Chemistry are being applied to challenges in the food industry to help control waste and resource depletion

Chemical Sciences
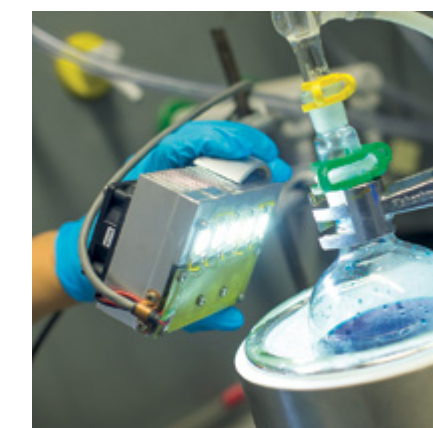
Key contacts: Trevor Farren, Steve Howdle

The Chemical Sciences make a pivotal contribution across a wide range of areas in the food and drink industry. Chemistry – and sustainable chemistry in particular – is already aiding the design of more environmentally friendly pest control methods, fertilisers and additives to enhance plant growth and development. Modern analytical techniques are being employed to analyse the composition of soils and identify components within foods and beverages. A fundamental understanding of chemical interactions is critical across a range of food and drink related areas including aromas, flavours, processing, preservation, storage, safety, quality, nutrition and packaging. Chemistry also aids in the design and understanding of new ingredients such as replacements for fats and sugars.

The School of Chemistry is recognised internationally for its pioneering research portfolio with 95% of our research activity judged to be 'internationally excellent' or 'world leading' (REF2014). The School has 47 academic staff, 160 postgraduate students, and 60 postdoctoral fellows.

Building upon its acknowledged strengths, the school has established a Centre for Sustainable Chemistry and Processing. This encompasses a GSK Carbon Neutral Laboratory for Sustainable Chemistry (see page 26), a Centre for Doctoral Training in Sustainable Chemistry (see page 28) and is the focus for the Sustainable Chemicals and Processes industry forum (Page 28).

Researchers work together with the chemical-using industries to embed sustainability within manufacturing processes, minimise energy usage and adopt new types of renewable feedstocks. We work towards cleaner chemical synthesis with new and efficient catalysts – including bio-catalysts – as tools, leading to a wider range of accessible products and new materials. We also develop alternative processing and reaction solvents, including ionic liquids and the use of supercritical carbon dioxide as a clean solvent for polymer synthesis and materials processing. The school also has major projects working towards novel routes to new renewable polymeric materials from wood and citrus waste.

Our aim is to transfer new technologies and approaches from academia into industry, in order to create real, global impacts. We work across a broad range of manufacturing sectors including pharmaceuticals, fine chemicals, agrochemicals, energy (including bioenergy and biofuels), advanced materials, industrial biotechnology, synthetic biology, food science and fast moving consumer goods.

Industry engagement and technology transfer are facilitated by the school's integrated Business Partnership Unit, which comprises professionals from both academic and industrial backgrounds with an expertise in business and innovation. Our flexible approach provides the opportunity to engage in projects with companies of any size on work ranging from feasibility studies all the way through to large scale collaborative projects.

Previous work within this sector has included: sustainable approaches to processing and valorising waste biomass, understanding the chemical and physical mechanisms of aging processes in food and drink products, enzymatic processes for the wine and food industry, and extraction of bioactive chemicals from crops. We also investigate methods of manufacturing new polymers and biomaterials and use spectroscopy and computational analysis to understand the behaviour of complex biomolecules including proteins (enzymes) and nucleic acids.
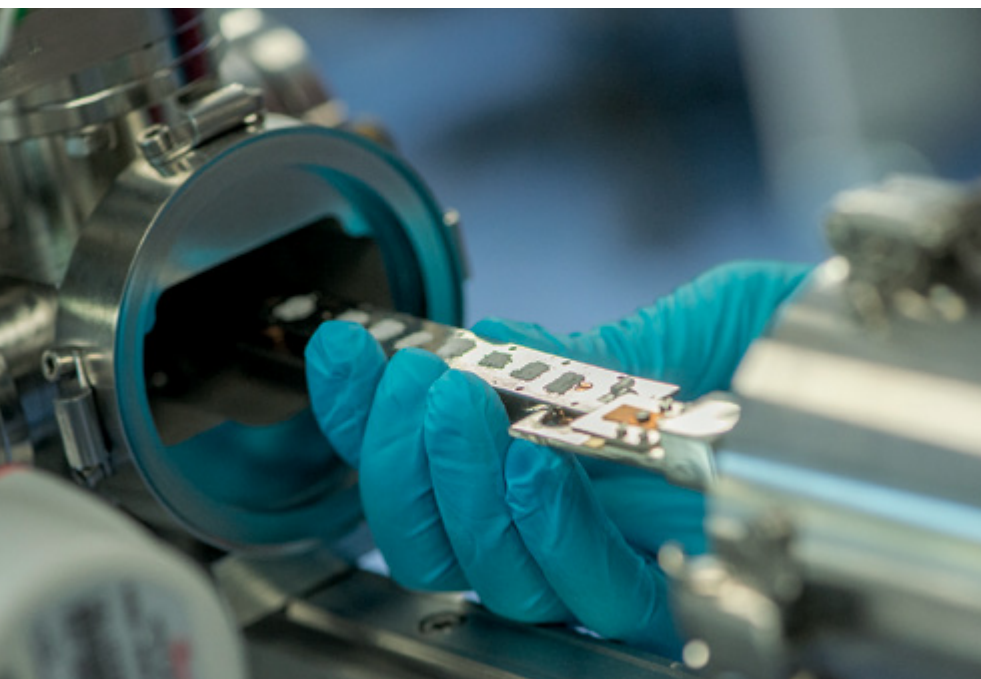
Analytical Facilities within the School of Chemistry

The School of Chemistry possesses an extensive range of state-of-the-art analytical equipment for the analysis of small molecules, materials, surfaces and for the study of biomolecules. Some of these techniques are listed below:

- Small molecule characterisation: nuclear magnetic resonance spectroscopy (NMR), mass spectrometry (MS) including LC-MS-MS, GC-MS and MALDI-TOF capability, X-ray diffraction (XRD), elemental analysis, infrared and raman spectroscopy, EPR spectroscopy, gas, liquid and ion chromatography

- Bulk characterisation of the structure and material properties of solids, including polymers, microcrystalline powders or other materials: solid state NMR, powder XRD, thermogravimetric analysis (TGA), differential scanning calorimetry (DSC) and gel-permeation chromatography (GPC), rheology and viscometry

- Surface chemistry and morphology of solids and liquids: X-ray photoelectron spectroscopy (XPS), scanning and transmission electron microscopy (SEM/TEM), atomic force microscopy (AFM), IR and raman microscopy

- Studies of biomolecules (proteins, peptides) and interactions with small molecules: high-field NMR, FT-ICR MS

There are many techniques available and we would recommend that you contact us to see what we can do to help, some examples of things we have assisted with in the past are:

- Investigation of radical decomposition (this could be linked to aging and fouling in food and drink for example) using EPR spectroscopy

- Residual chemical and trace element analysis using techniques such as GCMS and ICP to identify contaminants in feedstocks or final products

- Determination of vitamin content using HPLC

- Understanding the chemical and physical mechanisms of aging process in food and drink products

- Extraction of bioactive chemicals from crops

- The use of HPLC for the identification of active potential drug targets from natural sources

Fine Chemical Synthesis
Key contact: Anca Pordea

Expertise is in bio and chemical catalysis. The group is looking into the development of novel and efficient catalysts for the sustainable synthesis of organic chemicals, by combining approaches from both chemical and enzymatic catalysis. We investigate the genetic and chemical modification of proteins, their characterisation and their functionality.

Centre for Sustainable Chemistry: The Carbon Neutral Laboratory
Key contact: Pete Licence

The Centre for Sustainable Chemistry is housed in the unique Carbon Neutral Laboratory (CNL). The focus of the CNL, sustainability, is reflected in the building itself which incorporates the latest technologies to allow it to be carbon-neutral over its lifetime. The laboratory is built from natural materials and energy required to run the laboratory is met by renewable sources such as solar power and sustainable biomass. Excess energy created by the building provides enough carbon credits over 25 years to pay back the carbon used in its construction.

The Centre's world leading research focuses on 'clean and green' standards to minimise environmental impacts and ensure that the new chemistry developed is both energy and resource efficient, and sustainable. Research themes within the CNL include; the search for better medicines to improve healthcare in an ageing population, safer agrochemicals to aid food production in a growing population, the application of innovative chemistry based on alternative renewable feedstocks and the use of environmentally benign solvents and reagents, new oxidation chemistry to remove our dependence on metal based oxidants, pioneering use of new techniques and technologies that minimise energy and maximise reaction efficiency, including flow chemistry, microwave heating and solar photochemistry.

Pictured from top: X-ray photoelectro spectroscopy (XPS) and preparing a sample for the NMR machine - Chemistry.

Pictured: Carbon Neutral Laboratory (CNL), housing the Centre for Sustainable Chemistry, Jubilee campus.

Centre for Doctoral Training in Sustainable Chemistry

Key contact: Chris Moody

The Centre for Doctoral Training (CDT) in Sustainable Chemistry is training a new generation of innovative scientists and engineers in Green and Sustainable Chemistry; five cohorts of students over eight years training 60 students in total. Sustainable Chemistry takes a holistic approach to chemical processes, seeking to maximise the use of renewable bio-feedstocks, reduce hazards, minimise energy usage and eliminate waste. Sustainable chemistry aims to make chemistry benign by design.

The focus of the CDT is on three key sectors; sustainable synthesis, continuous manufacturing and renewables. The CDT has been developed in collaboration with companies from each interested industrial sector, including experts in food science, process engineering, biotechnology and life cycle analysis.

Alongside their core research skills, CDT students will develop their professional and business competencies, with industry partners participating in the training programmes. Consequently, students will be equipped for a leading career in the chemical sciences or chemical user community, with emphasis on the skill sets that are required for a more sustainable future.

Examples of CDT projects directly in collaboration with Food and Drink Sciences are; flavour intensity and persistence – and hence consumer acceptability – in low calorie foods, and the use of novel enzymes for enhancement of food and wine aromas.

Nottingham Sustainable Chemicals and Processes Industry Forum

Key contact: Trevor Farren

Sustainability is becoming a critically important business driver across the chemicals and process industries. The forum aims to bring together representatives from business and academia to share experience and best practice in appraising, developing and implementing more sustainable chemical processes, feedstocks and products.

The network aims to:

- influence, via industry input, a body of research in sustainable chemicals and processes
- share good practice, experience and information among participating businesses and between the University and business

The forum will meet three or four times a year with each meeting focused on a different topic/challenge related to sustainable chemicals and processes.

> **The forum aims to bring together representatives from academia and business to share best practice**

Corporate Social Responsibility

International Centre for Corporate Social Responsibility (ICCSR)

Key contacts: Paul Caulfield, Wendy Chapple

The ICCSR was founded in 2002 and has established an international reputation for the quality of its teaching and academic research. The ICCSR team engages in mainstream teaching and research under the following broad headings: strategies for CSR; business ethics; social and environmental accountability; CSR and governance; managing for sustainability. It adopts an interdisciplinary approach and has an international focus. Specialist programmes available through the ICCSR include an MBA in CSR, an MSc in Sustainability, and a PhD programme. The ICCSR is also highly active in practitioner forums and works closely in dialogue with Business in the Community (BitC), Institute of Corporate Responsibility and Sustainability (ICRS), and United Nations Principles for Responsible Management Education (PRME). ICCSR team members are also active in an advisory capacity with a number of leading global businesses and national governments.

Crops for the Future Research Centre

Key contacts: Sayed Azam-Ali, Sean Mayes

Crops for the Future Research Centre (CFFRC) is a non-profit company focused on research on underutilised crops for food, feed, fuel and materials. CFFRC is a joint venture between our UK and Malaysian campuses and the Government of Malaysia. Founded with a US $40m grant that covers infrastructure and wage costs until 2018, CFFRC embeds multidisciplinary research – from genomics to socio-economics and policy – into the design of CFFRC research programmes. Six exemplar programmes have been established, focused on Food Security (Bamyield), Fuels (BiomassPLUS), Complex Agricultural Systems (SystemPLUS), Nutrition (FoodPLUS), Aquaculture (FishPLUS) and Knowledge Systems (CropBASE) aiming to find new products and processes for minor and new crops species.

Diagnostics and Therapeutics Group

Key contacts: Cinzia Allegrucci, Kevin Gough, Lisa Chakrabarti, David Gardner, Catrin Rutland, Katie Woad

The group is focused on the discovery and development of novel diagnostics and therapeutics for life-changing and life-threatening diseases in animals and humans. We use a comparative medicine approach, employing animal models of disease to advance human medicine – and innovative human medicine to advance veterinary practice. This involves a unique combination of evidence-based medicine and cutting-edge tools, including next-generation pathology and pharmacology, bioinformatics and novel in vitro and in vivo models. Together, they enable us to develop advanced diagnostics for early disease detection and inform treatment decisions in modern medical practice. Our work covers a whole range of diseases and species, helping to fight cancer (Cinzia Allegrucci, Kevin Gough), kidney disorders (David Gardner), neurodegeneration (Lisa Chakrabarti, Kevin Gough), cardiovascular conditions (Catrin Rutland) and infertility (Katie Woad).

Pictured opposite: samples from a super critical water rig, Chemistry Laboratory, image top: Future Crop Greenhouses, Sutton Bonington and specialist programmes for corporate social responsibility at Nottingham.

Picture: the human digestive system. ©iStock.

