Institution: Heriot-Watt University

Unit of Assessment: 6 Agriculture, Veterinary and Food Science

Title of case study: Reducing Fat For Healthier Foods.

1. Summary of the impact

Research by Campbell & Euston (2001-present) into functional properties of food proteins has enabled protein manufacturers to process low-value protein ingredients into added value products such as fat replacers. This allowed food manufacturers to make products with reduced fat content and/or reduced "E-number" content ("clean-label" foods). The research led to the set-up of Nandi Proteins Ltd to transfer the findings to the market. It sells the products to end-use food producers such as Premier Foods and Quorn, which use the technology to make their food more appealing to customers by reducing fat content and e-numbers. The first fat replacement product was launched by Friesland Campina which produced protein using Nandi technology on a commercial scale, marketed as Hiprotal 60. The product was sold into the European dairy and formulated meat products market. Sales of 200 tonnes per annum are claimed over between 2007-2011. Hiprotal 60 sold at £6 per kilo which equates to approximate sales of £6M over the five year production period.

2. Underpinning research

The Campbell & Euston research groups have pursued a programme of pure and applied research on food proteins over 20 years resulting in the development of technologies for the production of protein ingredients that have wide application in the food industry. An enduring problem for the food industry is that one of the main ingredients of formulated food products, namely globular proteins such as egg, milk and soy protein, are inherently unstable on heating due to denaturation of the protein structure. In many foods this manifests itself as a breakdown in the food structure and loss of product quality. Both Campbell and Euston researched the role of heat- treated egg and milk proteins on emulsion stability in the 1990s when working in the food industry (Campbell at Nestle and Euston at Fonterra). Euston was interested in the mechanisms of instability of milk whey protein-stabilised emulsions and how this was influenced by interaction with other food ingredients (Euston, et al. Food Hydrocolloid, 14, 155-161, 2000; Euston, et al., Food Hydrocolloid, 15, 253-262, 2001; S.R. Euston et al., Food Hydrocolloid, 16, 499-505, 2002; Campbell et al., Nahrung, 47(6), 369-376, 2003. Campbell (Truck & L. Campbell: A heat stable oil-in-water emulsion and process for its manufacture, EP0702903A1, March 1996a; Truck & Campbell, Heat stable oil-in-water emulsions containing egg yolk and process for its manufacture, EP0716811A1, June 1996b) worked extensively on ways to produce heat stable emulsions. Independently, both found that instability in heat-treated food emulsions could be improved in the presence of other food ingredients (Truck & Campbell, 1996a; 1996b; Euston et al. 2001; Campbell et al., 2003) via a method that partly involved stabilization of globular proteins against heat denaturation.

When Campbell and Euston joined HWU in 2000/2001 they convinced the egg industry of the potential benefits of these findings and were funded [G1] to employ PhD student Raikos, 2002-2005) to investigate the effect of co-ingredients such as salt and sugar on heat stability and functionality of egg proteins. This research was extended to PhD studies on soy [G2], whey [G4] (PhD student Zhang), and cowpea proteins [G4] (Ahmed, 2010-2013). This work found that carbohydrate and salt increased the denaturation temperature of globular proteins (Campbell et al. Nahrung, 47(6), 369-376, [http://dx.doi.org/10.1002/food.200390084]; Campbell, et al., Food Hydrocolloid, 19, 533-539, 2005; Raikos, et al., Food Hydrocolloid, 21, 237-244, 2007; Raikos, et al. Food Res. Int., 40, 347-355, 2007; Campbell, et al. Food Hydrocolloids, 23, 344-351, 2009). Another significant finding was that reducing sugars were found to enhance the functional properties of denatured proteins (Gu, et al. Food Hydrocolloids, 23, 314-326, 2009).

Outcomes from this research were exploited through the creation of an SME, Nandi Proteins, established by Campbell in 2001. The research allowed Nandi Proteins to develop technology for production of novel protein ingredients with enhanced functionality in formulated foods:

- Production of partially denatured protein ingredients (L.J. Campbell: Fat replacement material and method of manufacture thereof, US716316B2, January, 2007; L.J.Campbell: EP2104433: Protein Denaturation control, September 2009. Campbell).
- Production of conjugated protein-carbohydrate ingredients (L.J. Campbell and X. Gu: Process for modifying proteins. Application GB1204160.4, March 2012)

- The applications of the technology in mayonnaise, yoghurts, cheese, baking are:
- fat replacement
- ingredient cost reduction
- replacement of E-numbers by clean label ingredients

Campbell and Euston are extending the understanding of protein-based fat replacers in a study funded by HWU. This aims to elucidate the molecular mechanisms by which fat-replacer molecules function, and to use this information in the intelligent design of improved ingredients.

The exploitation of the research has also been enhanced by a collaboration between the University, Nandi Proteins and other industry partners (Premier Foods, Quorn/Marlow Foods, Wright-Agri, Mantons Eggs) as an EPSRC/TSB funded project (£189K EPSRC EP/J501682/1, 2012-2014). This has used Nandi patented technology to develop novel foaming and fat replacer ingredients for the food industry.

