Institution: University of Birmingham

Unit of Assessment: UoA 12 - Aeronautical, Mechanical, Chemical and Manufacturing Engineering (Chemical Engineering submission)

Title of case study: Novel low fat food products leading to improved health and new market share using soft solid microstructures.

1. Summary of the impact

The impact presented is the use of research carried out in the School of Chemical Engineering by a range of multinational food industries (inc. Unilever, Cargill, PepsiCo) to engineer a series of fat-reduced foods such as low fat spreads (LFS), dressings, margarine, sauces and mayonnaise. This has allowed them to build up a portfolio of novel low fat products; this portfolio would be much reduced or in some cases non-existent without the research contribution and capability generated by the Birmingham group as stated by Peter Lillford[5.1] (former Chief Scientist, Unilever) and John Casey, (Vice President Biological Sciences, Unilever)[5.2]. These products are a significant and growing market segment e.g. LFS now outsell margarine/butter in a number of countries and are estimated to be worth globally 10 Billion Euros per year between 2008-13. Thus these products are having a significant impact on the industries' profitability. In addition, consumption of low fat foods act to tackle obesity with knock on effects for government (health service, lost GDP etc.) and the community as a whole.

2. Underpinning research

Research on designed soft solid microstructures has been carried out in Chemical Engineering at University of Birmingham since 1995 and is now led by Ian Norton (Professor of Chemical Engineering since July 2006).

The underpinning science is microstructure engineering of soft solid microstructure for food use. An example is a fundamental mechanistic understanding of emulsion behaviour in flow allowing control of the local physics in order to use phase inversion in the production of fat continuous products with as little as 10% fat phase. In order to do this the industry required detailed understanding of the role of the structuring agents and the kinetics of phase changes in the processes. This knowledge allowed process engineers to position crystals at the interface and thus to control droplet breakup and re-coalescence. The crystal position in the interface of droplets (Pickering emulsions) makes them inherently more stable on storage but can enhance coalescence in flow thus allowing the food manufacturer to economically produce stable fat continuous emulsions at fat contents which would inherently be more stable if water continuous (> 50% water). These structures are kinetically trapped as a result of the crystals in the interface, which can then be used to trigger flavour release and give the desired oral properties on consumption.

An additional key aspect was the research carried out to control the relative viscosities of the two phases in emulsion products. As the oil's viscosity is fixed (edible triglyceride oils) this required research on the use of hydrocolloid physical chemistry to structure the aqueous phase during processing. This is a complex issue as the hydrocolloids also impact on sensory properties of the final product. The research was thus aimed to control both in process and on consumption parameters separately.

In summary, the research carried out at the University allowed the industry to induce a self-catalytic inversion process by controlling and manipulating crystals at the oil/water interface. Because of this research inversion now becomes temperature controlled (not time controlled) allowing rapid inversion (the process runs at 10 tonnes/hour resulting in short residence times requiring control and manipulation of the kinetics of the material phase changes) and continuous production of low and very low fat spreads. This work was originally carried out by Prof. Pacek (at the time a PDRA, a Professor since 2006) who supervised Nixon[3.1] (PhD student) in the early to mid 90's and has been continued by Norton's group also with Dr Cox (PDRA 2006-2009, lecturer

2009-), and Dr Spyropoulos (PhD 2003-2006, PDRA 2006-2010 now lecturer 2010-)

The mechanistic understanding of the use of physical structuring of the aqueous phase to reduce coalescence rates in the process (a processing aid) and to produce small water droplets that give favourable organoleptic response due to control and manipulation of material breakdown rates; was carried out by Spyropoulos and Ding (PDRA) in Pacek's group from 2003-2007 and sponsored by Unilever[3.2] (Bettina Wolf).

This original work was then supplemented by further investigations at the University into phase separating biopolymer systems and how these can be controlled via the process conditions. Again the work carried out at the University into aqueous/aqueous two phase systems led to the ability to produce zero fat spreads (products marketed in the USA and UK) which are stable on storage and breakdown when consumed to give the physical properties and flavour release expected from margarine. This has been carried out by Spyropoulos[3.3] since 2007.

The second spin off was into what is now called fluid gels[3.4]. This is where the structuring of hydrocolloids is carried out in different flow regimes. The forming network is then constrained by the flow profile and gel is formed on a micro scale. The particles thus formed have the properties of the bulk gel but only over small distance scales. The particles formed can be manipulated by the choice of hydrocolloid type, the concentration and the solvent quality. If formulated in the right way we have shown that these particles can replace fat in emulsions.

