EPSRC CENTRE FOR INNOVATIVE MANUFACTURING IN

Food

Annual Report

2015/2016

UNIVERSITY OF BIRMINGHAM

Loughborough University

The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

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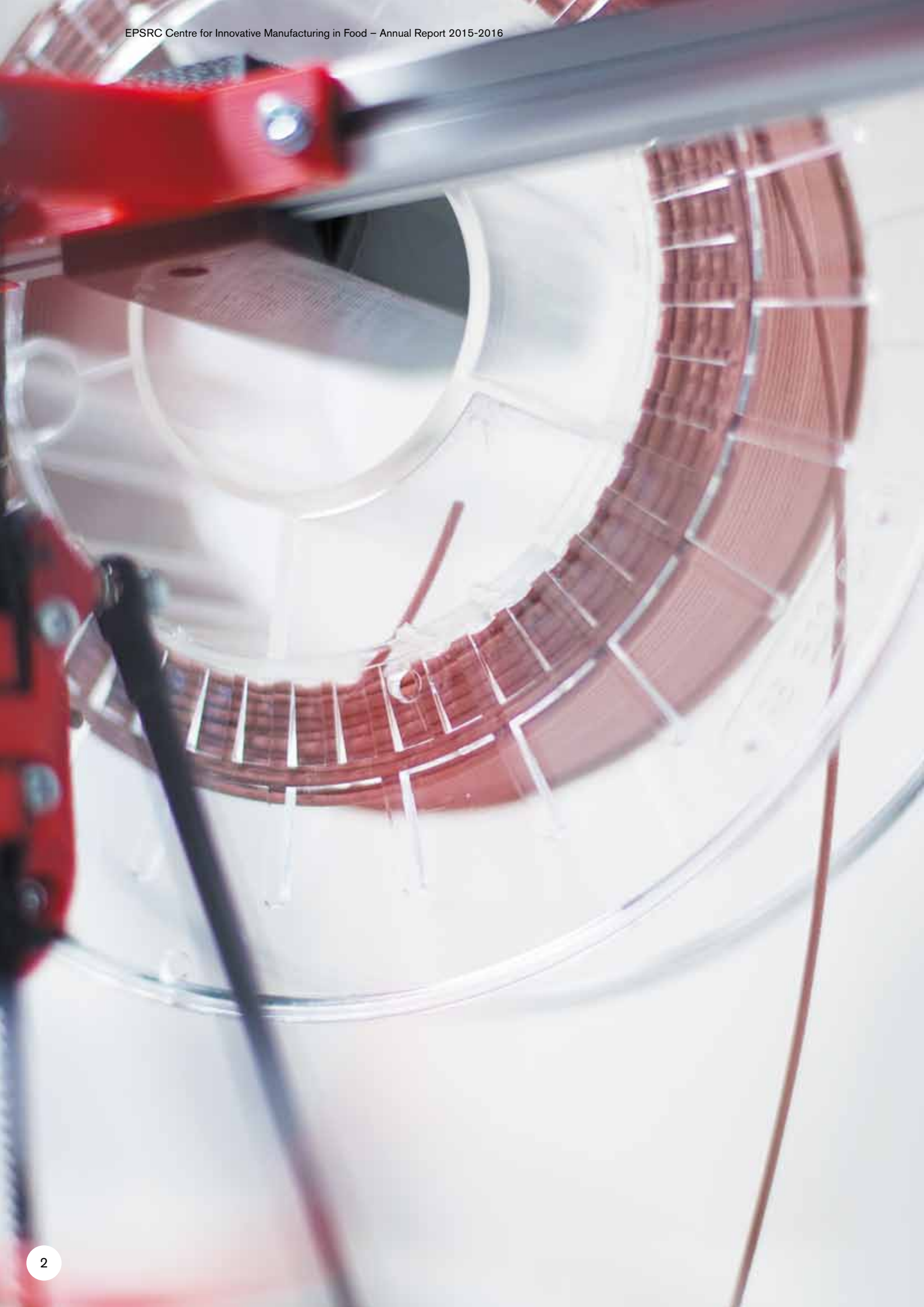


Contents

Centre overview

National Centre

- A partnership of three higher education institutes –The University of Nottingham, University of Birmingham and Loughborough University
- Funded by EPSRC and supported by industry
- Catalyst for collaboration in UK food manufacturing research
- Maximising impact and output
- Involvement in UK food manufacturing strategy development
- Building international collaborations

Research

- Upgrading ingredients
- Manufacturing for healthy diets
- Novel processing technologies
- New flexible manufacturing
- Eco-manufacturing of food
- Sustainable food supply chains

Industry

- Industrially-driven research challenges
- Fostering collaborations and building a community
- Enabling faster end user application and uptake of technologies

Training

- Enabling the thought leaders of the future
- Developing a pipeline of talent
- Doctoral and Masters level research training
- Industrial links for effective communication, network and experience
- Secondment opportunities

Centre vision
Towards realisation

Our vision is for the EPSRC Centre to meet the challenges of global food security through developing world-leading technologies, tools and leaders, tailored to meet the needs of current challenges while redesigning resource efficient and sustainable, nutritious foods of the future.

The multidisciplinary, multi-university Centre is carrying out the fundamental and translational research, aligned to meet both the manufacturing needs of industry, as well as the functional needs of the consumer of today, while building capability to serve the needs of future generations.

The EPSRC Centre's activities are already influencing practice, research and policy, and will continue to play a central role in the implementation of the UK strategy for global food security over the coming years.

Executive summary

As the Centre enters into its third year, this annual report reflects over the achievements and highlights of our first two years of operations.

A major decision taken in September 2015 was to dispense with our 'charge based' funding model in favour of an 'activity based' one. The consequence of this has been to significantly increase our membership numbers, allowing the core funded research to be visible to more industrial collaborators, engendering an opportunity of impactful delivery in 'activity' funded industry-based projects. This has increased our talent pool, with 29 researchers currently engaged in Centre projects. We have said farewell to three researchers who have taken up positions in industry.

The Centre was established in December 2013 with the objective to develop next generation strategies for food manufacture, aligned against the UK's food manufacturing research priority areas. We are part of the KTN Food Sector Advisory Group and the National Technology Platform for Food, providing an opportunity to work closely with RUK in developing the challenge areas of the future for food. Additionally, we are supporting the development of the Food Innovation Network, and are monitoring the development of the European Institute of Innovation and Technology call for a Knowledge and Innovation Community in Food.

Today, we have a portfolio of more than 20 intersected research programmes spanning the two Grand Challenges and six Research Themes of the Centre. Our activity and engagement strategy with our industrial Network Members, has allowed us to develop a suite of industrially sponsored research projects as our innovative technologies begin to be applied and realised for their commercial impact, leveraging the critical mass of research activity across the Centre.