3. References to the research (indicative maximum of six references)

Peer Reviewed Publications

[1] L. Campbell, V. Raikos and S.R. Euston, Heat stability and emulsifying ability of whole egg and egg yolk as related to heat treatment, Food Hydrocolloid, 19, 533-539, 2005. (9 citations) http://dx.doi.org/10.1016/j.foodhyd.2004.10.031

[2] V. Raikos, L. Campbell & S.R. Euston, Rheology and texture of hen's egg protein heat-set gels as affected by pH and the addition of sugar and/or salt, Food Hydrocolloid, 21, 237-244, 2007. (21 citations) http://dx.doi.org/10.1016/j.foodhyd.2006.03.015

[3] V. Raikos, L. Campbell & S.R. Euston, Effects of sucrose and sodium chloride on foaming properties of egg white proteins. Food Res. Int., 40, 347-355, 2007. (25 citations) http://dx.doi.org/10.1016/j.foodres.2006.10.008

Patents

[P1] L.J. Campbell: Fat replacement material and method of manufacture thereof, US716316B2, January, 2007. http://www.google.com/patents/EP1351578B1?cl=en&dq=Fat+replacement+material+and+method+of+manufacture+thereof&hl=en&sa=X&ei=Se-MUc_4J6Gb0QW424G4CQ&ved=0CDQQ6AEwAA

[P2] L.J.Campbell: EP2104433: Protein Denaturation control, September 2009. http://www.google.com/patents/EP2104433B1?cl=en&dq=Protein+Denaturation+control&hl=en&sa=X&ei=be-MUby3JKmN0AWpqICgCQ&ved=0CDcQ6AEwAA

[p3] L.J. Campbell and X. Gu: Process for modifying proteins. Application GB1204160.4, Mar 2012 http://www.ipo.gov.uk/types/patent/p-os/p-journal/p-pj/p-pj-ukappfiled?lastResult=40&perPage=10&startYear=2012&startMonth=April&startDay=25th+-+6414&endYear=2012&endMonth=April&endDay=25th+-+6414&filter=&sort=Publication+Date&status=undefined

Grants

Prior to 2001 Euston and Campbell's research was internally funded by their respective industry employers.

[G1] Campbell/Euston 2002-2005 – Michaels Foods, Minnesota, USA, £70 000 for PhD Project – Investigating the heat stability of egg proteins (PhD student Vasillis Raikos). http://www.ros.hw.ac.uk/handle/10399/135 .

[G2] Campbell/Euston 2005-2008– Libyan Government, £50 000 for PhD studentship - Improvement of Functional Properties of Soy Protein (PhD Student Al-Amari Al-Bakkush) http://www.ros.hw.ac.uk/bitstream/10399/2253/1/Al-BakkushAA_0908_sls.pdf.

[G3] Campbell/Euston 2010-2013 – Libyan Government, £50 000 for PhD studentship – Isolation and Modification of Protein from Cowpeas to Improve Functional Properties. (PhD Student Mohammed Ahmed)

[G4] Euston/Campbell 2010-2013 – HWU Life Science Interface Theme, £100 000 for PhD Project - Towards a Molecular Understanding of Fat Replacers. (PhD Student Zhuo Zhang)

[G5] Euston 2012-2015 – Technology Strategy Board, Nutrition for Life Mainstream, £189,000 (HWU contribution from EPSRC for Project) – Foaming and Fat Replacer Ingredients as part of £800K total consortium award). £25,000 contribution from Nandi from TSB as part of whole http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/J501682/1

[G6] Campbell/Nandi Proteins 2001 - SMART award – £60 000. Proof of concept for development of partial denaturation technology

[G7] Campbell/Nandi Proteins 2003 SPUR Award £150 000. Upscaling of partially denatured protein production.http://www.scotland.gov.uk/Resource/Doc/25954/0028247.pdf

4. Details of the impact (indicative maximum 750 words)

The research provided the original observation that food protein functionality can be enhanced by control of denaturation, aggregation and glycation during heat treatment. Protein modification could be controlled in real time during processing using a relatively inexpensive light scattering geometry. The understanding of underlying structural protein modifications translated this laboratory observation into technology for deployment in industrial food manufacturing conditions. Market Research commissioned by the University and Scottish Enterprise identified an opportunity for a new company delivering in-process real time monitoring technology for thermal processing of proteins conducted by food ingredient manufacturers. This technology offers efficient quality control procedures for industrial manufacturing of food proteins with improved functional properties. Historically, quality control methods for denaturated food proteins were complex, expensive and time consuming and not possible to conduct in factory processing conditions in real time. The novel ingredients are used as fat replacers in yoghurt and cheese and cakes and to replace E-numbers. Rival technologies exist to create fat replacers from whey and egg white proteins using expensive microparticulation machinery, but are owned by non-UK companies with resulting products imported and sold at a high price. Through Nandi, this technology offers food ingredient companies a tool to improve the functionality of their protein ingredients and to deliver products with standardised, reliable quality.

