EPSRC Centre for Innovative Manufacturing in Food

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EPSRC CENTRE FOR INNOVATIVE MANUFACTURING IN

Food

Annual Report 2014/2015

UNIVERSITY OF BIRMINGHAM

Loughborough University

The University of Nottingham
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Opening Remarks

Welcome to the first annual report of the EPSRC Centre for Innovative Manufacturing in Food. Over the past year, our focus has been establishing the Centre and recruiting its core operational team, as well as compiling ideas and forging research projects with academic and industrial collaborators. We now have a fully operational team, academic staff, post-doctoral and PhD researchers from across three institutions, and a blossoming academic and industrial network.

This Annual Review provides an insight into the first year of operations of the EPSRC Centre for Innovative Manufacturing in Food. We want to share our achievements, activities and events of our first year and our vision for the future.

Some of our achievements include the preparation of stable emulsions using associative biopolymer complexes, the formation of tightly controlled emulsion droplet distributions using novel membrane emulsification and microfluidics techniques, and reducing the amount of raw materials required to achieve the same level of structure in food systems. In our second year we will be progressing work in the area of understanding physical chemistry of hydrocolloid and food structure dehydration through novel drying processes for controlled rehydration properties, continuing to evaluate the life cycle of many food groups and the causes of food waste generated across the supply chain, for better food waste management, and valorisation in a biobased economy. We will also further explore the principles behind redesigning the manufacture of healthy foods and focus on redistributed manufacturing strategies for energy and water minimisation and meeting the ever changing consumer needs.

Centre vision statement

Our vision is for the EPSRC Centre to meet the challenges of global food security through developing world-leading technologies, tools and lead ers, tailored to meet the needs of current challenges while redesigning resource efficient and sustainable, nutritious foods of the future. The proposed multidisciplinary, multi-university collaborative programme provides a springboard for the establishment of an internationally recognised centre of excellence for Innovative Food Manufacturing, which will have the potential to significantly influence practice, research and policy for decades to come, and will play a central role in the implementation of the UK strategy for Global Food Security.

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About the Centre Director, Professor Tim Foster

Tim Foster worked for a little over 15 years in Unilever's R&D organisation where he led groups in the areas of biopolymers and new technology development. He acted as an advisor on a number of working groups such as the European Technology Platform Food for Life and WCFS/TIFN, and 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 become Associate Professor and Reader in Food Structure at the University of Nottingham in 2007, and has since supervised 17 post-graduate researchers and 5 post-doctoral researchers.

His current work focuses upon a further investigation of natural structuring agents including cellulose, rehydration phenomena and microstructure changes in food products during digestion, and is centred on understanding the creation of required food microstructures from the most appropriate ingredient supply, utilising the most appropriate processes. 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 and Function.

About Professor Shahin Rahimifard (Deputy Director)

Shahin Rahimifard 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)" (**www.centreforsmart.co.uk**), which was formed in 2004. Professor Rahimifard is also the Deputy Director in 'EPSRC Centre for Industrial Sustainability' and 'EPSRC Centre for Innovative Manufacturing in Food', in which he is leading a wide range of research focused on sustainability issues throughout a 'Product Lifecycle', including 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. These projects have benefited from involvement of a number of high profile global manufacturers and retailers, which include Rolls-Royce Fuel Cell, Jaguar, Toyota, GM, Unilever, PepsiCo, Heinz, Nike, New Balance, Clarks, Marks and Spencer, Tesco, and Next.

Prof. Rahimifard has an extensive range of editorial experiences. He was the Principal Organiser and Chair for the 5th International Conference on "Design and Manufacturing for Sustainable Development" which was held at Loughborough in July 2007 and has been the Editor-in-Chief of the 'International Journal of Sustainable Engineering' [**www.tandf.co.uk/journals/tsue**] since its launch in 2008 (published by Taylor and Francis).

About Professor Ian Norton (Deputy Director)

Prof Norton 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. After obtaining his doctorate in Physical Chemistry of polysaccharide conformational transitions, he joined industry and moved into the area of colloids and interfaces and developed a microstructure approach, where the material properties are designed by choosing the ingredients and the way they physically interact, 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.