To date, the EPSRC Centre for Innovative Manufacturing in Food has leveraged more than £3m of additional funding from governmental bodies and industry partners, and continues to seek to secure the sustainability of the Centre through further funding activities of national and international relevance.

As part of the EPSRC's 'Manufacturing the Future' programme, the EPSRC Centre for Innovative Manufacturing in Food is the only one of 16 Centres to be funded for sector-specific research owing to the hugely important role the food industry plays in the development of emerging, resilient food economies, the influencing of international health policy, and its ability to offer sustainable food and nutrition security.

Our engagement, outreach and in-reach activities have continued to evolve and develop over the past year as our team numbers grow. We have made an imprint on the manufacturing community through attending various conferences and workshops presenting preliminary data, visiting developing economies in both Brazil and India to learn of the national and international government initiatives to support the development of the food manufacturing industry, and sharing our strategy to tackle the global food security challenges through consultation with the KTN and NTP for Food. Closer to home, we are working with local food manufacturing communities, networks, multinational companies and SME's, who each have their own business models and strategic plans aligned with the Grand Challenges of the Centre, allowing us to conduct research from both a 'blue skies' innovative approach and one geared for industry, that will have real value and impact to all those that we engage with.

2015 Highlights

- **Throughout 2015, the EPSRC managed to secure an additional £3m of funding through direct industrial sponsorship of research projects and through public private partnerships with, Innovate UK and Research Council programmes. Further submissions so far in 2016 amount to more than £2.7m.**
- **The EPSRC Centre continues to align with The University of Nottingham's EPSRC Centre for Doctoral Training (CDT) in Sustainable Chemistry and the University of Birmingham's EPSRC CDT in Formulation Engineering.**
- **The growth of our research team throughout 2015 means we now have a high calibre talent pool consisting of 13 Postdoctoral researchers and research assistants, 15 PhD students and one MRes student.**
- **We held the first of our Annual Conferences in the spring of 2015, and hosted a precompetitive industrial workshop on additive manufacturing opportunities for the food industry in the autumn, contributing towards the UK strategy on additive manufacturing for food.**
- **Our Members Network more than doubled in size, and we now have almost 40 members from across the food value chain.**

The foresight for UK food manufacturing

In the developing world, it is estimated that a third of the calories grown to feed people are lost annually across all stages of the food chain. For this reason intensification production strategies are required to produce additional foods to meet the global demand; this is unlikely to be a long-term solution.

Food manufacturing can significantly contribute to the development of a sustainable food system by evaluating advanced manufacturing strategies (For example, flexible and distributed manufacture) to maximise the efficiency of food production and to reduce losses.

Food manufacturing is a high value industry; the low cost of production versus high purchase volumes means the industry is lucrative, with the highest turnover of all the manufacturing sectors.

The UK and other developed nations are becoming steadily dominated by Generation Y, the millennials, the boomers born between the early 1980's and the early 2000's, who are demanding convenient, sustainable, nutritious and tasty foods. However, extreme weather events, fluctuating oil prices, population booms in the East, and humanitarian crises are all factors threatening the security of food for millions of people. Food manufacturers are therefore investing into finding sustainable alternatives and energy efficient methods for producing nutritious foods, resilient to such perturbations, that can be made available to populations across the globe.

“The industry has a turnover of about £80bn, with exports contributing some £12bn. It also supports an R&D budget of over £300m. Various Foresight Studies have recognised that no single technology dominates this industry.”

The UK National Technology Platform for Food

Innovations in food and food manufacturing

Manufacturing healthier ingredients

Exploiting nature's offerings through novel and environmentally friendly primary processing for healthier foods and ingredients is one of the EPSRC Centre's specialisms.

For example, intact oil bodies can be recovered from crop seeds through aqueous extraction and can be used as an alternative ingredient for emulsion based formulations, or exploited for their phytonutrient (omega 3) composition or flow enhancing properties. Our research also explores the feasibility of nutrient-rich ingredients extracted from plant organelles for incorporation into food and feed, including the potential for these organelles to more efficiently provide nutritional factors into the food chain. We are also investigating how to functionalise cellulose as a food structuring material and tackling the challenge of increasing dietary fibre in foods.

Food manufacturers also want to address controlled or sustained release / delivery of actives, and research at the EPSRC Centre is concentrated on multifunctional gels and complex emulsions to act as a carrier of desirable payloads, such as tastants and flavour maskers, bioactives and probiotics.

Pickering stability of foams and emulsions is of huge interest to the food sector as it broadens the formulation space, removing the use of artificial surfactants from engineered emulsions. We are developing this interest further in several ways:

- by using Ayurvedic bioactive compounds we are engineering nanosuspensions of Pickering particles that, in amorphous state, reduce the interfacial tension of the phases of the emulsion
- by investigating the innate emulsifying ability of cocoa powder and cocoa fibre and hypothesising the presence of lignin to aid this phenomena, we are exploring the emulsifying capacity of other lignin-rich food waste that can be re-valorised as food grade ingredients.

