Institution: The University of Leeds

Unit of Assessment: 6

a. Overview

All UoA6 research staff work in the School of Food Science and Nutrition (FS&N), which sits in the Faculty of Mathematical & Physical Sciences (MaPS) at the University of Leeds (UoL). UoA6's overall vision is that its research should be based on rigorous investigation of fundamental scientific principles that underpin a wide range of aspects of food quality, safety and long-term health outcomes, so that the results of this research are of real benefit to the food industry, advisory bodies and consumers. There are 3 research areas: *Food Chemistry & Biochemistry* (*FC&B*) [**Morgan**, **Williamson**]; *Food Colloids & Processing* (*FC&P*) [**Akhtar**, **Chen**, **Ettelaie, Holmes**, **Murray**, **Povey, Rappolt**]; *Nutrition & Public Health* (*N&PH*) [**Alwan**, **Bosch**, **Burley**, **Cade**, **Evans**, **Orfila**].

In the RAE2008 no other UoA in Food Science was ranked higher than Leeds, based on 9 staff submitted. Since 2008 two staff have retired and 9 new research staff have been employed; **Williamson**'s time increased from 0.8 to 1.0 FTE by May 2012. FS&N was previously named the Procter Dept. of Food Science. In 2008 it was formally renamed to reflect its new direction.

b. Research strategy

Overall research strategy and achievements

The **key strategic aims** adopted by UoA6 in order to achieve its vision throughout the REF period and maintain its vitality and sustainability into the future are summarized below. The advice of our revitalized External Advisory Board has been taken into account in developing this strategy. [In the following #XYn refers to UoA6 researcher (X=1st initial, Y= last initial, with the exception of Janet Cade = JCa, output number n].

(1) Incorporate public health and epidemiological aspects into a new vision of Nutrition as 'food science-led nutrition' to include the wider issues of how health institutions and the food industry can change in practical ways to improve food quality and human health, maintaining industry profitability and sustainability. Internationally, Nutrition and Public Health disciplines have traditionally been relatively isolated from Food Science, but joined up research thinking is required to solve food-related health problems. This aim has thus had a big influence on staffing strategy.

(2) Increase research activity, particularly with regard to the effects of food processing on nutrition, to further exploit the unique position of UoA6 in the UoL in being able to produce edible food under scientifically controlled conditions for feeding trials with humans. New mechanisms have been put in place to this effect, including agreement of individual & group research income targets, numbers of grant proposals submitted for the 3 research groups (monitored 6x each year) plus total UoA6 income, reviewed annually by Dean & Pro-Dean for Research & Innovation.

(3) Strengthen research in physical aspects of food science, particularly in fats and lipids. Many challenges facing the food industry in providing healthier but still profitable products can only be met via microstructural alteration of foods. Solid fat structuring and/or its replacement are key here and the appointment of **Rappolt** is therefore central to this aim (see Sect. c).

(4) Increase interdisciplinary research within UoA6 and out towards the rest of UoL and beyond. New staff have been appointed to broaden the research scope of UoA6 to facilitate a multidisciplinary approach in addressing the strategic aims. A dynamic research culture has been promoted across UoA6 via attendance at weekly research seminars and Research away-days for 'brainstorming' of research ideas and strategy. Post-2011, 10% of publications are joint between at least 2 of the UoA6 research groups (prior to 2011, less than 2 %). Other examples include collaborations/joint PhDs with other UoL *Schools* and Faculties, including: *Chemistry*, *Mathematics*, *Psychology*, *Leeds Institute of Genetics, Health and Therapeutics (LIGHT)*, Engineering, Environment, Medicine. *FC&P* has also been part of recent successful collaborative bid for a Centre for Doctoral Training with the Schools of Physics and Mathematics at UoL (plus Durham and Edinburgh Universities). **Murray** and **Povey** contribute to Colloids Processing training for industry run by ParticlesCIC in Engineering. More UoA6 staff are also now active in interdisciplinary developments such as the Food Security Hub (FSH - see REF3a for details). UoA6 has brought its industry contacts and the FSH together, particularly in promoting access to

UoA6 food processing facilities and in UoA6's Industry Day (see (6) below and REF3a).