Digestive Physiology and Pathology

Nottingham Digestive Diseases Centre

Key contacts: Guru Aithal, Dileep Lobo, Luca Marciani, Gordon Moran, Robin Spiller

The Nottingham Digestive Diseases Centre (NDDC) is one of the largest and most successful digestive disease research groups in the UK and brings together 31 full-time NHS Consultant Gastroenterologists, Hepatologists, GI Pathologist, Radiologist and Surgeons with 34 clinical academics and 15 full professors – ten of whom are clinical – three associated professors and four lecturers.

The NDDC hosts 32 post graduate research students – clinical and non-clinical. We have a large core grant from The National Institute of Health Research (NIHR) which funds our Nottingham Digestive Diseases Biomedical Research Unit (NDD BRU),

a partnership between the University of Nottingham and the Nottingham University Hospitals NHS Trust. This is the only NIHR funded BRU to carry out translational research in luminal gastroenterology and one of two that includes liver diseases. The infrastructure of NDD BRU provides a facility that includes a four-bed area where volunteers or patients can undertake physiological studies such as Glucose clamp techniques, exercise training or liver stiffness measurements NDD BRU is also supported by eight senior research nurses, four health care assistants, a nurse manager, two sample technicians, a clinical research facilitator, a database manager, bioinformatician and a statistician.

In a long standing collaboration with the Sir Peter Mansfield Imaging Centre (SPMIC), the NDDC carries out research work including the gastrointestinal response to food and beverages, the effect of diet on gastrointestinal function, gut hormones and symptoms, diagnostics as well as clinical randomised controlled

trials of novel food materials and mechanistic studies of symptom causation, with extensive grants from both medical charities, the Medical Research Council and Biotechnology and Biological Sciences Research Council. Recent studies included the gastrointestinal effects of poorly absorbed carbohydrates, dietary fibres, novel food ingredients and the effects of bread's gluten content on gastric emptying. There is also a large programme investigating pre-operative drink supplements and peri-operative fluid management with industrial support. In addition, there are a substantial number of collaborative arrangements with food manufacturers and pharmaceutical companies.

1 in 4
adults in England is suffering from a mild or severe form of obesity
Source: renewbariatrics

Digital Economy Research

Horizon

Key contact: Tom Rodden

Horizon is a Research Institute at the University of Nottingham engaged in Digital Economy Research which brings together researchers from a broad range of disciplines to investigate how digital technology may enhance the way we live, work, play and travel in the future.

Established in 2009, this venture represents an initial £40m investment by Research Councils UK (RCUK), the University of Nottingham and over 100 academic and industrial partners; in both a Research Hub and Doctoral Training Centre within the RCUK Digital Economy programme.

Building on the Digital Britain plan, Horizon research focuses on the role of 'always on, always with you' ubiquitous computing technology. The aim of this venture is to investigate the technical developments needed if electronic information is to be controlled, managed and harnessed, with potential to develop new products and services for societal benefit.

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Edible Oils and Fats

Key contact: David Gray

Our research centres on the general area of edible oil quality and seeks to explore novel ways of delivering healthy oils to foods, with minimum loss to oil quality and minimum impact on the environment. Oils and fats provide certain vitamins, such as vitamin E; contain polyunsaturated fatty acids (omega-3 and omega-6) that are converted in the body into molecules that control important activities for example blood coagulation, blood pressure, membrane functions and reproduction); and carry desirable flavour molecules. When trying to improve the nutritional quality of a food product by increasing the amount of polyunsaturated fatty acids there is an increased risk of the development of off-flavours which must be minimised.

Electrical Drives for Agricultural Machines

Key contact: Chris Gerada

Our research expertise lies in integrated motor-drive solutions for traction, energy recovery actuation and processing. The aim is to generate significant gains in efficiency, fuel savings and reduced emissions which can be attained by moving from traditional mechanical and hydraulic systems to electrical ones. The University's high power density brushless machines, designed by the world-leading power electronics research group at Nottingham, can be applied to food processing, water spraying, tractor traction and other mechanical processes.

Pictured: Sustainable Processing of Oilseeds to Recover Oil Without Using Organic Solvents.
Pictures A and B: 'Imaging Lipids in Microalgae' – Microalgae can synthesise a range of lipids with nutritional value in food/feed.
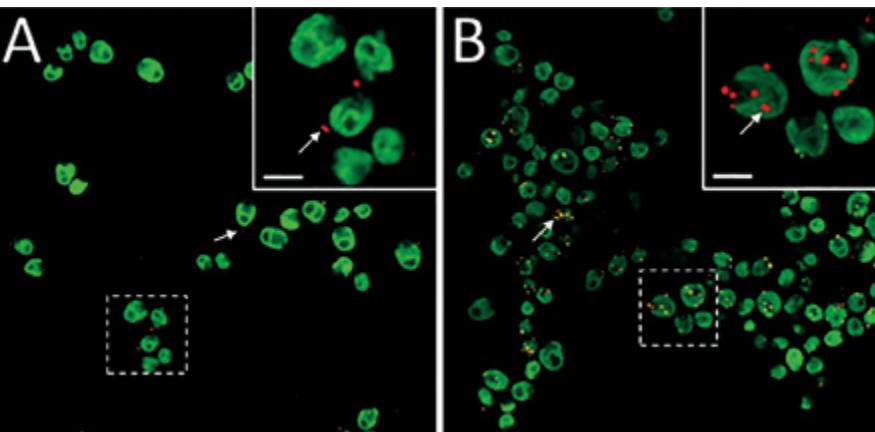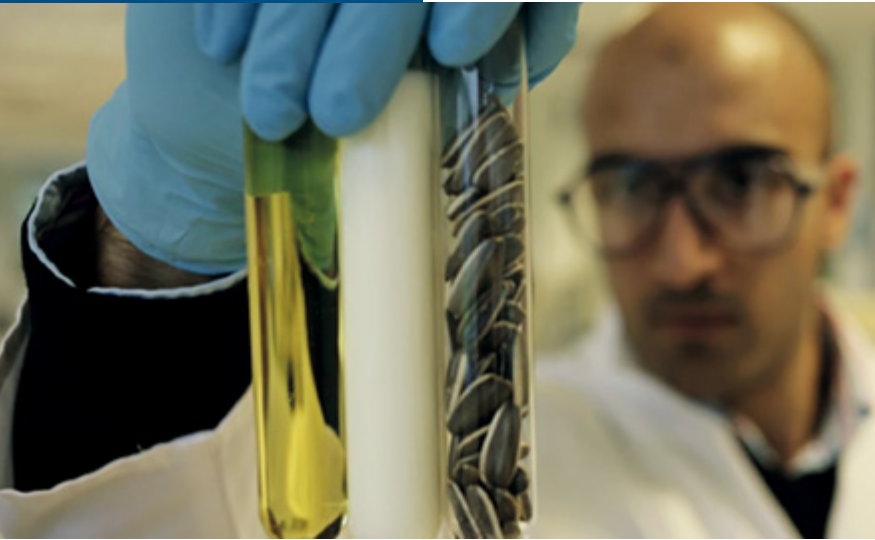
Electrical Energy Efficiency

Key contact: Mark Sumner

Research expertise in this group includes understanding and optimising electrical energy consumption for all processes – lighting, heating, and transport. We are part of the UK's leading power electronics research group that has a strong background in all aspects of electrical energy conversion including ac-dc, dc-dc and dc-ac conversion, motor drive systems – hybrid, all-electric propulsion – operation of micro grids – on and off grid – use of energy storage to optimise use of renewable energy sources – cost, peak power reduction. There are a wide range of high power test facilities available –300kW microgrid, 800kW dynamometer. The group has a strong track record of working with stakeholders to develop prototype solutions at all power levels.

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Food and Agricultural Ethics

Key contacts: Kate Millar and Pru Hobson-West

The Centre for Applied Bioethics (CAB), based across the School of Biosciences and School of Veterinary Medicine and Science (SVMS), focuses on research and training related to the social, legal and ethical issues raised in food and agricultural research and production.

Research capacity includes conducting research on specific themes such as the social dimensions of food technology assessment, food and biotechnology ethics, and the development and application of ethical frameworks to support decision-makers, for example policy and industrial sector. The group is also working with the European Commission's conceptualisation of Responsible Research and Innovation (RRI) and how this might be operationalised in the food and agricultural sector. The centre research group has experience in developing and conducting stakeholder participatory processes and applying qualitative social science research methods. Members of the centre have a wide range of EU, North American and Asian research partners. In terms of teaching, members are also involved in the development of graduate training in food ethics and responsible innovation – development of bespoke CPD is possible.

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Flavour Analysis

Key contact: Ian Fisk

Conventional flavour analyses focus on extracting, identifying and quantifying the volatile and non-volatile components of flavours using GC and LC techniques. This gives information on the flavour composition but does not represent the flavour profiles actually delivered to flavour receptors in the nose and mouth.

Mastication and food structure cause significant changes in the release of both tastants and aromas, creating significant differences in sensory perception. This is one reason why correlations between flavour composition and flavour perception are difficult to establish. For this reason, we have investigated techniques that measure the flavour profiles close to the receptors as well as the way that the profiles change with the time of eating. The online techniques have been used to study the generation of flavours during thermal processing as well as the release of pheromones from insects.

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Food and Biomaterials Rheology

Key contacts: Davide Lo Presti, Bettina Wolf

Rheology deals with the deformation and flow of matter, especially the non-Newtonian flow of liquids and the plastic flow of solids. This branch of physics is important in the context of food and biomaterials processing as most processes involve some sort of flow or deformation of material. Examples include the factory based processes of pumping, dosing, and coating but also extend to oral processing and transport and mixing processes within the digestive tract. The rheological properties of foods and biomaterials are valuable for process and product design. They provide fundamental insights into the material's microstructure as the rheological properties are a response to the application of flow and deformation to the product's specific microstructure.

Rheology is a practical as well as a fundamental tool. The rheology labs across the University offer a wide range of equipment including shear (rotational, oscillatory, capillary), extensional, high and low temperature, and high pressure rheometers, and we are able to offer many years of expertise in rheological analysis of complex fluids.

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Food Process Engineering

Key contacts: Serafim Bakalis, Becca Ferrari, Ourania Gouseti
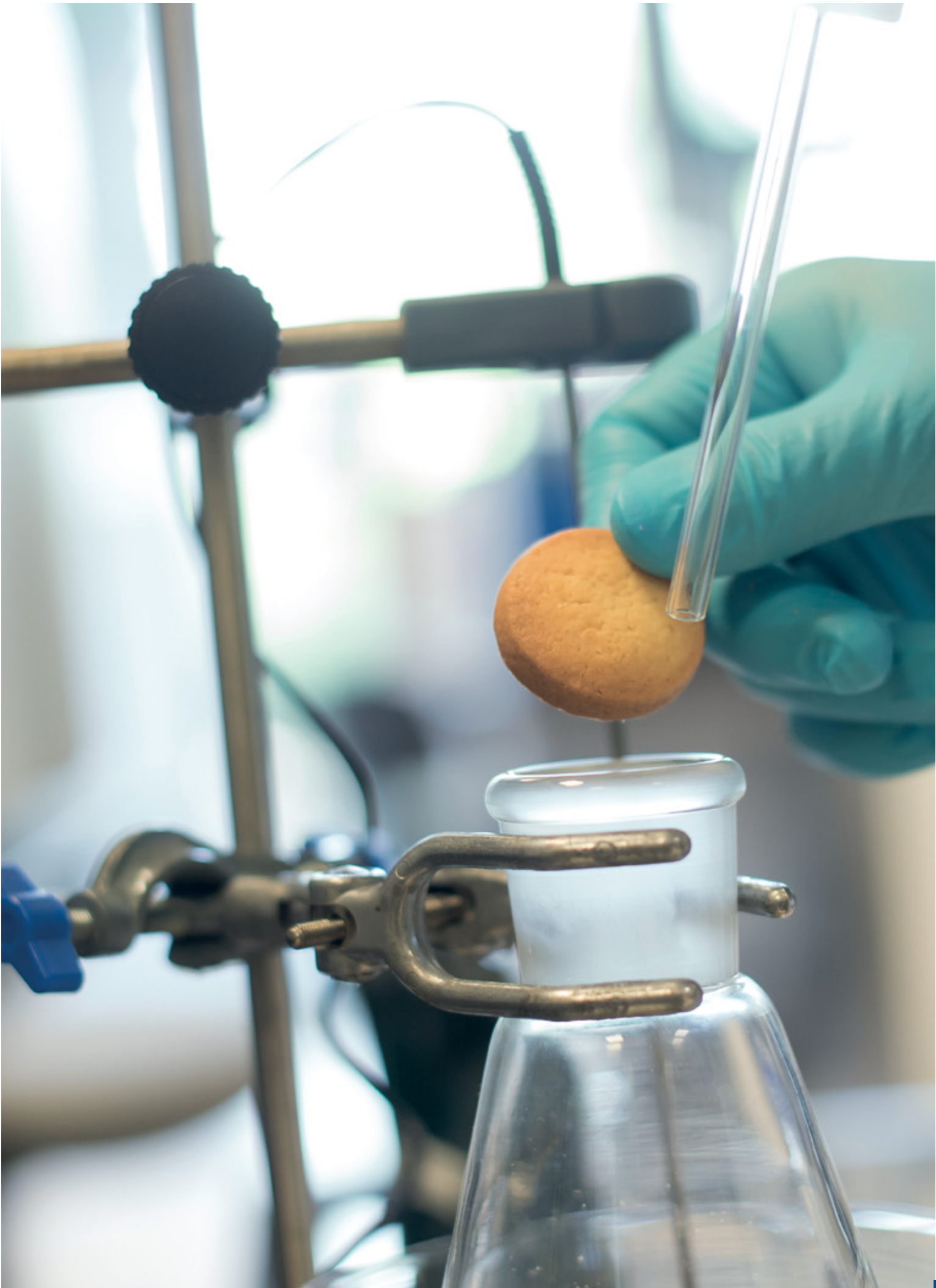
The Food, Water, Waste Research Group has expertise in using numerical (CFD) and experimental techniques to characterise processes, for example heat, mass, mixing and fluid flow, and micro-structures aiming to design small footprint manufacturing processes. We develop understanding of food structure formation and the link between structure and functionality.