Towards healthier food product choices for consumers

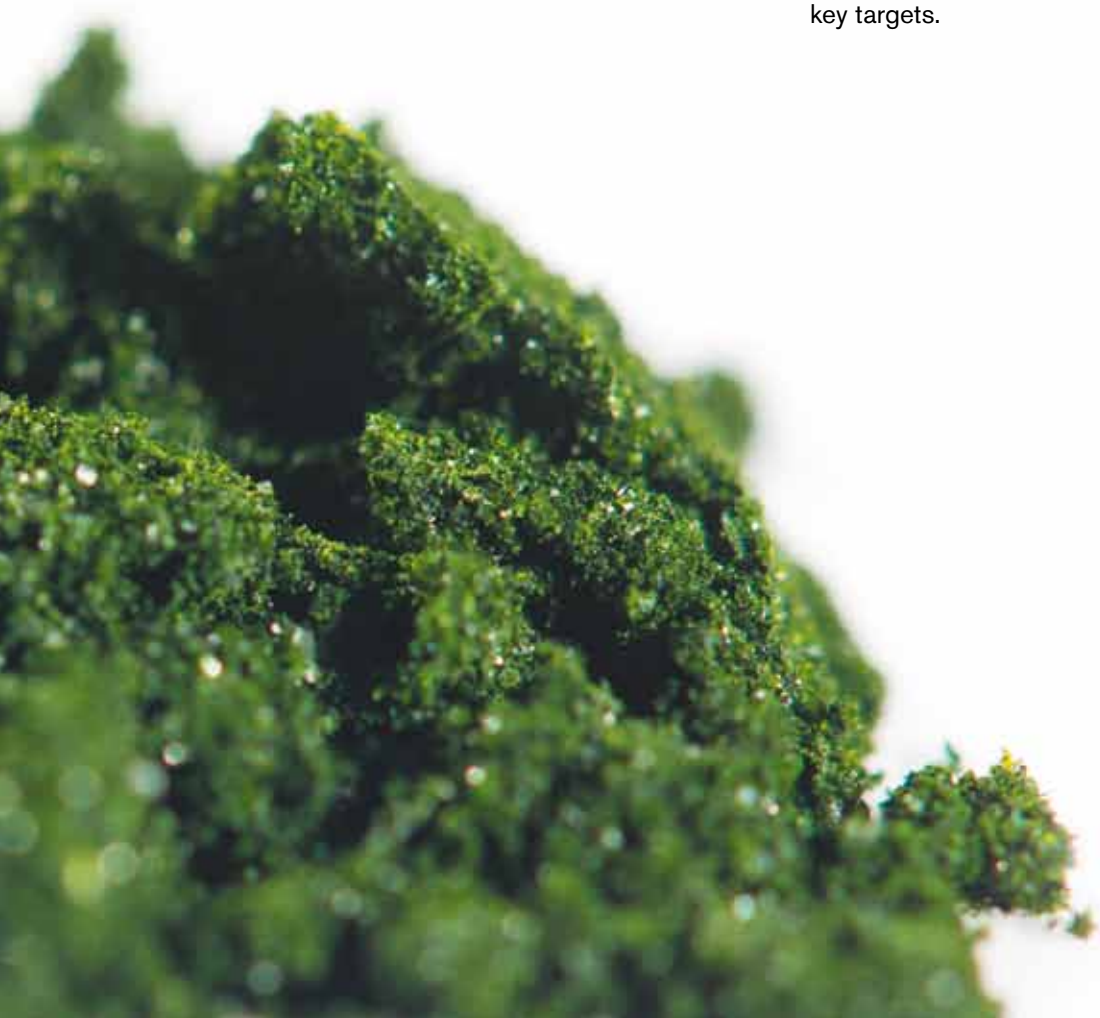
Research at the EPSRC Centre has international applicability, suitable for different food processing mechanisms, cultures and trends, beyond simply responding to the latest health agenda.

Consumers are beginning to understand the consequences of too much salt, sugar and fat, whilst still demanding extensive ranges of tasty foods providing the freedom *to choose* nutrition, *to choose* convenience, or *to choose* indulgence.

Some popular indulgent food products are comprised of delicate, liquid foams with limited stability. Improving the stability of these luxury products can be achieved using various ingredients, such as proteins (from dairy and plant), gels and gums, or fatty acid esters and surfactants, spray dried as fluid gels to create foaming particles.

Exploring the potential that plant-based ingredients and plant-based proteins (co-products of other processes) can offer the food industry, and ultimately the consumer, goes some way to providing resilience of producing nutritional food to meet consumer and population demands.

We are looking to create healthier alternatives of favourite foods by exploring new material properties and processes. Products explored to date are biscuits, cake and bread, where replacing gluten and reducing glycaemic load are key targets.



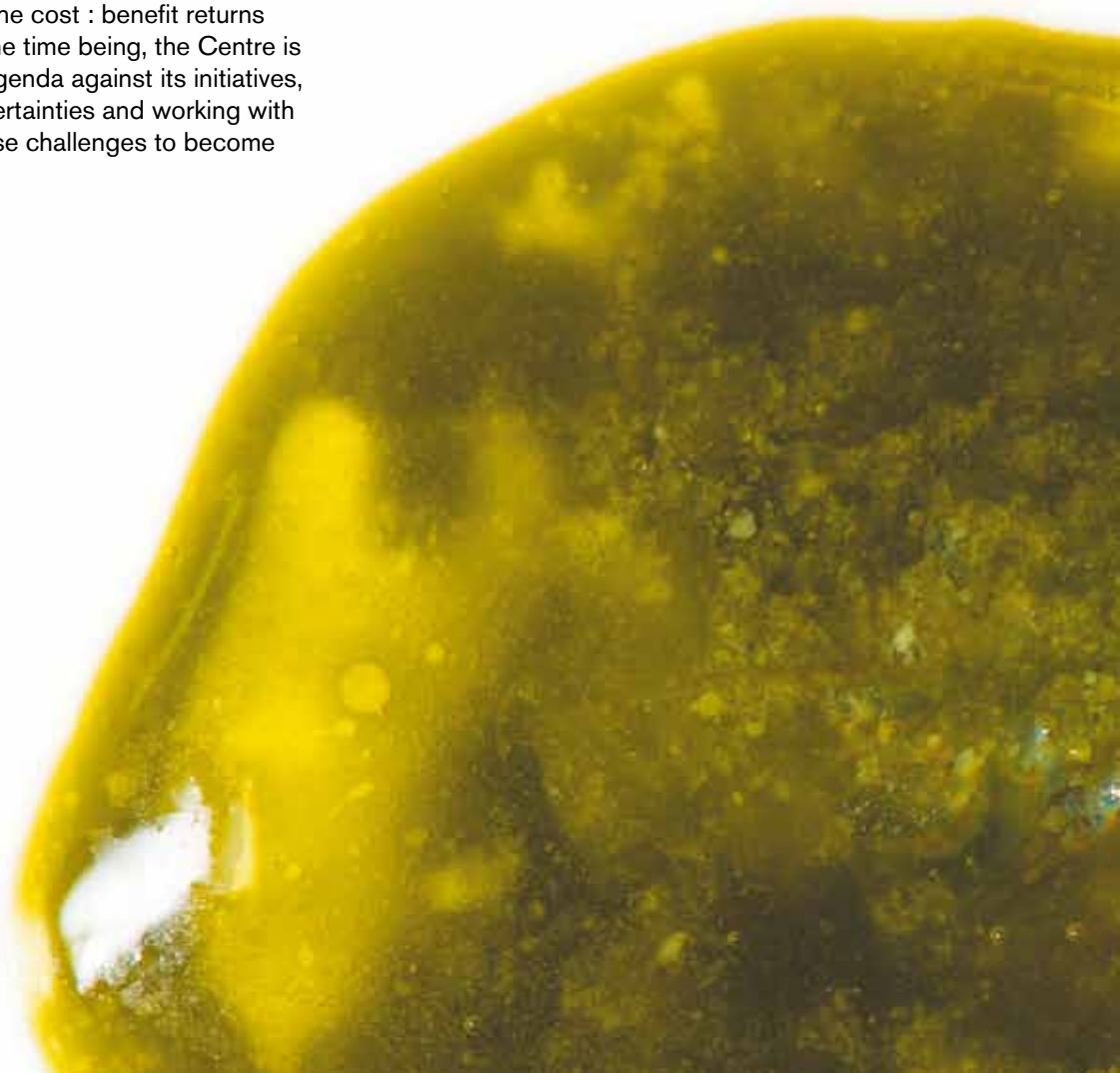
Driving technological innovations

The introduction of advanced manufacturing processes affording flexible, efficient and reproducible production with customisable features is starting to entice the food manufacturing community.