Professor Norton used this microstructure approach to design foods and home and personal care products for Unilever, resulting 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. In his role at the University, Professor Norton continues this work which has extended into a wider range of soft solids, which are used extensively in: Foods, Personal Care Products, Cosmetics, Paints, Pharmaceuticals, Home Care / Hard Surface cleaning and Laundry.

Executive Summary

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 (e.g. flexible and distributed manufacture) to maximise the efficiency of food production and to reduce loses.

Our research focuses on the manufacturing activities from 'post-farm gate to supermarket shelf' and more specifically, the implications of these activities on the areas of resource efficiency and sustainable production, delivering and disseminating our research to industries across the UK.

Additional funding to the original EPSRC grant has been sought from Innovate UK, as well as explorations into the Newton Fund, BBSRC and direct from industry. We have recently secured a Fellowship Award to fund a postdoctoral researcher for 2 years. Our industry membership continues to grow, and our direct input into two EPSRC Doctoral Training Centres in Formulation Engineering and Sustainable Chemistry means we are delivering front line knowledge to over 50 PhD students. We are affiliated with the BBSRC Food Waste and High Value Chemicals from Plants Networks in Industrial Biotechnology and Bioenergy (NIBB's), as well as playing a pivotal role in the decision making of policy makers and key opinion leaders within the food and drink manufacturing sector, ensuring our research remains at the forefront of the government's food and drink manufacturing strategy.

Our research team are covering two Grand Challenges: 1) innovative materials, products and processes, and 2) innovative food supply and manufacture, which then cover 6 research themes. Our Processing technologies theme covers research ranging from efficient novel drying processes of foods through to the design of microfluidic devices for emulsion production, exploring novel manufacturing and improved utilisation of functional ingredients are approaches for the production of healthier products, for example reducing fat, by exploring clean label emulsifiers and membrane emulsification. For a sustainable and resource efficient food supply chain we have a team of researchers dedicated to designing a food production approach, for adoption by industry, that reduces the impact of food waste, upgrading materials for value added ingredients, as well as re-evaluating the supply chain to implement sustainable methodologies.

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 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 closely with local food manufacturing communities, networks, multinational companies and SME's, who each have their own business models and strategic plans that cover the Grand Challenges put forward by the Centre for Innovative Manufacturing in Food, 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.

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Redefining Innovative Food Manufacturing

Food manufacturing is a valuable asset for the UK both through a vital and holistic contribution to the nation's well-being and through a valuable export contribution. Food and drink is the largest manufacturing sector in the UK with a turnover of £76.2bn, employing up to 400,000 people, with exports worth £10.8bn and salaries in excess of £10bn.

The rapidly increasing world population, changes in demand and dietary behaviours, both within developed and developing countries, and loss of arable land linked to climate change urgently demands a need to change the way we grow, manufacture and consume our food products.

In the food sector, innovation often deals with the adoption of new technologies to respond to different challenges: production of stable food products, new functionality and added value. Despite these premises, the food industry is often scored as low-tech, having one of the lowest R&D to sales ratio of any other industrial sector. This is because innovations in food industry are incremental rather than radical as food habits are part of the cultural heritage and change only slowly making the development of new technologies difficult. Indeed, innovation into processes and product development is a rather complex route that involves different stages, from basic research up to market penetration. In this perspective, the developed process must not only be excellent at developing new functional products; it must also have been able to manufacture them in a competitive cost structure.

Recently a great deal of focus has been given to innovation in food and nutrition, enabling the development of advanced materials with unique properties such as targeted delivery systems. The industrial implementations of such technologies will require faster translation of scientific results into high-value application as well as to utilise scientific advances from other disciplines.

The EPSRC Centre for Innovative Food Manufacturing aims to develop new manufacturing capabilities to deliver on the environmental, economic and social sustainability agendas. The Centre brings together expertise in the areas of biomaterial science, formulation engineering and sustainable manufacturing in a unique and multidisciplinary approach to address and stimulate the food manufacturing agenda of the future. By driving business growth and bringing together the national SME and global food community, we will enable the training and development of the thought leaders of the future.