The researchers are now developing the science for a number of other areas – including patented technology for chocolate involving Prof. Fryer and Jennifer Norton[3.5] (PhD student 2007-2010), patented technology for Bakery fats, low fat snacks for Pepsi, Safa reduced bakery systems etc. This has taken the area of Pickering emulsions to the next level of complexity, involving understanding of surface crystallisation and crystal growth, engineering of crystallisation process and physics of particles at interfaces. Additionally the University has funding to understand duplex emulsions – based on the physical chemistry and microstructure of shell formation around droplets. This has been carried out by Norton and Sarah Frasch-Melnik[3.6] (PhD student 2007-2010).

3. References to the research

Outputs which best indicate quality of the research identified by *

3.1 Nixon, A. J. P., A. W.; Nienow, A. W.; Norton, I. T.: The influence of fat crystals on the equilibrium drop size and coalescence rate in agitated sunflower oil/water dispersions. *IChemE Symp. Ser.* 1999, *146*, 177-186. ISBN: 0-85295-425-5

3.2 Ding, P.; Pacek, A. W.; Frith, W. J.; Norton, I. T.; Wolf, B.: The effect of temperature and composition on the interfacial tension and rheology of separated phases in gelatin/pullulan mixtures. *Food Hydrocoll.* 2005, *19*, 567-574. DOI: 10.1016/j.foodhyd.2004.10.020

3.3* Norton, I. T.; Spyropoulos, F.; Cox, P. W.: Effect of emulsifiers and fat crystals on shear induced droplet break-up, coalescence and phase inversion. *Food Hydrocoll.* 2009, *23*, 1521-1526. DOI: 10.1016/j.foodhyd.2008.09.014

3.4 Spyropoulos, F.; Frith, W. J.; Norton, I. T.; Wolf, B.; Pacek, A. W.: Morphology and shear viscosity of aqueous two-phase biopolymer-surfactant mixtures. *J. Rheol.* 2007, *51*, 867-881. DOI: 10.1122/1.27497

3.5* Norton, J.E., Fryer, P.J., Parkinson, J., Cox, P.W., Development and characterisation of tempered cocoa butter emulsions containing up to 60% water, *J. Food Eng.* 2009, 95, 172-178. DOI: 10.1016/j.jfoodeng.2009.04.026

3.6* Frasch-Melnik, S.; Norton, I. T.; Spyropoulos, F.: Fat-crystal stabilised w/o emulsions for controlled salt release. J. Food Eng. 2010 98, 437-442 DOI:10.1016/j.jfoodeng.2010.01.025

4. Details of the impact

"The understanding developed by Birmingham has enabled us to manufacture and develop superior quality low-fat foods.....In the absence of this research at the University of Birmingham we would have had considerably reduced ability... and arguably many products may not have been produced at all."

[redacted] Vice President Biological Sciences, Unilever R&D.

Examples are given in the below table of innovatory approaches to formulation based on Birmingham's findings used by leading companies along with the associated products. The products included have all been launched since 2008 or are in an advanced stage of commercial development. In each of these instances, the companies concerned have confirmed that Birmingham's research has made a distinct and material contribution to the product's formulation. They have drawn on the findings of commissioned research to do this and have continued to fund basic research in microstructure engineering of soft solids at the University of Birmingham, demonstrating continued investment in the research area.