The transition to distributed manufacturing via additive layer manufacturing requires understanding the materials properties required to achieve novel structures affecting taste profiles and textures, and is being pioneered at the Centre. The food manufacturing sector are exploring the potential additive manufacturing has for their own product portfolio and the efficiencies it offers towards manufacturing processes. Although the cost : benefit returns remain uncertain for the time being, the Centre is aligning the political agenda against its initiatives, addressing these uncertainties and working with industry to enable these challenges to become opportunities.

The Centre is also conducting research into membrane emulsification to produce uniform droplets one-by-one, in contrast to conventional methods such as comminution. The process uses pressure to force the dispersed phase to permeate through a membrane into the continuous phase, allowing for excellent control over size and shape formation.

Simple and complex emulsion architectures can be achieved in a low energy and reliable fashion using microchannels such as microfluidic devices (resulting in drop-by-drop formation) and confined impinging jet reactors (CIJR). CIJR's allow emulsion formation by head-on impinging of two coaxial jets generating a localised region of highly intense turbulent energy-dissipation. Different from 'top-down' routes, CIJRs guarantee highly uniform mixing conditions because of their small control volume.

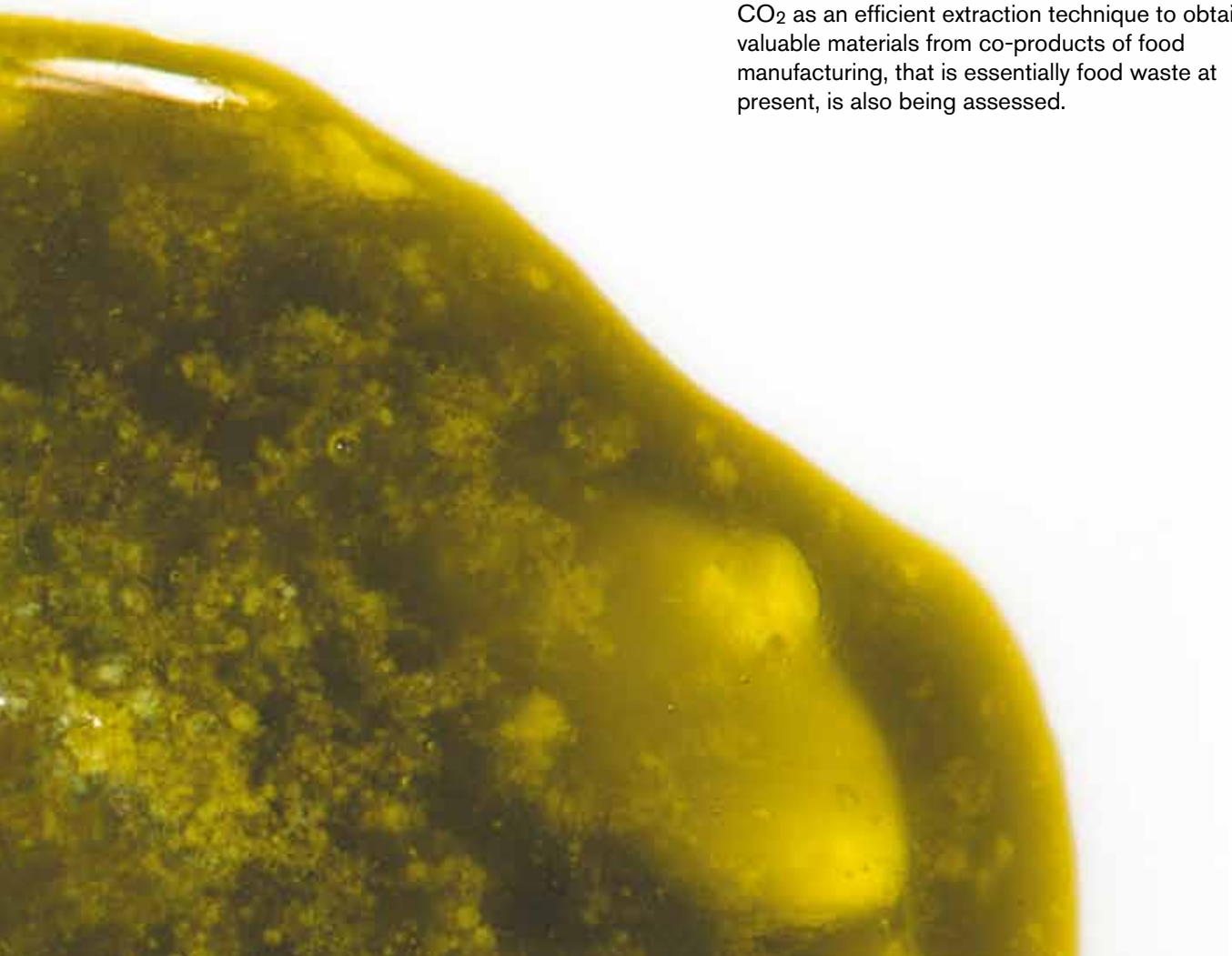


Food manufacturing with improved efficiency and flexibility

The Centre is enabling the movement of the food manufacturing sector towards distributed manufacturing through its research into dehydration and rehydration of hydrocolloids, and re-dispersible dry emulsions.

Distributed manufacturing of food will not only allow the consumer to rapidly produce finished products in-house to the same quality finish, but will also reduce industrial and household waste through extended shelf-life and stability during storage. Distributed manufacturing will therefore rely upon the introduction of innovative, efficient processes for the commercial manufacture of food structures. The Centre has microwave vacuum drying facilities that are scalable to industrial frequencies. Trials carried out on gel systems have demonstrated this technique to preferentially heat moisture rather than the hydrocolloid matrix, offering scope for reducing water content in both the dehydrated state and the amount needed for effective rehydration.

Supercritical drying is a technique that is currently being developed by the Centre as a means of dehydrating delicate structures (without causing damage), by passing through the supercritical region of the liquid-gas phase. The supercritical fluid dryer has been built by the Centre and will be assessed in its ability to produce quality finished products in an efficient way. As the Centre continues to collaborate with other research groups the feasibility of supercritical CO_2 as an efficient extraction technique to obtain valuable materials from co-products of food manufacturing, that is essentially food waste at present, is also being assessed.



Towards food manufacturing resilience and sustainability

One way of achieving global food security is by designing a manufacturing system that enables production to continue even when resources are scarce.

To this end, the Centre has set the challenge to design and, along with industrial partners, begin to implement some of the rules that will reduce resource consumption whilst maintaining (even surpassing) current production volumes.