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Processing Technologies

Redistributed manufacturing

Achieving greater flexibility within food manufacturing (in response to changes in demand and dietary behaviours and in order to deal with both the rapid increase in the variety of products and the resultant reduction in batch sizes) will involve replacing large scale and centralised globally based organisations with more innovative and organic structures based on 'distributed localised organisations'. Such distributed approaches in food production are reported to offer significant benefits including: reduction of the cost of logistics, and a reduction in environmental impact due to manufacturing the products closer to the point of consumption, reduction in the risk and cost of recovery from major failures occurring in a single production line, and support local economies by distributing the production activities. To enable these new systems of production and consumption new processing technologies will be explored to understand how to realise new systems from 'farm to fork' considering the challenges with utilising fresh perishable ingredients, the stringent storage and health risks associated with inappropriate distributions, together with short post-production shelf-life and production of more customised products.

Efficient novel drying processes of foods

A biopolymer matrix system represents an extremely high moisture structure, used to study whether a structure can withstand a significant removal of moisture (>95%) and still perform upon rehydration. Consideration of the properties of the biopolymer, including size, surface charge and structure, allows for investigation into the drying and rehydration kinetics. An innovative dehydration methodology (vacuum microwave) is being investigated and compared to conventional industrial drying methods, such as vacuum oven and freeze-drying. The dried and subsequent rehydrated material is currently undergoing analysis to investigate the level of moisture losses in addition to the structure and physical properties (for example viscosity profiles) of rehydrated material in comparison to its pre-dehydrated counterparts.

Design of Microfluidic devices for the production of compartmentalised emulsions

Manufacturing processes that deal with nanolitre amounts of fluids using channels with micrometre dimensions provide a promising approach to processing of dispersed food systems. The ability to manipulate nanolitre volumes of liquid enables the creation of highly uniform microparticles and droplets that can be further functionalised by employing creative strategies such as compartmentalisation, where the size and number of the compartments can be manipulated with unprecedented accuracy. One obstacle to the practical use of emulsion production through microfluidic technologies is the low-throughput preparation as the "droplet-by-droplet" formation is generally characterised by limited production rates. Even at the current throughput levels, sufficient quantities of functionalised emulsions can be efficiently produced for high-end applications, such as micro carrier applications of drugs. These properties are very difficult to achieve using conventional bulk emulsification methods. To this end, we have designed and implemented a simple Microfluidic device for the production of complex emulsion structures with the ability to control the temperature and surface chemistry. The next phase of this project is to expand the process-specific functionalities that can be imparted onto emulsion based sample and complex microstructures, and to also explore approaches for their successful industrialisation even if this ultimately means adopting a distributed manufacturing approach.

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Upgrading of Ingredients

Reducing fat

The long term objective of this research focuses on exploiting the functional properties of novel food-grade materials. These could either result from waste streams and by-products or could be natural materials which have found so far little utilisation in food applications. An example of novel ingredients belonging to this latter category is represented by oleosomes, which are natural oil-in-water emulsions contained in oil-rich seeds. The primary identified area of investigation focuses on exploring alternatives to saturated and trans fats for structuring edible oils via a novel route known as “oleogelation”. The general feature of this structuring strategy is represented by the gelation of the liquid oil (versus the conventional crystallisation occurring using saturated triglycerides) obtained with the addition of molecules able to “trap” the oil. Oleogels have gained increasing attention in recent years as potential materials from a fundamental understanding of the mechanisms involved in gel formation within oils, through to their application in foods, cosmetics, pharmaceutics and tissue engineering perspectives.

The research focuses on the use of plant waxes to structure oils as model food systems under quiescent conditions. These organogelators have demonstrable effectiveness in structuring oils and are gaining interest as novel food ingredients. In line with the concept of “upgrading materials”, a by-product of rice production is currently being studied to structure sunflower oil. Preliminary results have shown that a concentration of 0.5 %w/w is enough to provide solid-like structure to the oil. The microstructure of these gels reveals the existence of a network consisting of needle-like and fibrous structures.

Other aspects concerned with the formation of oleogels are currently under investigation. These include the rheological and thermal behaviour as well as their microstructure characterisation. The long term goal will be the formation of such materials under dynamic conditions and their use in real food systems.