Research Innovation	Type of Product	Producer	Brands	Funding /Patent apps.	Economic and health benefits
Phase Inversion/ colloidal structures	Low fat spreads, ice cream	Unilever	Flora light, , Delight	Unilever £200k Pepsico £804k 2 patents	New market segment. Alternatives available at the same cost as full fat products
	low fat & salt snacks	Pepsico	Lays, Walkers		
Fat Crystallis.	Cakes/ Bakery	Cargill Premier Foods	Expected launch 2014	Cargill £1.3M Premier £200k 6 patents	New market segment. New products with healthier salt/fat levels
	Chocolate/	Cargill	Expected launch 2014		New market segment Lower fat lower calorie products
Mixed Biopol.	Zero fat spreads	Unilever	Promise, Linera	Unilever £200k	0.5% fat alternatives available at same cost as full fat
	Dairy type spreads	Unilever	Crème Bonjour, B&B		Reduced cost, lower fat high quality soft cheeses
Sheared/ fluid gels	Sauces dressings	Unilever	Hellman's Lipton's (USA)	Unilever 220k Kraft £250k + £400k	Increased quality of product boosts sales. Low fat high quality Mayonnaise
	Coffee	Kraft	Tassimo		New lighter version
	Personal Care	Unilever	Dove		New products for shower gels and shampoos. Non petroleum based - lower env. impact
Pickering Emulsions	Low fat sauces/ dressings	Cargill	Expected launch 2014	Cargill £380k, EPSRC £120k	Step change in fat level for products. Reduction of hidden fat in the diet
	encaps.	TSB/ Syngenta		£905k TSB	New technologies for crop protection
Duplex & air filled Emulsions	Low fat Dressings	Kraft	None yet – launch 2014	BBSRC Kraft £493k 2 patents	Step change in fat level for products - Large reduction of hidden fat in diet in developed countries

The impact of this research has been to enable food manufacturers to develop and market a greatly-expanded range of low fat foods, contributing to measures to reduce fat consumption as well as generating substantial sales and profits in this key economic sector.

The findings from research carried out a Birmingham has fed directly into the investment in novel manufacturing processes and new low-fat food products by global companies including Unilever[5.1,5.2], PepsiCo[5.3], and Cargill[5.1,5.4]. Researchers at Birmingham have worked closely with these and other companies in long-term partnerships to maximise the impact from their research findings. The particular contribution of Birmingham's Chemical Engineering research to the economic success of the UK's food and drink sector was highlighted in 2010 in an independent report by Oxford Economics: this report used Norton's research as its leading example of chemistry's contribution to the industry and described the work as providing *"a useful illustration of the beneficial impact of chemistry research on the food supply chain."* [5.5]

This case study demonstrates one key strand of this work: the importance of Birmingham's research in enabling global food companies to address the specific challenge of producing volume-sales food products that have low or zero fat content whilst retaining the taste and texture required by consumers.

"...the food industry is global and highly competitive. This group has international recognition of its research. This is attracting inward investment to the UK. One of the clear targets for Impact"

[redacted] Chairman IFR, former Chief Scientist, Unilever[5.1]

Reach and significance. The take-up of this research by major companies has led to wide reach. Independent research published in 2011 identified Unilever and Kraft Foods as two of the four companies most frequently cited as driving innovation within the areas of fat reduction and replacement. This research also showed the importance of the issue for new developments in food products, with 8.6% of new food and non-alcoholic drink products launched worldwide in 2008-10 making "reduced fat claims" and the proportion reaching 18.9% in North America[5.6]. Many of the products identified in the table are examples of this including; Promise, Linera, Flora light.

The significance of the work for the collaborating industries has been their ability to innovate in the area and launch new products, see supporting letters from Unilever[5.2] and PepsiCo[5.3].

The link between diet, obesity and ill-health is well-established and forms a major element of public health advice in the UK and elsewhere[5.7]. The wider availability of attractive low-fat options in a growing range of everyday foods has helped consumers follow this guidance.

There is evidence that this is taken seriously by consumers; for instance, survey results included in Defra's most recent annual summary of food-related data reported that nutritional content is widely influential on shoppers' purchase decisions, particularly the level of fat within the food at 33% of shoppers, and that of people asked about what they were doing to obtain or maintain a healthy lifestyle, 38% said they were eating low fat versions of food (the third most frequent response[5.8]). In a broader sense, these measures bring benefits for society as a whole through helping reduce the incidence and health-related costs of obesity, acknowledged to be a widespread and serious issue.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Letter of support from Peter Lillford (Head of Board of Institute for Food Research, Norwich)

5.2 Letter of support from John Casey (Unilever)

5.3 Letter of support from Ian Noble (Pepsico, formerly Unilever)

5.4 Letter of support from Didier Bonnet (European Research Director, Cargill)

5.5 Oxford Economics (2010), *The Economic Benefits of Chemistry Research to the UK*, p. 93.

5.6 Business Insights (2011), *The future of fat reduction and replacement in food and drinks: evaluating innovative ingredients and technologies and future market opportunity,* p.114

5.7 E.G. Clinical Excellence (2006) *Obesity: the prevention, identification, assessment and management of overweight and obesity in adults and children*

5.8 DEFRA *Food Statistics Pocketbook 2010*, p39 and p.66