One such example is through the redesign of biscuit manufacturing, using intrinsic liquids present in raw materials to add functionality to the baking process when the mixture is exposed to high pressures. Another example is multilevel inventory management using digital augmentation in the form of either multi-use barcodes (for food manufacturers), loyalty card systems (for use by retailers) and mobile phone applications (for use by consumers). This will allow a resilience to be developed across the value chain in the sourcing of ingredients, production planning and distribution, offering the implementation of 'point-of-sale' and 'make-to-order' manufacturing approaches for products with very short shelf lives.

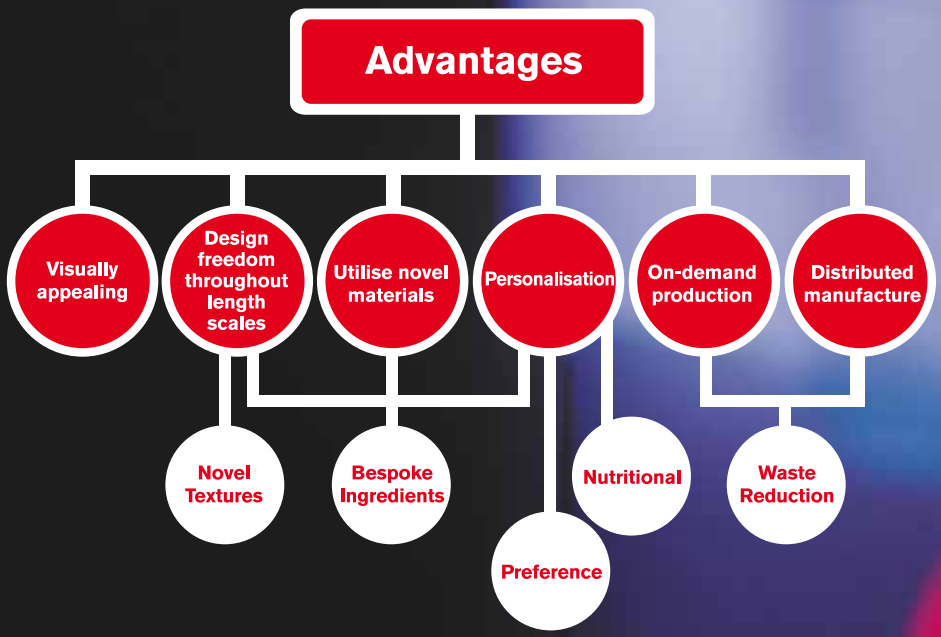
Case study

Edible materials and technologies towards additive manufacturing

Additive Manufacturing (AM) is the direct fabrication of end use products and components using technologies that deposit material layer-by-layer and point-by-point.

For the food industry, AM opens up several advantages, including:

- Design freedom, allowing for novel structures to be produced
- The use of novel materials to create bespoke ingredients
- Tailoring products to meet the nutritional needs and palate preferences of consumers
- Transitioning production models towards distributed manufacture and point-of-sale production, potentially reducing waste



By creating the design rules for harnessing the versatility and ability for the food manufacturing sector to produce novel structures through additive manufacturing, we are engineering edible filaments via fused deposition modelling (FDM) to create edible objects and structures, allowing for fast prototyping of end-products. Initial research has focused on gelatin based edible filaments, comparing currently used filaments (such as polylactic acid (PLA)) to the gelatin, with a view to printing in two colours using two different edible filaments.

Other research has concentrated on harnessing natures materials to create particles with interesting topographies, curvatures and Pickering particles for emulsion stabilisation. Cellulose, the most abundant polymer in nature, carries zero calories as a food ingredient and falls into the category as a dietary fibre, and could be a promising base material for these applications.

Case Study

Redesigning biscuit manufacture

Biscuits are baked products made principally from fat, sugar and flour. Some of their most important characteristics are the long shelf life, their great convenience as food, the consumer preference for sweet foods and their good value for money, all of which contribute to their success. Biscuit manufacture has evolved to reduce the labour input throughout the process; however no major changes have been made to the baking process.

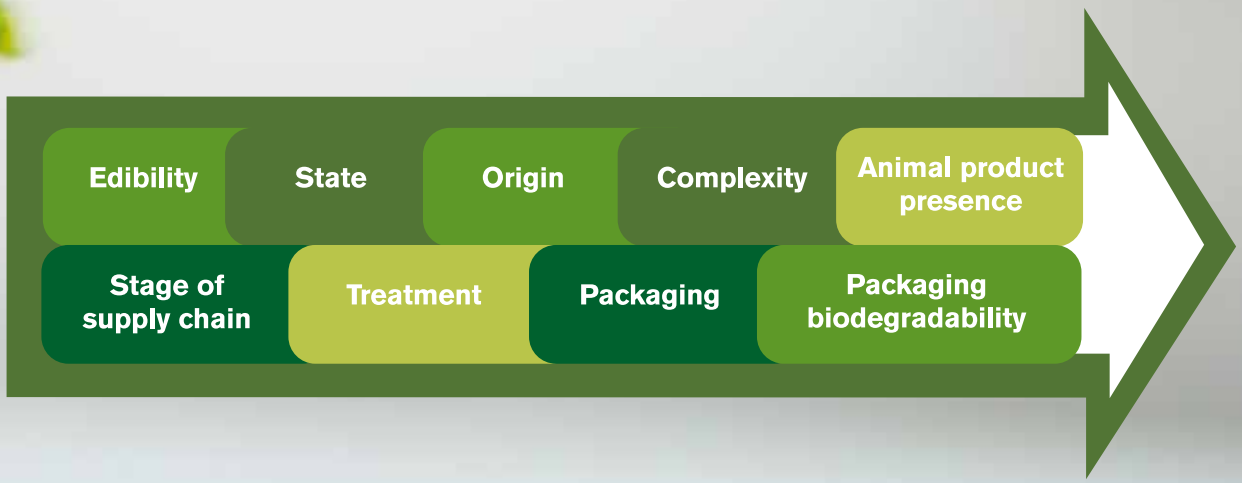
The traditional way of baking biscuits is through oven baking; however we have developed a new process to cook biscuits, by changing the part of the manufacturing process in which the dough is converted to a biscuit through drying, colour development and structure formation. By using a heated press, which combines the use of thermal treatment and applied pressure, a reduced water content dough can be modelled with two heated plates that will move with the desired pressure applied by a piston. The main advantages for making biscuits with a heated press are the potential of removing water in the formulation of the dough, and the reduction in processing time. In this study, the biscuits were made with a variety of recipes and different process parameters with the heated press, in order to fully understand the effects.

Case Study

Eco-production of food: reducing the impact of food waste

To address the 1.3bn tonnes of food waste generated globally each year, the Centre has developed a framework to optimise the waste management strategy of food manufacturers (with a view for use by retailers and consumers) by assessing the boundaries of the manufacturing systems, defining the category that the waste falls into, and analysing the environmental impact of existing and proposed management methods.