Clean label emulsifiers

The research aims to create clean label emulsifiers which are natural, food grade and particulate in nature. Particle stabilisation of emulsions has generated significant interest in recent years due to the enhanced stability of these emulsions over surfactant or protein stabilised emulsions. Once the particle is at the interface, it is considered to be permanently adsorbed as a high energy input is required to disrupt the particle layers to cause coalescence.

The range of food grade particles capable of stabilising emulsions has increased over the last two decades however most food grade particles require a degree of chemical modification. Creating interfacially active natural particles is a key focus of the work being carried out at University of Nottingham.

Current investigations involve elucidating the origin of the interfacial properties of a known and well studied particle to understand key attributes which are required for a particle to be interfacially active. Future work will involve creating natural particles from food waste with these characteristics.

Membrane emulsification

Membrane emulsification is an alternative technology for emulsion production which produces droplets individually in a single step. One of the advantages of membrane emulsification over more traditional technologies is the use of low shear stresses and less energy input for the droplet formation. The low shear stresses provide a way of controlling the microstructure of the emulsion produced by means, for example, that the primary emulsion is not disrupted when emulsified into a duplex emulsion. Several configurations are available and among them rotating membranes have the greatest potential in terms of dispersed phase flux. The type of membrane used, in particular the material, porosity and pore size, greatly influence the quality of the processed emulsion, and improvements are expected with new membrane materials. Much of the early work on membrane emulsification is of a rather empirical nature; more systematic studies on droplet formation as it occurs during process are needed. Work undertaken in this project so far includes physical characterisation (e.g. droplet size, size distribution, stability) of emulsions produced by rotating membrane with different membrane characteristics (e.g. pore-size, distribution, porosity). The aim of the project is to further the understanding on the membrane emulsification and to identify controlling parameters and conditions which eventually will lead to the production of an emulsion product using membrane emulsification.

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Manufacturing for Healthy Lifestyles

One of the big challenges we have set ourselves is in the redesign of healthy foods. Recently industry have described this as 'making healthy foods more pleasurable and pleasurable foods more healthy'.

Given that consumer expectations must be met (pleasurable foods) we ask the question: Can we unbind ourselves from the constraints of current ingredient mixes and processes?, and given that the final product form is fixed, then re-engineer processes to enable the use of healthier ingredients.

Currently two approaches are being followed. The first involves the use of cellulose and cellulose-rich materials. In previous work we have begun to understand the dependence of properties of the crystalline: amorphous ratio of cellulose, the way this can be controlled through process and the effect of both thermodynamics and kinetics in controlling the restructuring of these cellulose containing materials.

At worst cellulose is a dietary fibre and therefore has half the calorific loading of starch and a quarter of that of fat, on a weigh for weight basis, at best it is non-fermentable, and therefore zero calorie. The material is being assessed for partial or full fat replacement in products. One such product is a traditional 'cookie' and a researcher is developing low temperature, high pressure processing to control the molecular transitions often brought about through conventional baking technologies. These studies will allow us to question the functionality of materials in these new processes, and allow us to change the ingredients for the healthiest options.

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Flexible Manufacturing

New Flexible Manufacturing for Tailored Food Emulsions

A host of potential surface active biopolymers have been investigated for their potential to stabilise emulsions. Protein: polysaccharide complexes have a number of advantages, particularly because they have demonstrated ability to cross link at the interface of the emulsion droplets. An investigation into the formulation, pH conditions, and processing conditions has been investigated, including the use of thermal pre-treatments. Emulsions stabilised by these complexes are being characterised using optical and confocal microscopy and droplet size and distribution analysis. This method can also be advantageous as it can enable the encapsulation and subsequent triggered release (for example with a change in pH or temperature) of active ingredients, which is currently being investigated.

Eco-production of Food: Reducing the Impact of Food Waste

This work provides a framework to optimise decision-making regarding food waste management. It includes a detailed review of current literature pertaining to food waste categorisation, associated environmental impacts and management, and defines a novel framework consisting of four stages: clear definition of food waste and the boundaries of this term; categorisation and quantification across supply chains; assessment of environmental impacts; and selection of most appropriate technology/ management option.