The capability of the group spans beyond traditional processing, and it includes use of engineering principles to characterise product performance during consumption, including oral processing. We use unique experimental and numerical methods to understand digestive processes and to link food properties with digestibility and health.

We further work at designing processing trajectories of materials to deliver the desired structures at reduced energy and/or water costs in a flexible manufacturing environment using both established and novel technologies, such as microwaves, plasma and RF processing. We also use these technologies across the food chain in applications such as disinfestation, enzyme denaturing and in-package sterilisation.

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Pictured: GCN - MSMS (Thermo Desorption) Aroma Extraction and analysis, Food Sciences - Flavour Laboratory, Sutton Bonington.

Demand for water is expected to rise by

20%

in the agriculture sector alone by 2050

Source: Industrial Strategy 2017

Food, Water, Waste Research Group

Key contacts: Patrick Cullen, Bettina Wolf, Serafim Bakalis, Becca Ferrari, Helena Gomes, Ourania Gouseti, Nik Watson, Rachel Gomes, Richard Smith, Tim Foster, David Gray, Joanne Gould

Food Process Engineering combines food science and engineering to meet societal and industrial challenges of food production and security. We take an engineering approach to producing novel food products with designed structural or functional properties. Our approach encompasses consideration of waste streams for valorisation and advanced manufacturing processes to provide safe and nutritious foods and co-products. Activities span across the School of Biosciences and the Faculty of Engineering through involvement in Research Council, Charity, and Innovate UK funded projects. The Food, Water, Waste Research Group in the Faculty of Engineering address major industrial and societal challenges in the areas of food, water, and waste, with sustainability and resilience at its core.

Pictured: COD analysis (Chemical Oxygen demand) of samples - Engineering.
Top image ©iStock.

Future Food Beacon

Key contacts: David Salt, Simon Ridgway, Malcolm Bennett, Tim Foster, Andy Salter, Debbie Sparkes, Tony Pridmore, Richard Emes, Matt Loose, Tania Dottorini, Graham Seymore, Darren Wells, Richard Hyde, Marcus Owen, Festo Massawe

Future Food addresses the challenge of feeding a growing population in a changing world.

In the face of climate change we must develop new, resilient crops. Yields must also increase to feed the additional two billion people expected by 2050. Better access to healthier, safer, more nutritious food is needed in all countries due to the growing prevalence of pollutants, nutrient deficiencies and over-processed foods.

Our researchers have expertise across the food chain – from soil to molecule to meal – to deliver sustainable solutions to global food challenges such as 'hidden hunger': less diverse diets, naturally low nutrients in our staple crops, and an increasing reliance on over-processed foods mean that more than a quarter of the world's population are not getting the goodness they need from what they eat.

To provide sufficient quantities of nutritious, safe and palatable food to a growing world population, the Institute for Future Food will focus on two main programmes:

- agriculture resilience
- food for health and healthy ageing

Our experts offer novel solutions to tackling hidden hunger by examining the make-up of soil and its relationship to our health, root systems - how they take up nutrients and block toxins, new ways to adapt plants and farming practices in response to this global challenge.

We are working to develop plants that more efficiently take up and store nutrients from the soil. This allows us to pioneer the development of more resilient crops, to ultimately deliver healthier and more nutritious food and help combat hidden hunger.

Our research into nutrient-smart crops is being applied in collaboration with rice breeders in the USA, India, China and Bangladesh, and brassica – cabbage, broccoli and cauliflower –producers in the UK. Bambara groundnut and other minor crops in Africa and South East Asia.

In China and many other countries, where hidden hunger is prevalent, a huge population is dependent on rice crops that contain relatively low levels of nutrients and are increasingly susceptible to transferring pollutants such as arsenic from the soil to the table.

Pictured above: Measuring Stomata resistance, Future Crop Greenhouse, Sutton Bonington.

Geomechanics

Key contacts: Alec Marshall, Glenn McDowell

Physical compositions of soils can affect plant growth. Hence, work in soil mechanics is crucial in understanding deformations in soil structure and in characterising fluid flow within soil structures. Our expertise includes micro and macro modelling of multi-phase soil structures and their interaction with fluid and plant.

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Geospatial Positioning for Farming, Precision Agriculture and Global Food Security

Key contacts: Marcio Aquino, Chris Hill, Stuart Marsh, Xiaolin Meng, Terry Moore

The team is researching satellite navigation and positioning systems, photogrammetry, remote sensing, sensor integration, integration of large data sets/images, geoinformatics and data modelling, geospatial intelligence, location-based services, semantics, reasoning and cognition. New perspectives on food security and agricultural species diversity with respect to location are being explored by the integration and modelling of a wide range of geospatial resources – for example climate records, ground condition, crop traits – in a "geospatially orientated database." Geolocation-based plant breeding in concert with integrated workflow modelling will greatly support global food security.

The team are also working on addressing issues that affect precision agriculture in food-producing developing countries such as Brazil and India also parts of China, Indonesia to support precision agriculture in large regions of the globe as well as automation of off-road driving and remote platforms. In collaboration with the Animal Sciences Division of the

School of Biosciences, new radio-based ranging systems, data fusion algorithms and effective sensor integration are also being used to track and characterise cow mounting behaviour to detect oestrus and optimise insemination.

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Geospatial Science

Key contacts: Stephen Grebby, Stuart Marsh, Xiaolin Meng

The Geospatial Science group engages in all areas of geoinformatics research, resulting in collaborations across many disciplines and institutions. Research is undertaken in both long term fundamental challenges and shorter term applications-orientated issues and is global in scope. It has experienced strong growth since its launch, building an international reputation for research excellence. In 2009 we were designated an 'Oracle Spatial Centre of Excellence'.

Our current research is focused on these sub-themes:

- Spatial Data Infrastructures (SDI)
- Geospatial Intelligence (GI or GEOINT)
- Interoperability and Standards
- Location-Based Services (LBS)
- Semantics, Reasoning and Cognition
- Geoinformatics and Data Modelling
- Open Source Geospatial Research
- Geo Health Informatics Research

Genomics

Key contacts: Graham Seymour, Sean Mayes, Ian King

The University of Nottingham's researchers originally pioneered the use of transgenic technologies and gene silencing to create the first GM product for sale in Europe. Professor Graham Seymour is among a group of over 300 scientists from 14 countries, who form the Tomato Genome Consortium, which has sequenced the genomes of the domesticated tomato. These advances will help breeders to deliver fruits with improved taste and higher concentrations of nutrients and with better resistance to biotic and abiotic stresses.

The application of molecular genetics to understand crop trait inheritance and then to introduce desirable traits via marker assisted selection allows the development of tailored crop types for future environmentally-friendly production, processing and nutritional needs. Wheat, oil palm and tomato are a few of the crops being researched. Coupling the power of genomics with the ability to deliver the newly determined traits into crops via marker-assisted selection will reduce agricultural inputs, increase sustainability and crop resilience and produce raw materials for new products.

Pictured: Drone used for gathering images for crop health conditions on the University Farm.
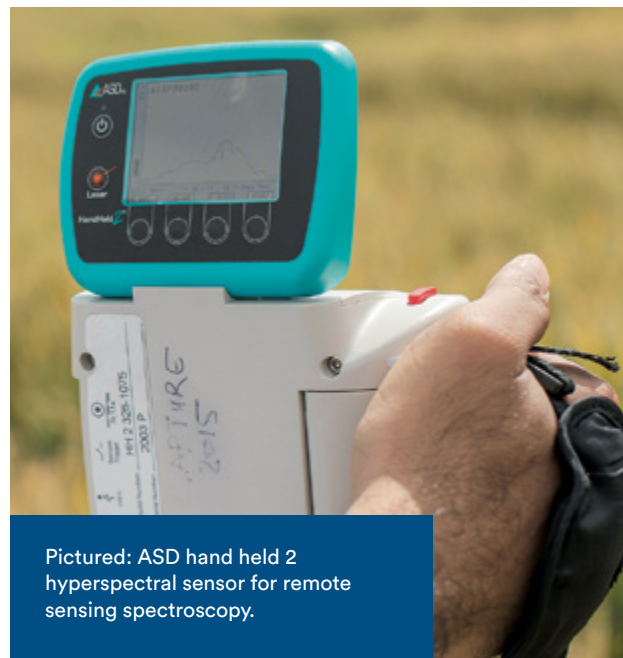
Pictured: ASD hand held 2 hyperspectral sensor for remote sensing spectroscopy.

Global Food Security

Key contacts: Sayed Azam-Ali, Festo Massawe, Zoe Wilson

Food production is an essential element of the world we live in and in the near future will be of increasing significance. Climate change, growing population and scarcity of resources will demand novel approaches to growth of both plant and animal-based foodstuffs. Our research interests utilise expertise in molecular biology, crop physiology and crop breeding and lie both in optimising the nutritional quality of plant foods and the use of plants as a bioenergy source. Our knowledge of animal nutrition, lactation, muscle and adipose tissue biology, and digestive efficiency is directed towards enhancing the performance and feed efficiency of livestock and controlling factors such as meat tenderness, milk fatty acid profile and environmental emissions. Research themes within the Global Food Security Research Priority Group include: waste, distribution and production, societal impact, climate change and environmental impact, governance and policy. It has strong links with the Centre for Globalisation and Economic Policy which has branches in Nottingham, Malaysia and China and which undertakes research on the effects of global trade barriers and agricultural economies.

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GLiCAN – Glycans, Lignins and Carbohydrates at Nottingham

Key contacts: Gary Adams, Steve Harding, Bettina Wolf, Joanne Gould, Tim Foster, David Gray, David Cook, Rod White, Nicola Everitt

The University of Nottingham became members of the European Polysaccharide network of Excellence (EPNOE) in 2005. This strengthened our connections into Europe in an already influential area of research for us. We have developed these areas further in recent times by focusing on the valorisation of food co-streams/by-products, and have identified new material and health functionalities from lignin, fibre and glycoproteins. We are well placed to look at the products of our agricultural technology development, in the conversion of such materials into new ingredients, and to test them in final product formulations.

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> The world will need
> # 60%
> **more food by 2050 to allow us to feed 9 billion people**
>
> Source: Industrial Strategy White Paper

Granular Material Behaviour

Key contacts: Paul Langston, Glenn McDowell and Carol Eastwick

Understanding the particle-scale and continuum scale mechanics of granular materials is important for numerous industries including food.

Modelling the flow of granular material can be done using Discrete Element Method (DEM) which uses numerical integration to solve the dynamics of elements from the forces acting on them over small time intervals. Characterisation of granular flow phenomena is important in predicting powder behaviour and handling during storage and conveying. Recent applications of DEM have concentrated on modelling non-spherical particles including high aspect flexible fibre packing, which could be important in the development of synthetic meat products.

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Human Factors in Manufacturing

Key contacts: Glyn Lawson, Sarah Sharples

Our research focuses on optimising human involvement in production processes and considering the impact of future automated, evolvable and cloud-based technologies on work in the manufacturing context, embracing notions such as Industry 4.0. When designing future manufacturing systems, training with technologies such as virtual reality offers advantages such as improved training efficiency, greater engagement and motivation, ability to train before the factory line has been built. For factory design, virtual reality and other visualisation techniques can support ergonomic design at an early stage in the development process, reducing the costs associated with late changes.

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## Human Factors in User Behaviour and Diet

Key contacts: Sarah Atkinson, Alexandra Lang, Judy Swift

Human factors are experienced throughout the product design cycle and in evaluation of interventions for usability, acceptance and impact. The team are researching the implementation of new technology for healthcare interventions and behaviour change. This includes understanding behaviour around healthy and unhealthy eating to design appropriate technology for improving food and drink choices, the use of technology as a communication tool for behaviour change – patients and clinicians/naïve users and experts – and novel innovation to improve food and drink choices in specialist populations.