As food waste emerges at the end of a particular supply chain, assessing whether the waste is *food waste* or *food loss*, and whether it is edible, or even planned, can help towards developing a waste mitigation strategy. According to Waste and Resources Action Programme (WRAP), food manufacturing activities resulted in almost 4m tonnes of food waste being produced in the UK (2010-2014), contributing towards environmental impacts such as carbon emissions, water usage, and land occupation required to generate the material in the first place. In response, we have developed a 9-stage categorisation toolkit that allows food manufacturers to consider the properties of the 'waste' and any potential value reserves that could feedback into the manufacturing process, effectively providing a circular economy for that particular process.



Engagement with the UK food manufacturing and research community

As a National Centre, it is our responsibility to build and strengthen links amongst the food research base here in the UK. Working closely with the KTN, we ensure alignment of our strategic objectives and the complementarity of our research programmes, with those being undertaken at other leading institutes.

Some of the research programmes we have contributed to are:

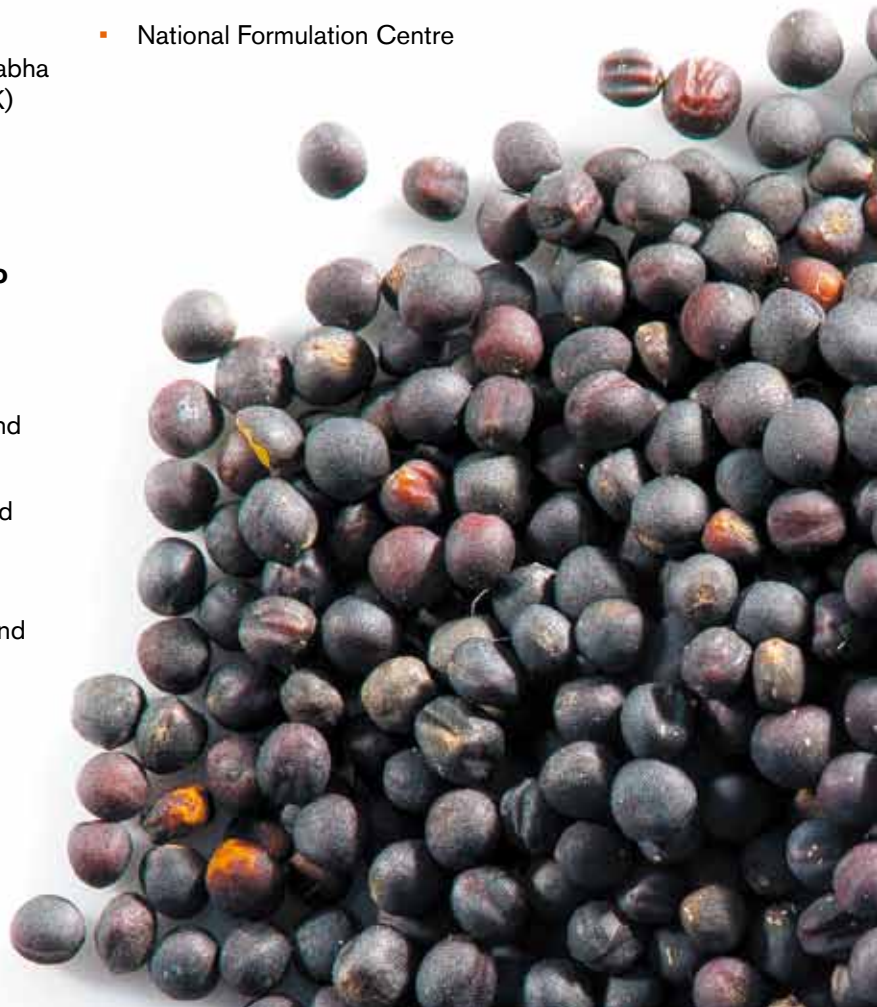
- Prototyping Open Innovation Models for ICT-Enabled Manufacturing in Food and Packaging (EPSRC)
- Scoping visit to India for the Newton Bhabha Fund (ODA, British Council, Innovate UK)
- Future Formulation of Complex Products (EPSRC)

Our research has been disseminated to international audiences at:

- CoCoTea 2015, Portugal
- European Federation of Food Science and Technology, EFFoST, Athens, Greece
- The 7th International Symposium on Food Rheology and Structure - ISFRS 2015, Zurich, Switzerland
- International Congress on Engineering and Foods, ICEF12, Quebec, Canada

National and international research centres we have engaged with include:

- Centre for Sustainable Energy in Food Supply Chains (EPSRC)
- National Centre of Excellence in Food Engineering (FDF; HEFCE)
- Sustainable Food Cities programme (Esmée Fairbairn Foundation)
- CSIR-Central Food Technological Research Institute; Indian Institute Crop Processing Technology (India)
- Centre for Innovative Manufacturing in Additive Manufacturing (EPSRC)
- Centre for Process Innovation (CPI, HVM Catapult Centre)
- Sustainable Materials and Research Technology (UNSW)
- National Formulation Centre



Developing our impact strategy by collaborating with our network

Over the past 12 months we have more than doubled our industrial partnerships, and we are proud of our almost 40-strong Centre Members Network.

Engaging with industry to share our vision, challenges, and research findings to date has enabled the establishment of research projects with some of our industry partners, some of which have been supported by funding mechanisms including: Innovate UK, BBSRC Networks in Industrial Biotechnology and Bioenergy (NIBBs), BBSRC Diet and Health Research Industry Club (DRINC) and BBSRC CASE Studentships. Other projects have seen partnerships directly with industry partners, either through sponsorship of researchers, funding of materials or loaning of equipment. Collaborations with our members has generated an additional £2.5m income to the EPSRC Centre.

Interaction with industry members allows us to continually assess the business readiness of our project portfolio, and the pre-competitive nature of our core funded research allows for translation of technologies into a range of applications, and therefore multiple end users. Throughout the year the EPSRC Centre staff and researchers have discussed ideas with industry and Campden BRI, to understand involvement in the Centre and to implement our tools, technologies and methodologies.

The diversity of research projects currently being undertaken by the Centre will allow for a greater impact footprint for a multitude of small, medium and large enterprises that not only span the food value chain, but also extend into parallel industries. Work aligning to LEP funding in food will ensure local delivery in the Midlands. Research projects founded in collaboration with industry or through public-private partnerships are subject to separate impact pathways as determined by the project.

Reaching out as a National Centre

The Centre prides itself in its knowledge sharing activities aimed at policy makers, industry and the broader public. Great examples of our showcasing activities are:

National Science and Engineering Week: Science in the Park

In March 2015, a team of EPSRC Centre staff took to Wollaton Hall for a family-oriented event, attended by more than 5,000 people, to demonstrate how family-favourite foods are engineered through an interactive microstructure game to introduce the intricate details found in natural and engineered food products.