A new categorisation of the different types of waste has been designed. It enables a better selection of the most appropriate waste management alternatives, minimising the environmental impact and maximising the economic output.

Part of this work has been published in the International Journal of Food Engineering and presented in the International Conference on Food and Environmental Sciences, held in Yangon, Myanmar on 8-9 February 2015.

The planned future work includes the application of this framework to real industrial case studies, a detailed analysis of the environmental impact of different waste management methodologies of specific foods, a revision of the most advanced and modern waste management technologies and an optimisation of some aspects of the selected technologies.

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Sustainable Supply Chain

With a central focus on food manufacturing, the objective of this work is to examine the roles of manufacturers, retailers and, where possible, consumers in improving the environmental sustainability of supply chains.

Current work has focussed on resilience in food supply chains, that is, the ability of different actors to bounce back from external shocks and ideally to grow stronger. It is projected that the food manufacturing industry will face an increasingly volatile operating area in coming decades due to a variety of factors, ranging from financial turbulence, to population growth and climate change. This work presents a detailed literature review as well as a framework for individual actors to map supply chain partners, assess vulnerabilities and risk, as well as to then implement strategies to enhance resilience. This work has been accepted for presentation at the European Society for Ecological Economics at the end of June 2015.

It is anticipated that future work will focus on applying this framework to numerous targeted industrial case studies, building up a strong picture of UK food supply chain resilience in the process. Beyond this, the aim is to examine how changes in the resilience of one food supply chain actor can affect overall supply chain sustainability.

Being a National Centre

Industry Engagement, Knowledge Exchange and Technology Transfer

Throughout 2014 and early 2015 we have submitted several applications into RCUK and Innovate UK competitions for funding in collaboration with industry members, 'Autonomous Manufacturing', 'Redistributed Manufacturing', 'Future Formulation of Complex Products' and 'Improving the Food Supply Chain Efficiency'.

Additionally, we submitted proposals into BBSRC DRINC, two IB Catalyst calls and applied for funding to become the Agri-Tech Centre in the UK. We have joined the BBSRC's Food Waste Network through which we have explored new project ideas around the topics of food waste, valorisation and value-add propositions. As a member of the KTN Food Sector Group and the NTP for Food, Professor Tim Foster helps in developing a national academic footprint in food manufacture ensuring that the research and development needs and applications across the agri-food supply chain are met.

Towards the latter end of 2014 and the start of 2015, we have been actively exhibiting our research and capabilities at prolific food industry events; the enormity of the Food Matters Live Exhibition in November gave us exposure to thousands of people involved in food and drink manufacturing, foodservice, retail, research and the general public. As we reached the end of the winter we were invited to attend the Food and Drink Innovation Network's Fuzzy Front End of NPD, which gave us the opportunity to hear first-hand how food retail multiples are adapting their business strategies to align with changes in consumer trends and the need for innovation in food processing and manufacturing to keep up with tomorrow's consumer, and exhibited at the Industrial Biotechnology Showcase, organised by the Knowledge Transfer Network. We also attended the 2nd Sainsbury's Research Day in March 2015.

Engaging with the food manufacturing community

For the Centre for Innovative Manufacturing in Food, 2014 was the year in which we established our connections within the food (and non-food) manufacturing network. We presented posters at the Third Annual Conference of the EPSRC Centre for Innovative Manufacturing in Industrial Sustainability and at the EPSRC Manufacturing the Future Conference, both in September 2014.

We have also had a poster presence at the Appetite for Engineering conference, at the Second European FUSIONS Platform Meeting and a podium presentation at the International Conference on Food and Environmental Sciences in Myanmar.

During a high level food processing mission in India, organised through the Science and Innovation Network and the British High Commission, Centre Director Tim was able to explore the prospects of building closer collaborations between India and the UK, including insight into nascent Indian government directives and upcoming funding opportunities to facilitate research relations between India and the UK at both a fundamental research perspective through the Newton-BHABHA fund, and also at a commercial level utilising the Global Innovation and Technology Alliance (GITA).