Pictured: Oculus Virtual Reality used to determine the human factors in user behaviour and diet.
Below: CT scan of a human gut.
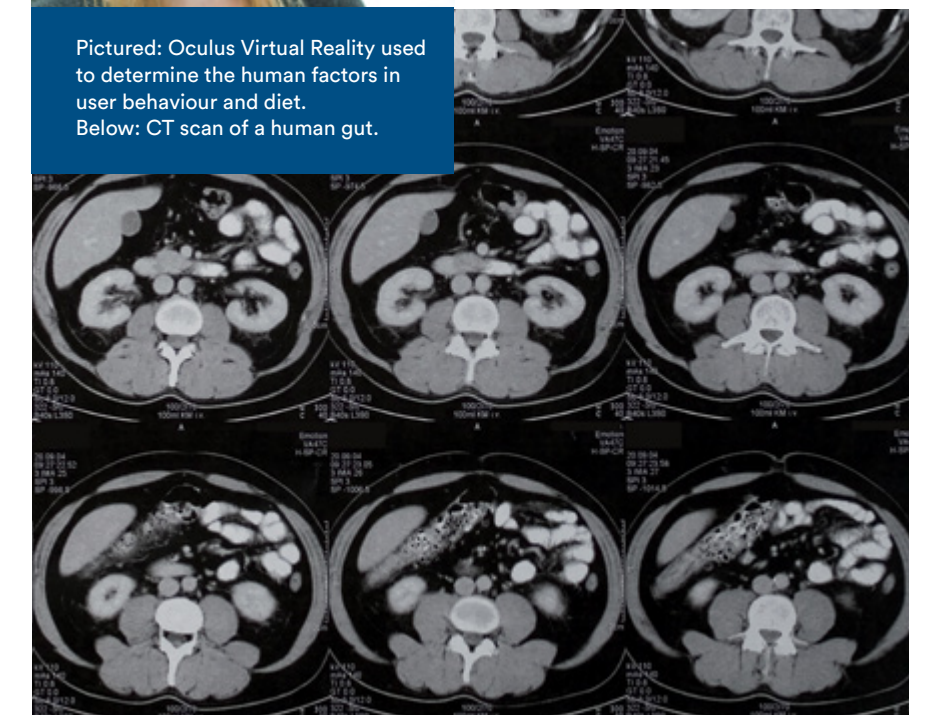
In-body Imaging of Food and Drink

Key contacts: Guru Aithal, Maura Corsetti, Penny Gowland, Dileep Lobo, Luca Marciani, Peter Morris, Gordon Moran, Robin Spiller, Moira Taylor, Ian Macdonald

A long-standing collaboration between the Nottingham Digestive Diseases Centre with its NIHR-funded Biomedical Research Centre and the Sir Peter Mansfield Imaging Centre specialises in imaging gastrointestinal function and the physiological response to food and drinks in humans. This includes non-invasive, in-body imaging of the fate of foods and drinks in the gastrointestinal tract, organ function, gut motility and transit, intestinal distribution of fluids, mechanisms of satiety, gut peptides response to nutrients, blood flow, liver function, magnetic resonance spectroscopy (MRS) of liver fat and hepatic energy metabolites and interactions between the gut and the brain including fMRI of taste, aroma, and oral fat. We have several state-of-the-art, fully research-dedicated MRI scanners. Examples of past industrial collaborations include imaging intragastric gelation of alginates, effect of cholesterol-lowering yogurts on gallbladder contraction and effect of fat emulsions microstructure on satiety.

Pictured: High Performance Liquid Chromatography and below, working on analytical ultracentrifuge to identify macromolecules. Opposite page: Pictured: processing of green leaf material for nutritional ingredients.

Industrial and Biomedical Macromolecules

The National Centre for Macromolecular Hydrodynamics

Key contacts: Gary Adams (Insulin Research); Stephen Harding (Physical Biochemistry and Glycobiology); David Scott (Physical Biochemistry and Archae)

The centre is a facility for the characterisation of the sizes, shapes and interactions of macromolecules of biomedical and industrial importance such as proteins, polysaccharides, DNA, synthetic polymers – in solution. Research is focused into the following areas:

- Crystallohydrodynamics – combining high resolution crystallographic information with solution data for elucidating the solution conformation of molecular assemblies, with particular reference to antibodies

- Therapeutic Polysaccharides – relating solution structure and interactions with bioactivity and mucoadhesion

- Macromolecular Stability –with particular reference to industrial preparations of antibodies and polysaccharides

- Archaea –a distinct domain of life ranked equally with the bacteria and the eukaryotes – we are trying to gain an understanding of the fundamental molecular biology and physical chemistry underpinning these fascinating microorganisms

- Insulin Delivery – using a detailed knowledge of its physico-chemical interactions to help develop a self-regulating insulin delivery route for the treatment of diabetes

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Improving the flexibility of food manufacturing to meet changing consumer behaviours

Innovative Manufacturing in Food

EPSRC Centre for Innovative Manufacturing (CIM) in Food

Key contacts: Tim Foster, David Gray, Bettina Wolf (in collaboration with the Formulation Engineering Centre, University of Birmingham – Professor Ian Norton, and the Centre for Sustainable Manufacturing, Recycling and Re-use Technologies – SMART, Loughborough University – Professor Shahin Rahimifard)

The centre's objectives are to meet the current and future needs of the Food Manufacturing Industry, tackling issues in the four main areas of global need:

- Global food security - providing manufacturing capability for conversion of (under utilised) crops

- Health enabling food structures to be manufactured with nutritional value and optimised nutrient delivery

- Sustainable production – reduced energy and water requirements including, reduce/re-use waste (for valorisation into new materials)

- Evaluate supply chain and business models to maximise the efficiency of food production and supply using advanced manufacturing strategies for example, flexible and distributed manufacture

This will be achieved by focusing on two specific Grand Challenges (GC):

- Innovative materials, products and processes

- Sustainable food supply and manufacture

The Grand Challenges incorporate multi-disciplinary technical input from process engineering, chemical engineering, material science, food science, microbiology and toxicology, life cycle analysis, ICT and advanced manufacturing, and spanning the manufacturing paradigm from the technology/process level through to production and supply chain level.

The connection to industry through support, involvement in the advisory board and links to SME networks, through an interaction with the Manufacturing Technology Centre and clear alignment with the Innovate UK High Value Manufacturing Strategy 2012-2015 will provide exploitation routes for the developments within the Centre. This should provide funding routes for sustainability beyond the first five years EPSRC funding (£5.5m spent on research).

Magnetic Resonance Imaging

Sir Peter Mansfield Imaging Centre

**Key contacts: Peter Morris, Penny Gowland, Sue Francis, Luca Marciani, Caroline Hoad**

The Sir Peter Mansfield Imaging Centre (SPMIC) is part of the School of Physics and Astronomy. It has been conducting research into Magnetic Resonance Imaging (MRI) since Sir Peter Mansfield's pioneering work in the early 1970s and is now one of the largest, physics-based MRI research centres in the world.

The SPMIC comprises seven academic staff, 18 research staff and 33 PhD students, with a current grant portfolio of more than £10m, and sustained University investment. Biomedical imaging is one of the University's key Strategic Priorities. The SPMIC houses a Paramed 0.5T upright scanner, GE 1.5T and 3T, Philips 1.5T, 3T and 7T MRI human scanners MR-compatible

electroencephalography (EEG) kit and a CTF magnetoencephalography (MEG) scanner, and 3.4T and 9.4T vertical magnets with a range of capabilities from dynamic nuclear polarisation to microimaging.

The SPMIC, in a long-standing collaboration with the Nottingham Digestive Diseases Centre, has been instrumental in developing MRI of gastrointestinal function and in-body imaging of foods. Work carried out with industrial support has investigated the physiological response to fat emulsions, intragastric behaviour of hydrocolloids, performance of meal replacement shakes and mode of action of dairy-based, stanol-containing drinks. Pioneering work at the SPMIC developed methods to monitor the body's energy stores using non-invasive spectroscopic techniques. This research monitored the response to feeding of hepatic and muscle glycogen and lipid stores in health and disease. The SPMIC also has a major, on-going programme in the development of functional neuroimaging to improve understanding of the neural response to foods. This

includes a BBSRC Industrial Partnership Award grant in collaboration with the Sensory Science Centre and a major food manufacturer which carried out pioneering work applying fMRI to study the impact of fat on flavour perception, linking behavioural and cortical response. A second BBSRC IPA grant project, again in collaboration with the Sensory Science Centre and industry, aims to form a gustotopic map and understand the phenomenon of thermal taster status.
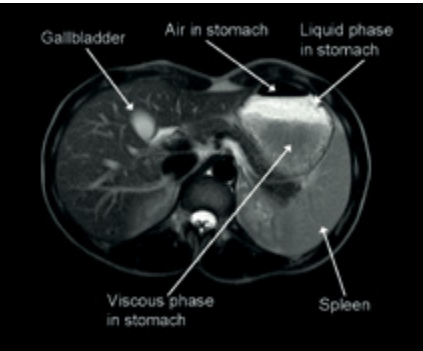
Pictured (top): MRI, 3T Wide Bore scanner at the Sir Peter Mansfield Imaging Centre on University Park campus, and a scan showing the human digestive system.

Mathematical Modelling

Centre for Mathematical Medicine and Biology

Key contacts: Ian Dryden, John King, Markus Owen, Dov Stekel, Jonathan Wattis, Andy Wood

The Centre for Mathematical Medicine and Biology (CMMB) is based within the School of Mathematical Sciences and comprises of members of the University of Nottingham who use mathematical methods to provide insights into biological and biomedical phenomena. We aim to promote the application of mathematical modelling to medicine and the biomedical sciences, and to stimulate multi-disciplinary research within the University and beyond. In particular, work is being undertaken in the area of food science, in collaboration with members of for example Centre for Plant Integrative Biology and the School of Veterinary Medicine and Science.

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Microbiology and Food Safety

Microbiology Investigation Centre

Key contacts: Ian Connerton, Christine Dodd, Phil Hill, Jon Hobman, Ken Mellits, Cath Rees

Research interests include the investigations of the roles of microorganisms in foodborne disease, food production, preservation and spoilage. There is a wide expertise base in our research team including both traditional culture-based approaches and a wide range of molecular microbiological analyses. We have experience of isolating, identifying and characterising bacteria, fungi and viruses associated with food, beverage and animal production, including determining their resistance characteristics.

A common theme is the survival and adaptive responses of microorganisms to environmental stresses. These include how the environmental cycling of micro-organisms can influence the micro-flora of farm produce, and the colonisation of livestock. Post-farm gate of particular interest are the inimical processes

imposed under food processing and preservation regimes, and how these will modify the interaction and survival of micro-flora within food products, packaging materials and on plant infrastructure for factory operations. Such information can be used to formulate micro-biological risk assessments and is key to the development of hazard analysis critical control points (HACCP) for food production processes. Research directed at new approaches for product decontamination is another common theme within the group through the use of novel physical methods and the development of biocontrol agents, such as bacteriophage and bacteriocins that are directed selectively to exclude unwanted micro-flora from the food chain. There is also an interest in identifying and characterising new antimicrobials, including natural 'green label' products.

Probiotics are live micro-organisms thought to be beneficial to humans by restoring the balance of microflora in the digestive tract. One project funded by the Food and Drink iNet investigates the optimum way of carrying and releasing these organisms. The aim is to pinpoint how effectively probiotics work when in the gut, obtain proof that they are effective, and to look at whether probiotics could become part of everyday foods such as bread.

With the ban on antibiotics used for growth promotion in livestock in the UK, we are also currently determining the value of both probiotics and prebiotics to the performance of farm animals, in terms of growth and how prebiotics and probiotics affect the microbiome. Here, we use next generation sequencing of 16S rRNA genes to identify changes in the microbiome caused by addition of prebiotics or probiotics to feed. How major zoonotic foodborne pathogens, such as *Campylobacter* and *Salmonella,* interact with and can be excluded from the developing microbiomes of farm animals are growing areas of research.

Microwave Process Engineering

Key contact: Chris Dodds, Sam Kingman, John Robinson, Eleanor Binner

The Microwave Process Engineering Research Group is led by Dr Chris Dodds and is a part of the Faculty of Engineering. This research group is the largest group of its kind in the world, and conducts multi-disciplinary research, development and commercialisation studies into electromagnetic technologies for material processing applications. These deliver economic and technical benefits across fields as diverse as food, fuels, mineral processing, pharmaceuticals and recycling. It has developed significant research expertise in microwave processing for applications in the food sector. Particular areas of interest in this sector include a resource efficient food manufacturing supply chain –energy and water; waste minimisation; manufacturing of the future – food safety, for example sterilisation – and smarter packaging. The MPE group focuses on the interaction of microwaves with materials and in the scale-up of microwave heating processes. To date they have led teams to successfully scale and license four industrial microwave technologies in the fields of industrial minerals, oil and gas and mining.

The group has led and participated in a wide portfolio of research grants from research councils, industrial institutions, Innovate UK, DEFRA, European Union and industry, produced over 100 papers in peer-reviewed journals together with more than 10 patents and contributed to numerous industry publications. It currently supports a research portfolio of approximately £15m and comprises ca. 45 multidisciplinary researchers working on a wide range of highly multi-disciplinary research, development and commercialisation projects in the field of industrial microwave processing. It has unique equipment for dielectric property measurements, an extensive selection of laboratory scale microwave and RF systems and a pilot scale facility containing hardware capable of delivering over 400kW of microwave power at 896MHz and 60kW at 2.45GHz.

Model Plants

European Arabidopsis Stock Centre

Key contact: Sean May

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At the European Arabidopsis Stock Centre, the University's plant scientists are at the forefront of international research studying the model plants *Arabidopsis thaliana* and tomato. They have identified several of the key genes that regulate their development, coordinating their genome sequencing efforts and providing underpinning resources to the international scientific community that have fuelled the recent impressive advances in our knowledge about fundamental plant processes. Although most of the *Arabidopsis* stocks are used by research institutions and academia, both energy and chemical industries use model plants in the development of alternative energy crops and as a mechanism for monitoring the effects of pesticides and fertilizers.

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Nanoscience

Nanoscale and Microscale Research Centre (NMRC)

Key contact: Karen Alvey, Andrei Khlobystov, Paul Brown, Martin Roe

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The Nanoscale and Microscale Research Centre (NMRC) is a cross-faculty and interdisciplinary research centre at The University of Nottingham. We provide managed open access to instrumentation and facilities within the Centre for all University researchers and external partners, including industrial companies. The access is supported by highly qualified research staff who run the instrumentation and assist with specimen preparation, structural characterisation, chemical analysis and data interpretation. In addition, all our research officers are actively leading developments of new methods, such as cryo sample preparation, manipulation and electron microscopy analysis, in situ transmission electron microscopy and tomography experiments, ultra-sensitive energy dispersive X-ray analysis and X-ray photoelectron spectroscopy of liquid materials, putting the NMRC at the frontier of international research.

Picture: JEOL 2100 Transmission Electron Microscope (TEM), Nanoscale and Microscale Research Centre University Park.