Manufacturing the Future Conference

In September 2015, EPSRC Centre staff exhibited at the EPSRC-hosted event along with the 15 other EPSRC Centres for Innovative Manufacturing. Presentations were also given by Unilever and PepsiCo, increasing the Food Industry exposure in the EPSRC manufacturing landscape.

British Science Festival fringe

During British Science week, the EPSRC Centre set up an interactive activity at the University of Bradford for families to explore how food manufacturers use ingredients to produce structure, texture and other sensorial properties in jelly sweets and aerated chocolate.

Food Matters Live

In November 2015, the EPSRC Centre showcased its six research themes at the Food Matters Live exhibition at the ExCel Conference Centre, London. Across the three-day event, with an international audience and over 10,000 visitors, students and staff from the Centre discussed their research, presented at seminars and debated policy with representatives from industry, academia and government.

Grime Scene Investigations

Our eco-manufacturing of food research requires insight into consumer behaviour and their treatment of food waste, and there is no better place to start than with the domestic waste from students halls of residence. Researchers are categorising food waste according to the 9–stage categorisation toolkit to glean valuable insights into the way food is manufactured, how it is presented to consumers, and how the consumer behaves post-preparation and consumption of food.

Your Green Futures

In March 2016, a team of research students and staff from the EPSRC Centre provided business mentoring for school children tasked in designing sustainable products.

Edible Engineering: 'Science Museum Lates' series

In January 2014, the Centre was invited to deliver a presentation to interested and enthusiastic adults under the engineering theme as part of the 'Science Museum Lates' series. The team invited an audience of over 150 people to analyse how food manufacturers can substitute or add ingredients to alter textures, oral processing and nutritional content in some of our favourite snacks and chocolates.

EPSRC Centre management

Prof Tim Foster
Centre Director

Tim worked for over 15 years in Unilever's R&D organisation leading groups in the areas of biopolymers and new technology development. His advisory roles include groups such as the European Technology Platform Food for Life and WCFS/TIFN, and he has supervised post-graduate and post-doctoral researchers in a number of publically funded projects. He left his position as Senior Scientist in Unilever to take up a role in The University of Nottingham in 2007.

His current work focuses on natural structuring agents including cellulose, rehydration phenomena and microstructure changes in food products during digestion. Optimal nutrient delivery through the microstructure of manufactured foods is something being developed with colleagues in the current collaboration between Nottingham and the Universities of Birmingham and Loughborough in the EPSRC Centre for Innovative Manufacturing in Food. He is on the management team of The University of Nottingham's Institute of Advanced Manufacturing, is a fellow of the Royal Society of Chemistry and is Associate Editor of the RSC's journal Food & Function.

Prof Ian Norton
Deputy Director

Ian joined Unilever after obtaining his doctorate in Physical Chemistry of polysacch-aride conformational transition, moving into the area of colloids and interfaces. There he developed a microstructure approach, designing materials properties by choosing the ingredients based on their physical interactions, and then designing the process to physically structure and trap the microstructure in the desired state. The resulting material and its properties can allow ingredient flexibility in terms of alternatives and replacement, and has resulted in more than 60 granted patents covering ingredients, spreads, dressings, sauces, skin creams, shampoos and ice-cream, leading to many new and innovative products, which are still on sale today.

Ian left his role as Chief Scientist at Unilever to take a Chair as Professor of Soft Solid Microstructural Engineering in the Department of Chemical Engineering at the University of Birmingham, where he continues his microstructure work, extending into a wider range of soft solids, which are used extensively in foods, personal care products, and pharmaceuticals.

Prof Shahin Rahimifard
Deputy Director

Shahin is a Professor of Sustainable Engineering in the Wolfson School of Mechanical and Manufacturing Engineering at Loughborough University. He is the Founder and Director of the Centre for 'Sustainable Manufacturing And Recycling Technologies (SMART)', which was formed in 2004. He is leading a wide range of research focused on 'Product Lifecycle' sustainability issues. This includes projects on sustainable product design, low carbon and energy efficient manufacturing, sustainable business and consumption models, product service systems, sustainable resilient manufacturing supply chain, and remanufacturing and recycling technologies.

Shahin has extensive editorial experience. He was the Principal Organiser and Chair for the 5th International Conference on 'Design and Manufacturing for Sustainable Development' held at Loughborough in July 2007, and since its launch in 2008, has been the Editor-in-Chief of the 'International Journal of Sustainable Engineering'.

Dr Elliot Woolley, Loughborough University
Elliot obtained his PhD in the field of atomic physics and nuclear magnetic resonance in 2007 from The University of Nottingham, joining Loughborough University in 2010 in a business strategy development role for the Competitive Sustainable Manufacturing research cluster. In April 2012 he was appointed as Lecturer in Sustainable Manufacturing within the Wolfson School of Mechanical and Manufacturing Engineering. Elliot's research focuses on energy minimisation and intelligent management of operations and process planning within manufacturing. Research activities include eco-intelligent manufacturing and planning response to uncertainties in supply.

Dr David Gray, The University of Nottingham
David obtained his PhD in Plant Lipid Biochemistry from the University of Birmingham in 1992, joining The University of Nottingham's Division of Food Science in 1993. David is interested in the general area of lipids, and exploring novel ways of incorporating healthy lipids into foods, with maximum benefit to the consumer and minimum impact on the environment. Research interests include sustianable nutrition, characterisation of functional and nutritional properties of plant cell organelles (ex vivo), alternative sources of omega-3 fatty acids, microalgae as food / feed, novel processing of oilseeds.

Dr Fotis Spyropoulos, University of Birmingham
Fotis completed his PhD on 'The phase, rheological and interfacial behaviour of water-in-water emulsions' at the School of Chemical Engineering at the University of Birmingham in 2006, where he remained as research fellow until his appointment as Lecturer of Chemical Engineering in 2010. Fotis' research interests lie in the areas of 'Food Structure Development', 'Encapsulation and Release' and 'Formulation Engineering of Emulsions and Soft Solids'. Fotis is a member of the Diet and Health Research Industry Club (DRINC) steering group and of the 'Gums and Stabilisers for the Food Industry' Conference Organising Committee.

Dr Bettina Wolf, The University of Nottingham
Bettina completed her PhD in Technical Sciences in the Food Process Engineering group at the Swiss Federal Institute of Technology (ETH), Zurich. In 1997 she joined the Product Microstructure unit and then Corporate Research at Unilever Research Colworth, UK, as Research Scientist. In 2006, Bettina left Unilever to take up a post as Associate Professor in Biomaterials Science in the Division of Food Sciences at The University of Nottingham. Her research interests lie in the fields of rheology, food microstructure and processing, oral processing and food interfaces.