Engaging with academia

As we embark upon our vision to become the National Centre in Food Manufacturing, our engagement with the academic community has been continually growing. At the turn of 2015 we attended the Food and Drink Industry Network meeting at the University of Leeds, and have developed strong working relationships with a team at the University of Liverpool whom we are currently exploring sustainable supply chain solutions with. Our developing rapport with the Centre of Excellence in Food Engineering at Sheffield Hallam University means between our two Centres we can provide unprecedented research support and expertise to the food and drink manufacturing sector. Working alongside other Centres for Innovative Manufacturing, namely Industrial Sustainability, Additive Manufacturing and Continuous Manufacturing and Crystallisation, as well as the Manufacturing Technology Centre and the Centre for Process Innovation allows us to be at the fore front of emerging technologies as they are developed, enabling project ideation, pull together of strong consortia for collaborative research, or joined-up thinking for enhanced impact to the food and drink manufacturing industries.

In October 2014 Tim Foster visited the Food Research hubs in New Zealand (AgResearch, Plant and Food Research, Massey University, University of Auckland, the Cawthron Institute, the Riddet Institute and the New Zealand Food Innovation Network) as part of an EUFRIENZ delegation on food processing.

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Being a National Centre

Engaging with the wider public

For societal benefit and outreach to the wider community, we have also been fairly active with developing our own corporate social responsibility policy; whilst our agenda continues to emerge we have performed an interactive session called Edible Engineering at the Science Museum Lates event and now have over 100 followers on Twitter from just 2 months of sharing stories and responding to the latest news and trends on food manufacturing.

Influencing Strategy and Policy

Professor Tim Foster is a member of the KTN Food Sector Group and forms part of the steering group that helps direct the angle in which innovative competitions are themed, ensuring they fit the research and development needs and applications across the agri-food supply chain.

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Advisory Board

The Engineering & Physical Sciences Research Council (EPSRC) requires that each Centre for Innovative Manufacturing appoints an Advisory Board whose mission is to provide independent and external advice to the EPSRC Centre Director, the Executive Board and the Operational Committee.

Our Advisory Board is comprised of key opinion leaders and policy drivers within the food industry, including Peter Lillford, Sam Millar (Campden BRI), Ian Noble (PepsiCo), Richard Bailey (EPSRC), Gerry Flynn (Innovate UK), Ardjan Krijgsman (Unilever), Yvette Sowerby (Sainsbury's), Didier Bonnet (Cargill) and Stephen Parry (Chair of Food Sector Knowledge Transfer Network (KTN)). Academic board members include David York (University of Leeds), John Gray (University of Manchester and FMEG) and Richard Hague (University of Nottingham and EPSRC Centre for Innovative Manufacturing in Additive Manufacturing).

The Team at the EPSRC Centre for Innovative Manufacturing in Food

Lead academics

Professor Tim Foster
Centre Director
The University of Nottingham

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Deputy Director
Loughborough University

Professor Ian Norton
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Academics

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The Year Ahead

2015 looks to be the year where the Centre for Innovative Manufacturing in Food impresses a footprint on the global and local food community. With our research programmes almost 6 months in, the next phase of our investigations in our New Flexible Manufacturing theme will look to continue to understand the effect of pre-treatments on the microstructure of biopolymer gels and emulsion stabilisation via enzymatic cross-linking, establishing the rules for solid emulsion processing.

In our New Processing Technologies theme we will continue to explore the potential of 3D printing for the manufacture of complex structures, structures formed through dehydration-rehydration techniques and microfluidics.

Future work to explore the role of surface roughness on the emulsifying ability of natural particulate emulsifiers, by looking at the hydrothermal treatment of food processing waste material to create interfacially active particles, is just one of the ways we will develop our know-how in the theme of Upgrading Ingredients.

Our Sustainable Food Supply Chain theme will be developed by applying the framework we established in our first year of operation, which serves to map supply chain partners and assess vulnerabilities and risk, to start to implement strategies to enhance resilience to numerous targeted industrial case studies, building up a strong picture of UK food supply chain resilience in the process. Beyond this, we will examine how changes in the resilience of one food supply chain actor can affect overall supply chain resilience and sustainability.

We are already in the process of applying for several industrial and academic collaborative research projects, and so far we have confirmed our presence at several events, where we will continue to grow internationally and introduce our innovations to the global food manufacturing community.