Instrumentation available in the NMRC includes:

- Field Emission Gun Transmission Electron Microscope (FEG-TEM) equipped with EELS and EDX spectroscopy detectors, tomography, heated and cryo specimen stages for in situ experiments
- Focused Ion Beam Scanning Electron Microscope (FIB-SEM) equipped with EDS detector and cryo capabilities
- Environmental SEM with water mode, cryo capabilities and microtensile stress stage
- FEG-SEM with heating stage and detector for electron backscatter diffraction
- X-ray Photoelectron Spectrometer (Kratos Analytical Ultra XPS)
- Raman spectrometer/microscope with different lasers and heated/cryo specimen stages
- Particle sizing equipment (NanoSight nanoparticle tracking, dynamic light scattering, and iZone particle analyzers)
- Specimen preparation laboratory equipped with high pressure freezer, critical point dryer, cryo microtome, cryo plunger and cryo transfer system
- Time-of-Flight Secondary Ion Mass Spectrometer (TOF-SIMS) for label free chemical imaging of materials with cryogenic capabilities and integrated high performance OrbitrapTM mass spectrometer

Types of food products previously studied in the NMRC:

Cocoa, cheese, chewing gum, mushroom, plant based fibres and gels (sea weed and cellulose), bread, muffins, vegetable oil based emulsions, sorgum (a type of grain), seeds (sunflower etc.), arabidopsis, beer and yeast, starches (from potato, rice, wheat etc.), ice cream and various salts.

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Nutrition, Diet and Health

Key contacts: Phil Atherton, Sarah Atkinson, John Brameld, David Gardner, Paul Greenhaff, Preeti Jethwa, Alexandra Lang, Simon Langley–Evans, Paul Loughna, Ian Macdonald, Tim Parr, Kirsty Porter, Andy Salter, Liz Simpson, Kenny Smith, Judy Swift, Moira Taylor, Kostas Tsintzas, Simon Welham, Vince Wilson

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Internationally recognised translational research which focuses on the identification of nutrition and diet related factors that contribute to understanding how health and wellbeing can be achieved across, and between, stages in the life cycle. A proven multidisciplinary approach is exemplified by collaborations across the University (for example between the Schools of Life Sciences, Medicine, Biosciences and the Centre for Mathematical Medicine and Biology, and externally (for example MRC/ARUK Centre for Musculoskeletal Ageing Research between the University of Nottingham and University of Birmingham). State-of-the-art, in-house laboratory facilities, (for example the David Greenfield Human Physiology Unit, the University of Nottingham Derby Medical School site, the Division of Nutritional Sciences, and the Nottingham Digestive Diseases Biomedical Research Unit) enable investigation of the mechanistic basis of human disease processes using cellular to whole body techniques including energy expenditure and substrate utilisation measurement, body composition, imaging and spectroscopy (for example the Sir Peter Mansfield Imaging Centre at Nottingham). Stable isotope tracers, biochemical techniques (for example intermediary metabolism) and molecular approaches (for example nutrient gene interactions, analysis of genes and proteins regulating muscle fuel use and size) are also key. Dietary intake, knowledge and behaviour patterns can be estimated and psychosocial influences on food choice and dietary behaviour explored, drawing on expertise in health psychology, dietetics and public health nutrition.

Research projects include understanding behaviour around healthy and unhealthy eating to design appropriate technology for improving food and drink choices, the use of technology as a communication tool for behaviour change (patients and clinicians/naïve users and experts), novel innovation to improve food and drink choices in specialist populations and investigating the metabolic responses of consumers to functional foods, neutraceuticals and dietary supplements. In addition to acute, well controlled dietary studies based in the laboratory, strong links with clinical colleagues and the wider community facilitate longer term intervention and observational studies in a broad range of locations – for example Nottingham University Hospitals Trust, Sure Start centres, schools and in the work place. Current key areas of interest, that utilise fully integrated qualitative and quantitative techniques, include addressing the current multiple – and closely interrelated – challenges of firstly, the global increases in the prevalence of obesity and

Picture: metabolic monitoring in the Exercise Laboratory, Queen's Medical Centre.

associated metabolic diseases – such as cardiovascular disease (CVD) and type 2 diabetes – and secondly, an ageing population. Throughout our work ethical guidelines are adhered to.

Research into the relationships between nutritional status and obesity, diabetes, CVD and other related conditions includes consideration of the role of inflammation, insulin resistance/sensitivity (ectopic fat content, muscle and liver glycogen content), factors which control gene and protein expression, and the control and integration of fuel utilisation in health and disease.

The expertise and facilities available allow us to better understand underlying mechanisms and then design and test dietary manipulation including the manipulation of macronutrients and meal pattern and the impact of specific dietary supplements on outcome measures such energy balance, lipid metabolism gene expression and appetite. Other areas of interest include cultural obstacles to dietary change, such as body-size preferences.

Supporting healthy ageing, a closely related theme, includes exploring the relationship between diet in pregnancy (fetal programming) or early life nutrition and the risk of disease in later life, including obesity and the metabolic syndrome. The relation between muscle mass and ageing is a key focus and is studied in association with the impact of exercise, inactivity and disease – for example MRC/ARUK Centre for Musculoskeletal Ageing Research and the ARUK Centre for Sport, Exercise and Osteoarthritis.

Collaboration between the University of Nottingham and the food and drink industry with respect to nutrition, diet and health includes the following potential benefits: informing industry-based decisions relating to the reformulation and creation of new products; to demonstrate that new products are safe; to demonstrate that they are effective in meeting dietary and health requirements; and to explore consumer acceptance and behaviour change drivers.

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Nutritional Analysis (NUVetNA)

A nutritional analysis service to support research, external trial work and offered commercially to the veterinary and animal nutrition industry which specialises in minerals and metabolites is run out of the School of Veterinary Medicine and Science. We currently routinely test tissue, blood, forages and urine samples for mineral composition – with creatinine correction for urine – utilising acid and alkali wet digest metholodology with analysis through ICP-ms and metabolites are run from blood, urine etc on a clinical chemistry autoanlyser. This includes nutrtional metabolites such as betahydroxybutyrate, non-esterified Fatty acids, glucose, urea, total protein albumin, liver enzymes and functional trace element enzymes (GSHPx, SOD, CP). The lab will consider contract analysis and have previously run batches of ELISAs for clients. For further details email: NUVetNA@nottingham.ac.uk

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The University Farm has

446 hectares

(1,100 acres)
based across three land
centres at Sutton Bonington,
Bunny Park and Clifton

Resource Efficiency

Key contact: Richard Smith

A transition towards a closed loop system (circular economy) in which wastes become resources provides a focus to improve the environmental and sustainability performance of manufacturing and treatment processes. In line with this, working with industry and regulators, research areas and expertise includes the application of risk assessment principles, fate and transport of contaminants, life cycle analysis, industrial symbiosis (wastes as fuels), waste treatment, emissions control and mitigation, resource efficiency, process performance and sustainability metrics.

Energy Innovation and Collaboration team

Key Contact: Colette Mchugh-Putman

The team offers support to SMEs in the areas of energy efficiency, resource efficiency and waste minimisation. There are a number of ways in which we can help businesses, ranging from understanding how to use resources more efficiently, to improving water and energy management and identifying new technologies to make improvements to processes. Qualifying businesses can receive up to five days of funded consultancy.

Rural Business Research Unit

Key contact: Paul Wilson

The Rural Business Research Unit (RBRU) undertakes a wide range of economic, management and environmental assessment studies including the DEFRA Farm Business Survey (FBS). Much of the data is used to generate and support policy developments at national and European Union level.

The data forms the basis of research projects that examine efficiency and performance variation in the agriculture and horticulture sectors, estimating relative performance and identifying key managerial actions and associated characteristics associated with high and low performance. These analyse and demonstrate the breadth of performance that exists across farms and enterprises.

The RBRU, as lead unit of Rural Business Research (RBR), is ideally placed to undertake further research programmes that can add value to the FBS data, through the collection, analysis and interpretation of additional enterprise and farm level data.

A key part of the role of RBR is to ensure effective knowledge transfer mechanisms are in place and are utilised via making the FBS data available on-line to farmers and advisors to aid business comparative analysis via business benchmarking tools. The FBS data also provides an immensely valuable research resource for undergraduates and postgraduates.

Rural and Environmental Science

Key contacts: Neil Crout, Stephen Ramsden, Debbie Sparkes, Paul Wilson

Rural Efficiency, Economics and Risk Management

This research group provides policy-relevant data and analyses to enable increased understanding of the key performance drivers affecting efficiency, performance and stability of rural businesses and agri-food firms. The group draws upon data derived from the Farm Business Survey (FBS) and associated additional primary data relating to farm-level energy usage, environmental activities, water practices and business management activities; these large scale surveys are supplemented by in-depth case-study or postal survey approaches. Applied econometric and farm-level mathematical modelling techniques and expertise are the key analytical approaches utilised within the group.

Farm Systems Assessment of Bioenergy

Bioenergy research integrates with the wider biofuel research within the University and in collaboration with external universities and research organisations, to examine the farm-level issues and potential for biomass production from UK agriculture, and additionally the impacts of bioenergy production in developing countries. Bio-economic modelling approaches draw upon primary and secondary data sources. The group also draws upon expertise in field crop experimentation and associated analysis in addition to expertise in the design, implementation and analysis of farmer surveys.

Agricultural and Environmental Systems Analysis

We aim to improve our understanding of agri-environmental systems, including the management and policy interventions that can influence these systems. To achieve this, representative surveys are conducted and models constructed; these models are designed to capture trade-offs within the under-lying systems with particular emphasis on the mitigation of negative externalities (greenhouse gases, nitrate loss, ecotoxicity) and resulting trade-offs from different mitigation measures. Systems analysis draws upon primary and secondary data sources. Modelling expertise is provided within the group and the wider research community within the School of Biosciences.

Pictured opposite: External view of Sutton Bonington Farm, Sutton Bonington Campus. Above: dairy cattle at University Farm, and business facilities on campus. Below: Bioinformatics analysis of animal data.

Pictured bottom left: Measuring emotional response to beer in sensory booths. Bottom right: Measuring the effect of visual cues on flavour perception.

Sensors and Process Analytical Technologies

Key contacts: Nik Watson, Patrick Cullen, Becca Ferrari

The Food, Water, Waste Research Group has expertise in the development and application of novel measurement technologies suitable for the food manufacturing sector. These include online sensors for automation and product inspection and offline techniques for measurements of food structure and physicochemical properties.

Sensing capabilities include: Ultrasonics, Hyperspectral imaging, infrared and lasers, Dielectric Spectroscopy, Electrical Tomography, gas sensors, NIR Spectroscopy, laser induced breakdown Spectroscopy, process characterisation analytics, digestion processes, and structural characterisation.

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Sensory Science

Sensory Science Centre

Key contact: Becki Ford

Flavour perception is affected by many factors including complex interactions between visual clues, taste, aroma, appearance, mouthfeel, and sound. The focus of research at the University of Nottingham is the development and combination of sensory and instrumental techniques to further our understanding of sensory perception and multi-sensory interactions whilst also considering inter-individual differences. Such differences can occur due to differences in culture and hence prior exposure, whilst others are a result of genetic and other physiological differences in the individual. Emotional response to sensory properties of food products also has a significant role in determining product liking and consumption behaviour. We have considerable expertise in understanding how the consumption environment impacts consumer perception, liking and emotional response to products through the development of consumer

relevant methods for the assessment of emotional response to food and beverages.

Understanding perception not only involves sensory science but draws upon other disciplines such as cognitive psychology, imaging and aroma chemistry and we have strong collaborations with these groups in the University. A key part of our research is inclusion of cognitive neuroscience expertise and brain MRI techniques to map sensory perception. We have combined sensory and analytical approaches to understand the contribution of different stimuli to flavour perception both in vitro and in-vivo. We have studied cross-modal interactions in a range of systems, such as the effect of fat on flavour perception. We are now using high resolution fMRI to understand taste representation in the brain

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Surface and Nanoscale Analysis of Food and Packaging Materials

Laboratory of Biophysics and Surface Analysis (LBSA)

Key contacts: Morgan Alexander, Clive Roberts, David Scurr

Extensive experience of supporting the development of academic and industrial formulation and packaging solutions across a range of disciplines including food and drink. World-class analytical facilities and expertise in surface and depth profiling chemical, spectroscopic and mass spectrometry analysis aligned with nanoscale quantitative imaging and mechanical analysis through a range of state-of-the-art scanning probes microscopes. This capability allows a rapid multi-parametric breakdown of material properties and interactions at the micro and nanoscale, facilitating increased understanding of food properties and structure. Examples of previous studies include the resolution of industrial sticking problems in confectionary, identification of food packaging barrier properties and profiling the release of compounds from processed teas.

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Sustainable Proteins

Key contact: Jo Gould, Andy Salter, Tim Parr, Ian Hardy

The demand for animal derived protein is expected to double by 2050, which alongside an increasing demand by consumers for sustainable, natural ingredients and free from products (for example: gluten free, dairy free, nut free), makes investigating alternative proteins a necessity, for direct human consumption and livestock (aquatic and terrestrial) feed. Proteinaceous ingredients in addition to the nutritional value contribute significantly to the physical properties and microstructures of the food products, through their ability to stabilise foams, emulsions and form gels and fibres. Our research seeks to explore ways of producing and incorporating alternative plant and insect proteins into food and feed. Research expertise in this group includes insect biology, agro-ecology, feed utilisation efficiency, nutritional value, protein structure and function characterisation.

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Sustainable Crops

Key contact: Festo Massawe, Sean Mayes (UK contact)

Sustainable Crops is a joint UK and Malaysian campus venture which focuses on both major and under-utilised food crops to generate knowledge that will contribute to improving the sustainability of food crop production. Alongside plant and crop physiology, a great deal of our research is committed to crop and molecular genetics and breeding. Topics include: molecular genetic analysis and crop improvement; plant-pathogen interactions; plant and fungal genetics; photosynthesis research; resource use efficiency; mass production of selected plants using tissue culture technology; control and expression of morphogenesis in the cloning of plants; development of vaccines in plant systems; abiotic stress research – specifically drought resistance traits in crop plants – and antioxidant properties in crops.