Dr Tom Mills, University of Birmingham
Tom is a lecturer in Food Manufacture, Chemical Engineering. His primary research interest is in the area of *in-vitro* methods to study the mouth, focusing on tribology as a method to look at thin film and lubrication behaviour. Additionally he is involved in projects looking into edible 3D printing technologies, saturated fat crystallisation and emulsifier performance, the production and behaviour of particle-stabilised emulsion systems and particulate fluid gels. The aim of this research as a whole is to understand material property and behaviour from formulation through production, into breakdown and in-mouth experience.

Key individuals

Research Fellows

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University of Birmingham

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Publications and acknowledgements

Chiu, N., Hewson, L., Fisk, I., and Wolf, B., Programmed emulsions for sodium reduction in emulsion based foods. Food & Function, 2015. 6, 1428-1434

Garcia-Garcia, G., Woolley, E., Rahimifard, S., A framework for a more efficient approach to food waste management. International Journal of Food Engineering (IJFE), 2015. Vol. 1, pp. 65-72

Koganti, N., Mitchell, J., MacNaughtan. W., Hill, S., and Foster, T., Effect of granule organisation on the behaviour of starches in the NMMO solvent system. Carbohydrate Polymers, 2015. 116, 103-110

Makkhun, S., Khosla, A., Foster, T., McClements, D.J., Grundy, M.M.L., and Gray, D.A. Impact of extraneous proteins on the gastrointestinal fate of sunflower seed (Helianthus annuus) oil bodies: a simulated gastrointestinal tract study. Food and Function, 2015. 6, 124-133

Moakes, R.J.A., Sullo, A., and Norton, I.T., Preparation and characterisation of whey protein fluid gels: The effects of shear and thermal history. Food Hydrocolloids, 2015. 45: p. 227-235

Norton, J.E., et al., Functional food microstructures for macronutrient release and delivery. Food & Function, 2015. 6(3): p. 663-678

Torcello-Gomez., A, Fernandez-Fraguas, C., Ridout, M.J., Woodward, N.C., Wilde, P.J., and Foster, T.J., Effect of substituent pattern and molecular weight of cellulose ethers on interactions with different bile salts. Food and Function, 2015. 6(3), 730-739

Abbaszadeh, A., Lad, M., Janin, M., Morris, G.A., MacNaughtan, W., Sworn, G., and Foster, T.J., A novel approach to the determination of the pyruvate and acetate distribution in xanthan. 2014. 162-171

Abbaszadeh, A., MacNaughtan, W., and Foster, T,J, The effect of ball milling and rehydration on powdered mixtures of hydrocolloids. Carbohydrate Polymers 2014. 102, 978-985

Abson, R., Gaddipati, S.R., Hort, J., Mitchell, J.R., Wolf, B., and Hill, S.E. A comparison of the sensory and rheological properties of molecular and particulate forms of xanthan gum. Food Hydrocolloids, 2014. 35, 85-90

Bot, A., Foster, T.J., and Lundion, L.O., Modelling acidified emulsion gels as Matryoshka composites: Firmness and syneresis. Food Hydrocolloids, 2014. 34, 88-97

Bradbeer, J.F., et al., Self-structuring foods based on acid-sensitive low and high acyl mixed gellan systems to impact on satiety. Food Hydrocolloids, 2014. 35(0): p. 522-530

Choi, H., Mitchell, J., Gaddipati, S.R. and Hill, S.E., Shear rheology and filament stretching behaviour of xanthan gum and carboxymethyl cellulose solutions in presence of saliva. Food Hydrocolloids, 2014. 40, 71-75

Delime, P., Lemmens-Smink, N., and Wolf, B., Competitive adsorption of lecithin and saliva at the o/w interface in relation to the oral processing of lipid continuous foods. Food Biophysics, 2014. 9, 285-291

Douaire, M., et al., Fat crystallisation at oil-water interfaces. Advances in Colloid and Interface Science, 2014. 203: p. 1-10

Douaire, M., Stephenson, T., and Norton, I.T., Soft tribology of oil-continuous emulsions. Journal of Food Engineering, 2014. 139: p. 24-30

Erten, T., Adams, G., Foster, T.J., and Harding, S.E., Comparative heterogeneity, molecular weights and viscosities of xanthans of different pyruvate and acetate content. Food Hydrocolloids, 2014. 42, 335-341

Farres, I.F., Moakes, R. J. A., and Norton, I.T., Designing biopolymer fluid gels: A microstructural approach. Food Hydrocolloids, 2014. 42: p. 362-372

Gladkowska-Balewicz, I., Norton, I.T., and Hamilton, I.E., Effect of process conditions, and component concentrations on the viscosity of kappa-carrageenan and pregelatinised cross-linked waxy maize starch mixed fluid gels. Food Hydrocolloids, 2014. 42: p. 355-361

Lee, L., et al., Production of water-in-oil nanoemulsions using high pressure homogenisation: A study on droplet break-up. Journal of Food Engineering, 2014. 131: p. 33-37

Norton, J.E., et al., Designing Food Structures for Nutrition and Health Benefits. Annual Review of Food Science and Technology, Vol 5, 2014. 5: p. 177-195

Payne, G., Lad, M., Foster, T.J., Khosla, A., and Gray, D.A., Composition and properties of the surface of oil bodies recovered from Echium Plantagineum. Colloids and Surfaces B: Biointerfaces, 2014

Torcello-Gomez, A., and Foster, T.J., Interactions between cellulose ethers and a bile salt in the control of lipid digestion of lipid-based systems.Carbohydrate Polymers, 2014. 113, 53-61

Torcello-Gomez, A., Maldonado-Valderrama, J., Jodar-Reyes, A.B., and Foster, T.J., Interactions between polymeric surfactants and bile salts: New routes for controlling lipid digestion of oil-water emulsions In: Gums and Stabilisers for the Food Industry 17 - The changing face of food manufacture - the role of hydrocolloids, 2014. 334-341

Vo, L.T.T., Hajji, F., Siroka, B., Manian, A.P., Davis, A., Foster, T.J., and Bechtold, T.,Direct carbamation of cellulose fiber sheets. Cellulose, 2014. 21(1), 627-640

Zhou, Y., Winkworth-Smith, C., Wang, Y., Liang, J., Foster, T.J., and Cheng, Y., Effect of a small amount of sodium carbonate on konjac glucomannan-induced changes in thermal behavior of wheat starch. 2014. 114, 357-364

Zhou, Y., Zhao, D., Foster, T.J., Liu, Y.X., Wang, Y., Nirasawa, S., Tatsum, I.E., and Cheng, Y.Q., Konjac glucomannan-induced changes in thiol/disulphide exchange and gluten conformation upon dough mixing. Food Chemistry, 2014. 143, 163-169

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