Obesity is a major challenge facing the health of the UK population, blamed on combination of diet and lifestyle. Yet consumers have been resistant to reduced fat foods on grounds of “mouth feel”, taste and suspicions of E numbers. Proteins such as egg and whey protein with enhanced functionality offer improved sensory properties compared to starch based fat replacers. Many commercially available bakery products contain emulsifiers and foaming ingredients with E-numbers which could be replaced by proteins with enhanced functionality. Also, in “mature” markets, such as Western Europe, the trend for “clean label” foods containing fewer E-numbers is growing. The market opportunity in the UK for the application of novel protein products to deliver new ambient stable-foamed food products is in excess of £100 million, and novel ingredients that act as fat mimetics is a significant technology platform with a market excess of £400 million in the UK alone. Currently the UK and European market for protein based fat replacers is dominated by one or two large dairy companies and is limited to whey protein. Small to medium size cheese manufacturing companies, which reflect the trend towards consumer preferences for “local” products cannot afford to implement facilities to add value to whey protein and it is either sold as a commodity product or processed as waste. The commodity whey protein EU market is approximately 300 million Euros. The technology developed by Nandi Proteins offers the possibility of processing this whey stream to a higher value product. Nandi Proteins expects to be able to access 10% of this whey market within the next five years.

In forming Nandi, Scottish Enterprise, with venture capital company Sigma Technology

Management Ltd provided development funding and the business and technical support required to form business partnerships and provide proof of principle to food ingredient companies. Heriot-Watt University provided commercialisation support via Research and Enterprise Services, use of bench scale processing and analytical equipment in the School of Life Sciences in addition to funding salaries of core staff. The analytical support was important as the company could not have funded equipment purchase. The physico-chemical modifications of new food ingredients and associated functionality in food applications require corroboration by sophisticated analytical equipment and methods, important in building customer confidence in the technology.

Nandi Proteins Ltd. employs 3 people (two at PhD level) and will create a 4th (PhD level) position in 2013/2014. The employees demonstrate the use of the monitoring technology and to work alongside customers to prove the principle of enhanced ingredient functionality in food. Nandi's business model is to license the technology to customers and not to manufacture its own products. The first fat replacement product was launched by Friesland Campina DMV in the Netherlands. [S2] DMV has produced protein using Nandi technology on a commercial scale and has marketed this as Hiprotal 60. The product was sold into the dairy and formulated meat products market within Europe. Sales of 200 tonnes per annum are claimed over a production period of 2007-2011. Hiprotal 60 sold at £6 per kilo which equates to approximate sales of £6M over the five year production period. In addition, Friesland has incorporated Hiprotal 60 as fat replacer in products such as a low fat yoghurt drink Dutch Lady, sold widely in Malaysia. The rights to Hiprotal 60 product manufacture and sales were transferred in 2012 to Rovita GmbH, a German ingredient manufacturing company which sells and markets the whey products as Roviprod 60.

Nandi also has contracts with Premier Foods, the UK's largest food company. Nandi's latest patent application was acquired by Tate & Lyle Investments on behalf of Tate & Lyle Food ingredients in December 2012, and is a central part of their food development strategy. The agreement grants Tate & Lyle an exclusive worldwide licence for the technology for food and beverage use while Nandi Proteins Ltd retains the rights to develop the technology for other applications such as pharmaceutical. Tate & Lyle are responsible for developing and in due course commercialising the technology including its manufacturing, applications development, sales and marketing. This has brought a high level of investment to Nandi Proteins (£3M). While tied by confidentiality agreements that prevent disclosure of details, Nandi is working toward a license agreement with a major food producer in November 2013, with the launch of a major product line in January 2014. A Senior Executive of Nandi Proteins is clear that "Without the research carried out by Heriot-Watt University, Nandi Proteins would not have been created. Nandi sells its products to end use companies and because of this, companies can apply the technology to reduce fat and "clean label" products such as yoghurt and milk based drinks, making them more attractive to consumers" [S1]

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

[S1] Senior Executive, Nandi Proteins Ltd will confirm that research by Stewart and Campbell was instrumental in forming the company. Nandi licenses technology to major food ingredients manufacturers.

[S2] Senior Intellectual Property Manager, Premier Foods will confirm that Premier Foods has used the technology developed HWU to assess the the fat content of its cake batter and icing on its Mr Kipling brand

[S3] Business Development Manager, Friesland Plc Will describe how they used the fat replacement product (Hiprotal 60) in their products and the economic difference it made.

[S4] Innovation & Entwicklung, Prolactal und Rovita GmbH will verify that the rights to Hiprotal 60 product manufacture and sales were transferred in 2012 to the company and how they have used it in product development.