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Synthetic Biology

Synthetic Biology Research Centre

Key contacts: Alan Burbidge, Nigel Minton

The University of Nottingham has been awarded a £14.3m grant to create a new Synthetic Biology Research Centre (SBRC). The SBRC-Nottingham will use a synthetic biology approach to develop microorganisms than can make the chemicals and fuels that our modern society needs. A key focus for the SBRC-Nottingham is to demonstrate that we can break our reliance on fossil fuel and make chemicals and biofuels in a sustainable, cleaner and greener way. These organisms will convert simple gases, such as carbon dioxide and carbon monoxide into valuable chemicals. Carbon monoxide in particular is a waste gas from many industries such as steel mills. It can also be produced by converting waste biomass, for example from the forestry and agriculture industries into 'syngas.' By using waste biomass and greenhouse gases we aim to remove competition between fuel and food

production and open the way to having positive impacts on climate change.

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University Farm

Key contact: Stephen Ramsden

The University Farm has 445 hectares (1100 acres) of land, across three sites – Sutton Bonington, Bunny and Beeston – a herd of high-yielding Holstein dairy cows – approximately 200 cows yielding 10,500 litres per year, robotically milked – and a small flock of sheep (80 ewes).

Within constraints and protocols imposed by its role as a provider of research and teaching resources, the farm operates commercially: currently, circa two million litres of milk per year is sold through a contract with Arla (owner of the Anchor and Lurpak brands), to provide liquid milk for Tesco.

Crops are sold through Frontier Agriculture (jointly owned by Associated British Foods and Cargill plc) at their Edwalton site on the southern edge of Nottingham. Through a Service Level Agreement, the farm provides research, teaching and KT facilities for the two Sutton Bonington schools: Biosciences and Veterinary and Medical Science.

Research at the farm is based around four areas: crops, livestock, environment and engineering, although in many cases there is considerable interdisciplinariity – for example research based around farm waste products involves environmentalists, engineers, geographers, microbiologists and modellers.

Recent research projects in each area include:
- measurement of greenhouse gas emissions (methane) from dairy cows; manipulation of diets to reduce emissions
- resource use efficiency in ancient cereals and their potential for providing genetic diversity in modern wheat varieties
- veterinary treatments and their effects on invertebrate species living in cattle pastures
- 'profit from waste': anaerobic digestion, microbial fuel cells, production of biogas energy

In this latter category, a prototype Microbial Fuel Cell, originally KTP funded, is being tested at the farm in a joint project between the School of Engineering, Lindhurst Engineering and University Farm.

The farm can be thought of as a laboratory, where research can be conducted across a range of different academic disciplines and as a system – with strong links to the food supply chain – which brings together these different disciplines. This is particularly useful in interdisciplinary research bids, for example the EPSRC's recent (2014) 'Bridging the Gaps between the Engineering and Physical Sciences and Antimicrobial Resistance' initiative.

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Veterinary Science

Key contact: Gary England

Opened in 2006, the School of Veterinary Medicine and Science has established itself as a centre of excellence in both pure and applied research in whole animal biology in line with the overall aims of integrating veterinary biological research within the other relevant schools at the University of Nottingham. The school conducts research that is relevant not only to the wider veterinary, biomedical and bioscientific community, but also to local consumers of biotechnology and veterinary services. The school achieves excellence in research within the two themes of (i) Reproduction and Integrated Food Chain Research [NB the school has an on-site abattoir] and (ii) Comparative Medicine – the use of animals as models for human disease.

Within the two overarching research themes the school has strengths within the following main areas:
- Animal nutrition
- Animal infection and immunity
- Comparative medicine
- Population health and welfare
- Reproductive biology
- Veterinary educational research

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Case study: Peel and Spice

Peel and Spice is an all-natural sparkling drink – designed as a stimulating alternative to alcohol – blended using a unique combination of herbs, peels and spices to offer a range of premium, ready-to-drink, carbonated sugar-free soft drinks. Exciting new flavours include Lemongrass and Black pepper and Ginger and Cinnamon. Company owner, Sabrina Brooks, said "When we first started… from home… the drinks went down very well with family and friends, but … we knew we needed input from experts at The Food Innovation Centre. With support from food sensory scientist Alice Jones, the formulation of the drinks was scrutinised to ensure the challenges of taste, shelf-life, and health and safety were all met. Alice Jones and Richard Worrall developed a literature review into key ingredients and suppliers, and produced a relevant pasteurisation process for our sparkling drinks. In addition, we took the opportunity to gather valuable market research information during sensory testing. They have changed the course of everything we have done for the better and have been amazing".

Wastewater treatment and reuse

Key contact: Rachel Gomes, Helena Gomes, Becca Ferrari, Richard Smith

Water use, treatment, and reuse are integral to food security. We use analytics and modelling, fate studies and process engineering to understand how waste/water reuse impacts on, and propagates through the urban water cycle – for example wastewater treatment, irrigation, dairy farm wastes. Key to developing and evaluating processes to produce wastewater fit for reuse and valorisation is understanding and accounting for the complex and variable nature of wastewaters and how this impacts on process performance and reuse. Our research includes:

- Pollutants to products – waste valorisation opportunities from wastewaters, for example green bedding for the dairy farming industry, bioreactors or materials with tuneable properties for metal/chemical recovery from wastewaters
- Plants on the pill – wastewater reuse for irrigation and impact on food and water security

- Evaluating the impact of dairy waste/waters and green bedding (recycled manure solids) on antimicrobial resistance and coselection drivers (metals, antibiotics)
- Wastewater/waste treatment and reuse in food processing industries
- Data analytics and modelling to inform on process evaluation and technology development

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Whole Systems Analysis

Key contact: Jon McKechnie

Expertise is in taking a multi-disciplinary, 'whole-system approach' to biomass-derived fuels and materials. On-going work assesses sustainable biomass supply chains, conversion technologies, and chemicals/plastics production from biomass sources. The whole-systems approach is also applied to research in non-bioenergy fields including: carbon fibre composites recycling; critical materials; microgrids and energy storage systems; and heavy-duty vehicle fuels.

Pictured from top: activated sludge process for wastewater treatment. Wastewater outflow for reuse into urban water cycle. (Photos © Oliver Fisher). Sutton Bonington dairy farm slurry wastewater tank for reuse to crops (©Thomas Dodsworth).

3D Imaging through X-rays (MicroCT)

Hounsfield Facility: 3D Imaging through X-rays

Key contacts: Sacha Mooney, Craig Sturrock

A world-leading multidisciplinary centre which uses state-of-the-art x-ray micro-tomography equipment to visualise and quantify the internal microstructures of an object in 3D. Through using the latest equipment, we are able to acquire images at high pixel resolutions down to <1µm without altering or destroying the sample.

A range of food products can be analysed ranging from snack bars to desserts. The technology can be used for:

- detecting defects
- optimising a manufacturing process in order to reduce costs whilst maintaining quality

- exploring food quality in 3D, visually and quantitatively, studying characteristics such as:
  - porosity for example to investigate food texture.
  - macro and microstructure (for structural and mechanical properties, for example deformation, fracture, homogeneity
  - distribution and size of particles such as salts
  - the 3D location and morphology of different ingredients

Features and benefits

The technique has a number of advantages over current methods of analysis such as optical and electron microscopy:

- Food products can be investigated in their natural state at atmospheric pressure and temperature. Other methods such as electron microscopy require a vacuum and coating of the sample
- Microscopy requires the product to be cross-sectioned into thin

slices. Even the most careful preparation can have destructive effects on the product. In contrast, x-ray tomography can visualise the internal structure in 3D without any cross-sectioning or preparation. Reliable 2D and 3D information can then be derived from the data

- Microscopy is restricted to analysing small sections of the overall product. A large number of repeats are required in order to give statistically relevant results. With x-ray tomography, the entire product can be imaged and analysed, reducing the number of repeats that are needed
- X-ray tomography data can be acquired at relatively high spatial resolutions ranging from <1µm to 500µm depending on the product's size
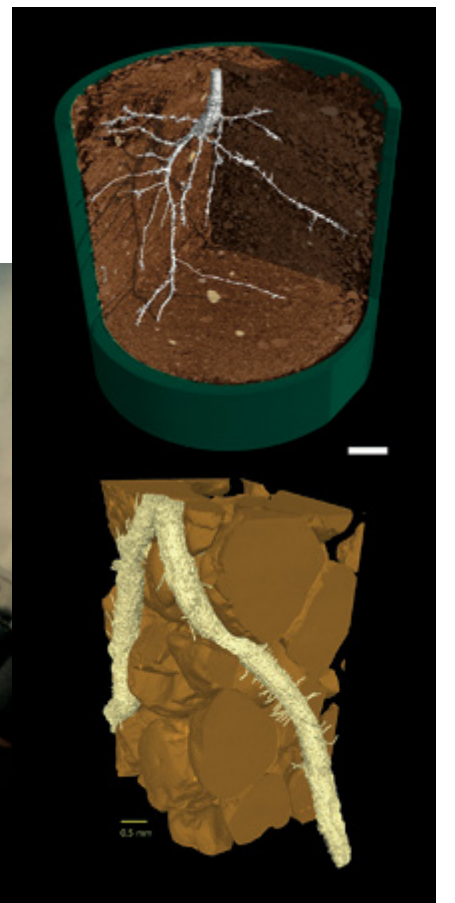
Pictured: using X-ray micro tomography to examine wheat plants at Sutton Bonington.

Research projects and student placements for your company

Would you like to improve or enhance your business processes, develop a new product, improve productivity, or tap into innovative ideas with a fresh perspective?

Making the most of student talent

We are always looking to create new partnerships with businesses and offer opportunities ranging from year-long placements to short-term summer internships. Specialist placements and careers staff work with a range of companies from large corporations to SMEs to help employers find the right student for their business needs.

Year in industry placements

Biosciences

Undergraduate (BSc/MSci)

Starting between July and September (placements are from 9 months up to a maximum of 15 months).

- Work as full-time paid employees
- Student access to UoN facilities and support
- Students can apply to work towards the Science Council's Registered Scientist status

Key contact: Dr Judith Wayte
Email: biosciplacements@nottingham.ac.uk

Undergraduate (BSc/MSci) students in the School of Biosciences from Agriculture and Environmental Sciences, Animal Science, Food and Nutritional Sciences and Plant and Crop Sciences can choose to undertake an optional additional year in industry as part of their degree course. Students on these courses have a considerable body of academic, technical and practical knowledge by the end of their second year.

BSc students can do a year in industry during the third year of a four year course, whereas MSci students have the option of doing a year in industry during the third or fourth year of a five year course.

Students who undertake a Year in Industry placement can choose to work towards applying to become a Registered Scientist with the Science Council by collating evidence of key skills during the placement. The University of Nottingham is the first UK university to agree the process, which provides lasting benefits to students.

Find out more
Further information about year in industry, student videos and stories: nottingham.ac.uk/biosciences/placements

Engineering

Undergraduate (BEng/MEng)

Starting between July and September (in the penultimate year of the student's degree programme).

- Work as full-time paid employees
- Students supported for the duration including a visit
- Student access to UoN facilities and support
- Aligned to Engineering Council UK specification

Key contact: Sarah Shackleton
Email: engineeringplacements@nottingham.ac.uk

Students from across the Faculty of Engineering have the opportunity to undertake a year in industry as part of their degree programme, including the following disciplines: Chemical Engineering, Chemical and Environmental Engineering, Electrical and Electronic Engineering, Electronic Engineering with Computing, Mechanical Engineering, Manufacturing Engineering and Product Design and Manufacture. Students have no University work during their placement though they maintain their student status and have full access to University facilities and support. They are expected to complete a reflective report at the end of their placement to record their experience in line with the Engineering Council UK Spec. Students are also supported by a University placement tutor who will visit them and their supervisors during the course of the placement.

Find out more
Visit our placements for business pages: nottingham.ac.uk/engineering/industrial-placements/for-business

For year in industry placements: There is an expectation that the company offers a specific role with a full-time salary, and provides training and development opportunities. These placements can be in the UK or abroad.

Short-term placements

Food Production Management and Biotechnology programmes
Postgraduate (MSc)

May to July

- Compulsory 8-10 week project at the end of the year-long course
- Completed on your company premises, at the University or a combination of these

Key contact: Dr Judith Wayte
Email: biosciplacements@nottingham.ac.uk

MSc Food Production Management; MSc Applied Biomolecular Technology for the Biopharmaceutical, Food and Biotechnology Industries; MSc Applied Biopharmaceutical Biotechnology and Entrepreneurship; and MSc Biotechnology include a compulsory 8-10 week project at the end of the year long course. Having completed a Bachelor's degree in a related subject as well as almost a full year of Master's level study, students on these courses have a considerable body of academic, technical and practical knowledge as they come to start their project. Many of the students are international and bring significant and diverse experience from their home country. The project can be completed on your premises, at the University, or a combination of the two. These placements are not normally paid as they are part of the student's course. These placements can be in the UK or abroad.

Postgraduate projects
Postgraduate Placements Nottingham

Part-time (up to 200 hours) for a period of between 3-6 months

Funded by

European Union
European Regional Development Fund

Key contact: Kerry Wright,
Research and Graduate Services
Email: ppnenquiries@nottingham.ac.uk

Postgraduate Placements Nottingham (PPN) offers placements and internships to students from across the University that are designed to provide companies with the opportunity to work with high calibre postgraduates on projects that will make an impact on the development of the business, and be mutually beneficial to students and their employers. The PPN team provide guidance and support to both parties throughout the duration of the project. There are also a number of funding sources available, through the programme, to support the costs of the placement.

Summer internships
Undergraduate

June to September

- At your company for the duration of the summer holiday
- Up to four weeks unpaid, or up to three months paid
- Nottingham Internship Scheme funding available for qualifying businesses

Key contact: Diane Blything
Email: diane.blything@nottingham.ac.uk

Recruit one of our undergraduate students from a wide range of disciplines to undertake an internship at your company during the summer holiday. First and second year students are keen to get work experience and can help you with a range of projects. We can advertise up to four weeks unpaid internships or up to three months paid internships to relevant students. In addition, SMEs who are located in Nottinghamshire/Derbyshire can apply to the Nottingham Internship Scheme, which can provide financial support towards the cost of employing an intern.

Graduate placements
Undergraduate and postgraduate

Between September and January

- Highly qualified graduates
- Up to four weeks unpaid, or over four weeks paid internships

Key contact: Careers and Employability Service
Email: eventsandvacancies@nottingham.ac.uk

Graduates who have completed either one of our undergraduate or postgraduate degrees are often looking for work experience following their graduation, particularly if they have not yet secured a graduate job. These highly qualified graduates have significant technical knowledge and understanding and can be used to resolve problems, or work on short-term projects. We can advertise up to four weeks unpaid internships or over four weeks paid internships to relevant students.

Research projects on campus

Final year research projects
Undergraduate (BSc)

Agriculture and Environmental Sciences, Animal Science, Food and Nutritional Sciences and Plant and Crop Sciences

October to May

Key contact: Dr Susie Lydon
Email: susannah.lydon@nottingham.ac.uk

Undergraduate students from Agriculture and Environmental Sciences, Animal Science, Food and Nutritional Sciences and Plant and Crop Sciences are required to complete a research project during the final year of their degree. We encourage industry projects to provide relevant real-world experience to students. Students carry out research, design the study, gain familiarity with the techniques and undertake data collection on behalf of the company and under the supervision of a member of academic staff. Most projects are done on campus and we would welcome an opportunity for the student to visit your company or work at your premises for up to one day a week during term time.

Research projects
Postgraduate (MSci)

Starting in October

Fourth Year MSci Food Science and Nutrition and MSci Food Science

- Industry research challenges
- Offer competitive final year fee bursaries

Key contact: Dr Bettina Wolf
Email: bettina.wolf@nottingham.ac.uk

MSci students from Food and Nutritional Sciences are required to complete a year long research project during the fourth year of their degree. Industry is invited to provide research challenges for the project module, through offering final year fee bursaries. The research challenges can build on the skills the students have learnt in project management, communication and public engagement, and viewing the food industry globally. Students will undertake the challenge on campus and under the supervision of a member of academic staff. The coursework in these modules relates to the research project. Industry is invited to provide research challenges for the project module through offering competitive final year fee bursaries.

New Product Development projects: Food Sciences
Undergraduate and postgraduate

January to May

- Real-life product idea to develop project brief
- Teams of 5-6 students
- Duration 10 weeks, around 40 hours per week
- Whole NPD process
- NPD showcase in May

Key contact: Dr Bettina Wolf
Email: bettina.wolf@nottingham.ac.uk

Teams of 5-6 undergraduate and postgraduate students from Food Sciences undertake new product development projects for 10 weeks of around 40 hours' work from January to May. We encourage industry projects to provide relevant real-world experience to students. Companies provide a real-life product idea and, working with our academics, this is converted into a project brief involving significant innovative and scientific merit. The brief is given to one of our student teams to work on, before presenting a report and the results at an NPD showcase in May, attended by companies. The project covers the whole NPD process including ideation, product design, formulation, production and process layout through to labelling, nutrition, packaging and marketing.

Food Process Engineering Projects
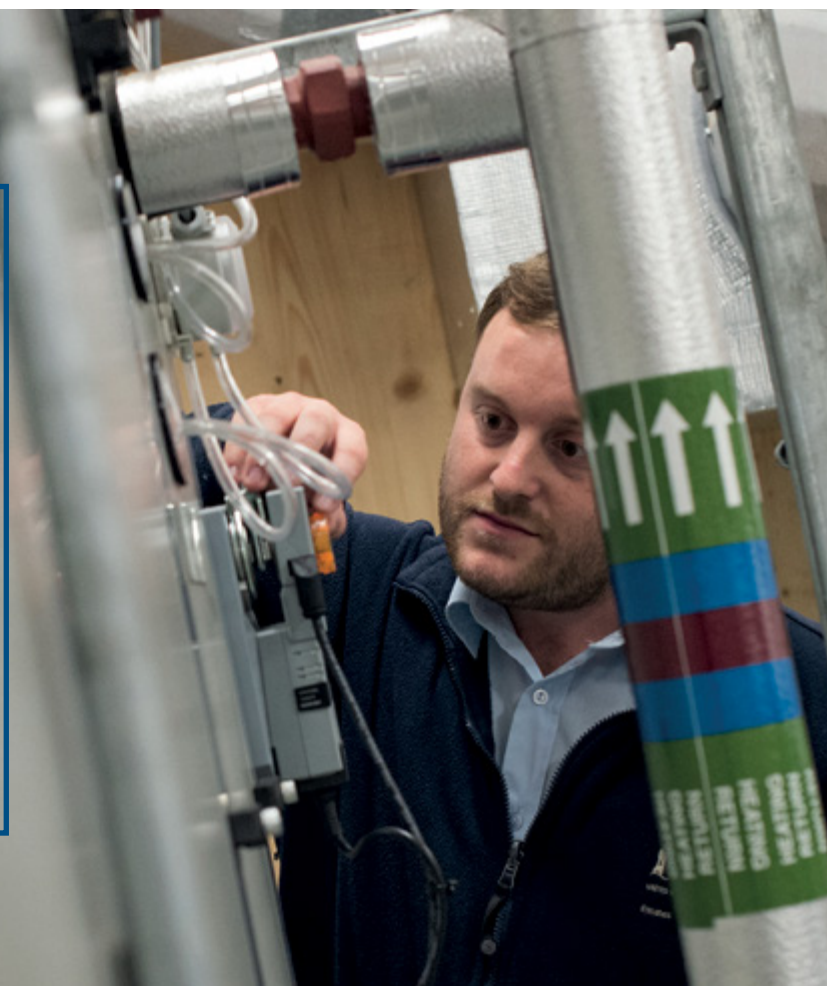#### Postgraduate

Starting October to July

- 4th /5th year Chem engineers and MSci
- Multi-discipline engineering teams of 5-6 students
- Industry research and development projects
- Green and brown field projects
- Complete process lines and packaging design
- Process flowsheets to detailed P & ID level
- Full economic and environmental analysis

Key contact: Seamus Higgins
Email: seamus.higgins@nottingham.ac.uk

A major component of the final year MEng and all MSci process engineering programs is to complete a detailed research project relevant to their intended specialisation. The research challenge, I Chem E accredited, builds on our students in-depth learning experience and endeavours to provide a current real life project experience for the post graduate student. As such we would encourage companies that would be interested in cooperating with us as a client on real life project ideas and or concepts for further development to contact us.

Developing your workforce

Competencies for Food Process Engineers

Key contacts: Seamus Higgins and Serafim Bakalis
Email: seamus.higgins@nottingham.ac.uk
Email: serafim.bakalis@nottingham.ac.uk

While change has always been a constant in food manufacturing the more recent acceleration of change in terms of technology, robotics, automation and the information age is creating a seismic shift in what customers want and expect from the industry. Given the ongoing nature and trajectory of consumer's evolution, transformative change, as opposed to incremental improvement, becomes a must for any food company seeking growth and or indeed future survival.

In turn, difficult choices and significant future capital investment decisions are required.

In more recent times the food industry has typically viewed the role of engineering purely as a maintenance function and outsourced process decisions, justification and capital spend to others. Yet, Engineering, at its heart, is the one profession aimed at making things or making things better by way of modifying manufacture and technological systems.

Engineering, at its core, is about causing change, and therefore management of change is central to engineering practice so why outsource it?

A 2017 FDF/ Grant Thornton survey found that 50% of food companies with a turnover >£100m <£500m already find it very difficult to recruit engineers in the UK, the other 50% classify it as difficult. As the industry progresses towards advanced manufacturing with the balance shifting from manual activity to an automated knowledge based activity the current skills shortage will intensify with more specialised food industry engineering professionals becoming even scarcer.

It is for this reason that Nottingham has created its new M.sci Programme in Food Process Engineering. www.nottingham.ac.uk/engineering/food. Developed under the auspices of the Chemical and Environmental Department within the faculty of Engineering this new programme has been designed by both Food academics and professionals from the industry. It combines the wealth of Food Science that is Nottingham with the strength of its Engineering faculty to produce world class graduates equipped to deal with the agile needs of a modern food industry.

If you want to retain/upskill your existing engineering talent and or encourage new talent for future development talk to us.

Competencies for Food Graduate Careers

Key contact: Emma Weston
Email: emma.weston@nottingham.ac.uk

Food and drink is the largest manufacturing sector in the UK with turnover of over £100Bn per annum and employing around 400,000 people. The challenge is to provide the anticipated 140,000 new recruits needed by 2024 to meet growing demand. (FDF, 2017) and a significant proportion are needed within the technical field coming from food science or technology based courses. To meet this demand, 33 degree programmes (BSc and MSc), accredited by Institute of Food Science and Technology (2017) are available from 16 providers across the UK and there are many more related degree courses on offer in the country.
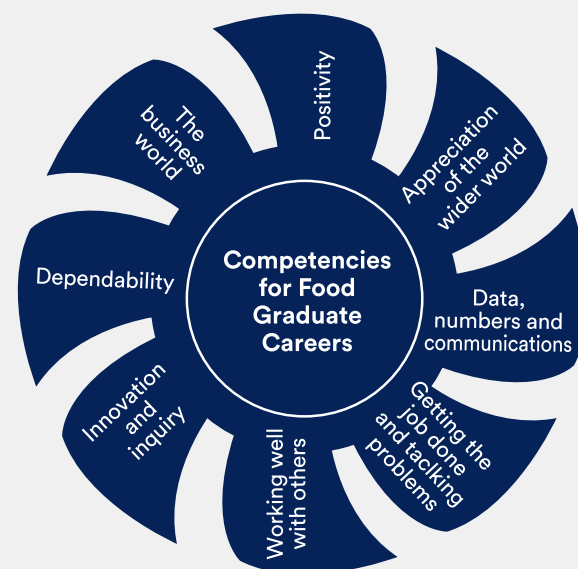
To ensure job-readiness Food Sciences degree providers need to ensure that course content reaches beyond the science and technology of the subject matter and also encourages development of the associated personal competencies that make a great graduate for the industry across the range of initial roles they could choose as a graduate.

The Competencies for Food Graduate Careers project seeks to develop, test and disseminate a competency framework tailored to typical technical careers pathways for graduates entering the food industry. This framework aims to:

- inform students intending to join the food industry as a technical graduate as a key objective

- support recruiters and employers in providing consistent, accurate advertisement and selection criteria
- optimise food science degree courses to reflect the needs of the industry

The Competencies for Food Graduate Careers comprises of a list of 48 elements. They provide a tailored, consistent and relevant set of behaviours, knowledge and skills or 'elements' that may be desirable in a food sciences graduate. The tool informs all future stages of the project and aims to support students in gaining clarity in what elements they may need to develop in themselves or articulate in interviews for a particular role.

Degree Apprenticeships

Key contact: Ruth Eccles
Email: ruth.eccles@nottingham.ac.uk

Degree apprenticeships are a powerful way to develop your workforce and to drive innovation and growth. The University of Nottingham has ambitious plans for a comprehensive programme of demand-led level 6+ programmes to be delivered across all of our faculties.

Our apprenticeships will be crafted in partnership with industry to develop skills and knowledge which is directly relevant to your business. With our global reputation and world-class research and teaching, we are uniquely positioned to provide training which will have the most impact on your organisation. Apprentice students will undertake academically rigorous, part-time study that is built around your business.

Our programmes will help your employees to bring ideas and up-to-date knowledge and skills back into the workplace. Delivered under a blended learning model, apprentice students will benefit from a minimum of 20% of their working time being spent in off-the-job learning, whether on campus in lectures, seminars and practical workshops; through work

based learning projects that directly benefit their learning and your business; or accessed online through remote learning.

We will work with local, regional and national businesses to understand your strategic priorities and challenges. Our programmes will be built to offer real value which can be tailored to a sector, or even developed bespoke to your own business. We are consistently ranked in the Top 100 universities in the world. Combining our excellent, TEF Gold award winning teaching with our outstanding research capabilities and world leading campuses and facilities presents a compelling case both for talent attraction and for retaining and developing existing staff within your business.

We are working with employers to develop degree apprenticeships in the following areas:

- Management
- Healthcare
- Scientific careers
- Engineering
- Digital and Computer Science

Training and Continuing Professional Development

Programmes developed for business and industry professionals

The University of Nottingham is able to provide a range of training solutions for food and drink industry professionals across the global agrifood supply chain. Combining the world-class research of Nottingham's academics and their teaching capacity, the University is also able to provide bespoke or open professional development courses tailored to the needs of industry.

The University has a dedicated CPD team within its Research and Innovation services who's purpose is to assist industry professionals with development of training and professional development courses and you can find out more about the team by visiting their website, **nottingham.ac.uk/cpd** or contact the team on **cpd@nottingham.ac.uk.**

The University of Nottingham has extensive experience in training Agricultural, Food Industry and Health related professionals in part-time and distance-learning courses that are flexible and accessible and may be taken as stand-alone Continuing Professional Development or, in many cases, as part of accredited Postgraduate award. One such specialist training programme, specifically designed for industry-related Continuing Professional Development, is the BBSRC Agrifood Training Partnership (AFTP). Course titles and study modes centres are detailed in Appendix B.

Key contacts:
Michelle Hill: michelle.hill@nottingham.ac.uk
Lizzy Martin: lizzy.martin@nottingham.ac.uk
Debby Lin-Read: debby.lin-read@nottingham.ac.uk

Programmes developed to suit the way you learn

- Bespoke training
- Executive Education
- Online and distance courses
- Part-time postgraduate programmes
- Short courses
- Summer schools
- Training workshops

Contact us: **cpd@nottingham.ac.uk**

" When I go out to meet growers, my training has helped me to ask the right questions and have much better discussions with my suppliers. "

Hella Lipper, Technical Manager – Waitrose

BBSRC AgriFood Training Partnership (AFTP)

The School of Biosciences at the University of Nottingham is one of the core partners of the AgriFood Training Partnership (AFTP); which combines the skills and expertise of the three previous Advanced Training Partnerships into one and has been awarded funding by the BBSRC (Biotechnology and Biological Sciences Research Council, UK), to deliver skills and training to businesses in the agrifood sector until December 2019. Since the three partnerships commenced activities in January 2012, the AFTP partners have trained over 1,500 UK based agrifood employees working at around 1,000 businesses from self-employed start-ups to internationally recognised corporations. Training is delivered by six leading, internationally recognised university partners: University of Nottingham, Harper Adams University, Cranfield University, Aberystwyth and Bangor and Reading University, as well as industry partners including Campden BRI and Leatherhead Food Research.

Training is delivered in face-to-face short courses and e-learning that can be done when and where is convenient for the student. Courses aim to explain the relevance and allow students to contextualise the latest scientific and technical developments that have an impact on their business. The AFTP is managed to ensure that the latest industry issues and developments feature in courses and workshops. This is achieved by including industry representation at all levels of decision making including the Executive Board and each of

From one day workshops to online distance learning and short courses through to postgraduate awards including PGDip, PGCert, MSc and Research Degrees AFTP training areas span the entire agrifood sector.

BBSRC AgriFood has trained over 1,500 UK-based agrifood employees working at around 1,000 businesses from self-employed start-ups to internationally recognised corporations.

the subject subgroups that have an impact across the whole food supply chain: livestock and forages, crops and fresh produce, food and nutrition, environment and sustainability. Each subject area is governed by a group which reviews and approves new courses for the partnership, this is chaired by an industry representative.

Key contacts: Deborah Kendale and John Brameld
Full details can be found at: www.aftp.co.uk
For more information: Email info@aftp.co.uk

Innovation support for business

The University of Nottingham provides a wide variety of services to help make your business grow and become more profitable. The University has built a strong reputation for the quality and impact of its collaborative work, with a range of services that include research and development, offering new technology for licensing and other forms of commercialisation, providing consultancy expertise to solve business issues, and delivering training to meet staff development needs.

Support for business and industry at the University of Nottingham is organised through our Research and Innovation department. The department provides a range of services for both major corporations and the SME business sector, with support and advice services delivered through a number of dedicated teams:

Corporate Partnerships Team – develops and manages long-term strategic relationships with key corporate businesses in order to enhance the relevance and impact of the University's research and training activities, derive increased industrial income and further the University's external reputation.

Key contact: Amreesh Mishra
Email: amreesh.mishra@nottingham.ac.uk
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Ingenuity – Ingenuity is the University of Nottingham's local business network. With some 2000 members, the networks main aim of the network is to transfer knowledge and expertise from the University into the local SME business community. An extensive range of events and workshops are designed to encourage innovative collaborations between business and academia and for both parties to benefit from the connections they make.

Key contact: Steve Upcraft
Email: steve.upcraft@nottingham.ac.uk
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IP Commercialisation Office – helps to commercialise technologies which have been developed through research by licensing the use of our technologies to a third party, utilising joint ventures to develop technology further and through investing in spin-out companies which frequently retain close links to the university. With our strong links to industry and investors, the IP Commercialisation Office provides invaluable market knowledge and experience, which is used by a highly professional team of Intellectual Property specialists to foster University research and develop it into marketable businesses.

Key contact: Gillian Shuttleworth
Email: gillian.shuttleworth@nottingham.ac.uk
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Asia Business Centre – is the integrated Knowledge Exchange team located at our UK and China Campuses, incorporating the Continuing Professional Development Services team and India Office to deliver the University's knowledge exchange with Asia. Knowledge Exchange Asia is transforming the way the University develops its business partnerships in Asia. It is delivering sustained value for students, staff, and the University, and large scale commercial returns for partners. Specialist business knowledge and cultural competence is deployed to leverage strategic investment in student employability and entrepreneurship, international teaching and research partnerships and global alumni engagement.

Key contact: Min Rose
Email: min.rose@nottingham.ac.uk
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Enabling Innovation – is a collaborative tri-university programme, it's primary objective is to stimulate interest and investment in research and innovation within SME's across the counties of Derbyshire and Nottinghamshire. The programme is part-funded by the European Union which enables the University to deliver many of Enabling Innovation's activities at no cost to participating businesses. The Enabling Food Innovation team is based at Sutton Bonington and is helping SME businesses access knowledge, facilities, students and experts from across Food, Flavour, Sensory, Brewing and Nutrition Sciences, with very effective results.

Key contact: Richard Worrall
Email: richard.worrall@nottingham.ac.uk
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Appendix A
Critical mass

UoN Centres mapped against R&D Research themes	Page numbers	Primary production	Post-harvest	New ingredients, development	Food engineering and processing	Behaviour, consumer health, and clinical application
Advanced Data Analysis Centre	20	✔	✔			✔
BBSRC/EPSRC Centre for Plant Integrative Biology (CPIB)	47	✔				
Biomedical Research Centre	39					✔
Centre for Analytical Bioscience (School of Pharmacy)	17		✔			✔
Centre of Excellence for Post-Harvest Biotechnology	47		✔	✔	✔	✔
Centre for Mathematical Medicine and Biology	43	✔	✔			✔
Centre for Sustainable Chemistry	26		✔	✔	✔	✔
Crops for the Future Research Centre	29	✔		✔	✔	
EPSRC Centre for Innovative Manufacturing (CIM) in Food	41		✔	✔	✔	
European Arabidopsis Stock Centre	44	✔				
Food and Biofuel Innovation Centre (FBIC)	22		✔	✔	✔	
Food and Bioproduct Processing Centre	23			✔	✔	✔
Institute for Advanced Manufacturing	17	✔	✔	✔	✔	
Institute for Future Food	35	✔	✔	✔	✔	✔
International Centre for Corporate Social Responsibility	29	✔	✔	✔	✔	✔
Laboratory of Biophysics and Surface Analysis (LBSA)	51				✔	✔
Microwave Process Engineering Research Group	43				✔	
MRC/ARUK Centre for Musculoskeletal Ageing Research	44	✔		✔		✔
Nanoscale and Microscale Research Centre (NMRC)	44	✔	✔			✔
National Centre for Macromolecular Hydrodynamics	40			✔	✔	✔
Nottingham Digestive Diseases Centre	30			✔		✔
Nottingham Geospatial Institute	20	✔	✔		✔	✔
Rural Business Research Unit	48	✔				
Sensory Science Centre (School of Biosciences)	51		✔	✔	✔	✔
Sir Peter Mansfield Imaging Centre	30		✔			✔
Synthetic Biology Research Centre	52		✔			

Appendix B
Relevant postgraduate courses for the food and drink industry

Courses of interest to people working in primary production

Course title
Animal Nutrition MSc/PGDip
Applied Genomic and Proteomic Sciences MRes
Applied bioinformatics MRes
Applied Biomolecular Technology for the Biopharmaceutical, Food and Biotechnology Industries MSc
Crop Biotechnology and Entrepreneurship MSc
Crop Improvement MSc/PGDip
Global Food Security MRes
Plant Genetic Manipulation MSc
Sustainable Bioenergy MRes
AgriFood PGCert/PGDip/MSc

Courses of interest to people working in post-harvest

Course title
Crop Biotechnology and Entrepreneurship MSc
Crop Improvement MSc/PGDip
Global Food Security MRes
Plant Genetic Manipulation MSc
AgriFood PGCert/PGDip/MSc

Courses of interest to people working in new ingredients development

Course title
Sensory Science PGCert
Brewing Science PGCert/PGDip/MSc
AgriFood PGCert/PGDip/MSc

Courses of interest to people working in food processing and engineering

Course title
Food Production Management MSc
Food Process Engineering MSc
Brewing Science PGCert/PGDip/MSc
Brewing Optimisation PGCert
Brewing and Packaging PGCert
Chemical Engineering MSc
Industrial Physical Biochemistry MRes
Environmental Engineering MSc
AgriFood PGCert/PGDip/MSc

Courses of interest to people working in behaviour, consumer health and clinical application

Course title
Integrated Physiology in Health and Disease MSc
Nutritional Sciences MSc
Clinical Nutrition MSc/PGDip
Dietetics MRes
Behaviour Change PGCert
AgriFood PGCert/PGDip/MSc

Food and drink key contacts

Contact

Amreesh Mishra
Corporate Partnerships Senior Executive
Food and Drink Sector
Mobile: +44 (0) 7815 508755
Email: amreesh.mishra@nottingham.ac.uk

Stephen Parry
Honorary Professor and Industry Adviser
Food and Drink Sector
Mobile: +44 (0) 7802 946127
Email: stephen.parry@nottingham.ac.uk

Simon Ridgway
Future Food Beacon
Telephone: +44 (0) 115 9516 400
E-mail: simon.ridgway@nottingham.ac.uk

Richard Worrall
Enabling Innovation Lead
Telephone: +44 (0) 115 9516 696
E-mail: richard.worrall@nottingham.ac.uk

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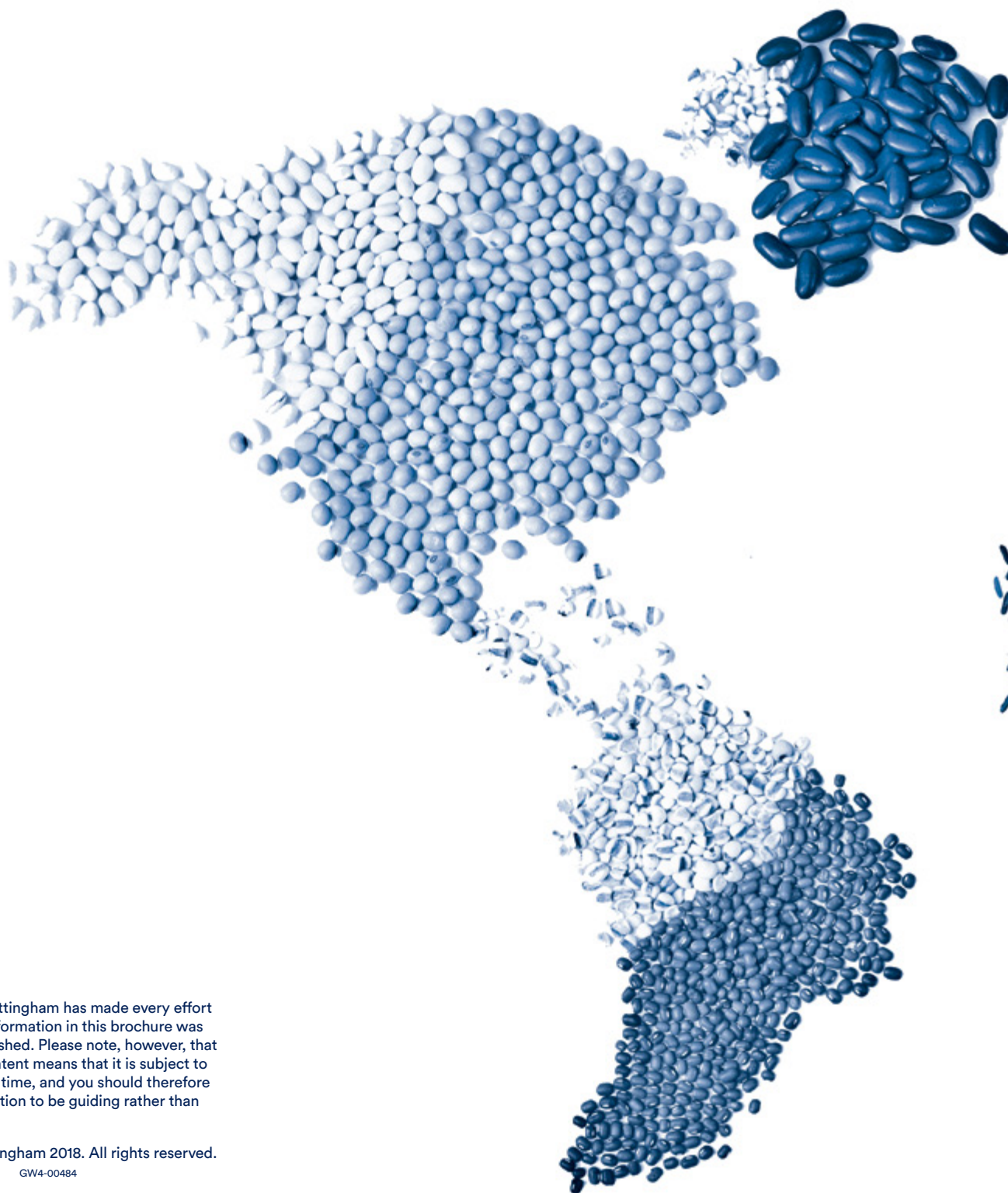
Find out more:

✉ **agrifood@nottingham.ac.uk**

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