Most UoA6 research involves collaboration with other UK and Overseas Universities: 10 % of UoA6 research publications have at least one author from a different UoL school; 20% have collaborators from other UK Universities and 36 % have Overseas collaborators. Over 40 invited researchers (from > 20 countries), from Professorship to PhD student level, have visited since 1.1.08. Over 7% of UoA6's REF outputs are a direct result of such collaborations.

(**5) Respond to a wider range of national and international priorities and initiatives.** Staff enlargement has allowed UoA6 greater response to a wider range of such priorities and initiatives. Examples include: applications to the BBSRC DRINC scheme, resulting in DRINC grant to **Williamson**; **Williamson** as Work Package Leader and full partner in two EU FP7 projects, PlantLIBRA and BACCHUS; **Akhtar** on a DEFRA-LINK project with Colour Chemistry (UoL), Asda and VeriVide Limited on fruit ripening; Northern Way (METRC) funded research with **Ettelaie**; **Murray** as work-package leader in COST Action INFOGEST. The number of staff involved in EU projects has increased 4-fold since the last RAE. Attendance (**Murray**) at the monthly MaPS Research & Innovation Committee, membership (**Orfila**) of the Bioscience for Business KTN and membership (**Orfila** & **Murray**) of the FSH Executive Committee, has promoted better communication of strategic intelligence to staff.

(6) Increase Enterprise & Knowledge Transfer (EKT) activities and the impact of UoA6's research. Akhtar has been utilized as UoA6's key industrial liaison person (see Sect. c), resulting in a significant increase in outside consultancy work for companies. (See REF3a, Sect. b). EKT now involves far more academic staff than pre-2008: all staff now have at least one industrial project. Consultancy-generated income has been invested in research facilities for future impact, such as upgrade of light scattering and rheometry in *FC&P*. More major projects have stemmed from such short consultancy work - see REF3a, Sect. b for details. In this way UoA6 has balanced the long-term and short-term research demands of stakeholders. Measures of the importance of UoA6's research to industry include Nestlé Research Centre (Lausanne) paying for 20% of **Williamson**'s salary as their scientific advisor on Nutrient Bioavailability up to 05.2012 and **Ettelaie** as acting consultant to the Colloid Steering Group of ICI (now AkzoNobel) until 2010. Longer term collaborations have also led to significant research outputs by many staff with industrial partners, e.g., #BM1, #CO2, #GW3, #JC4, #MP3, #RE3.

An 'Industry Day' (see REF3a) has been initiated to increase awareness of the new-look UoA and opportunities for collaboration. Due to UoA6's successful increase of EKT, UoL have approved recruiting a research laboratory technician (in 2014) to give extra support for equipment maintenance and rapid response to future demands from potential research collaborators.

(7) Build higher research student numbers. Through its larger and broader staff component, total PhD student numbers have increased significantly since 2008 (the annual no. of completions varies significantly since this does not correlate well with start dates in a small UoA). They also come from a wider range of subject backgrounds, that will allow UoA6 to respond flexibly to a broader range of future research opportunities. Since 1.1.08, applications for PhD study p.a. in UoA6 have risen 8-fold, the average no. of applicants enrolled has increased > 3-fold. Laboratory accommodation has been expanded by 25% into other locations within UoL to accommodate this.

The integrated broadening of the range of staff expertise, expansion of the specialist research equipment base, plus the ability to incorporate the facilities of FS&N's Food Technology Lab., has placed UoA6 in a unique position in delivering on strategic aims (1) to (7) and achieving its vision. In addition, UoA6 is a service provider to increased nos. of Schools at UoL and also at other Universities. Implementation of this strategy to date has resulted in award of over £ 5.4 M (£4.4 M spend) research funding, with significant fractions of this coming from OST Research Councils, charities, other Government bodies, industry, commerce, public corporations and the EU.

Detailed Research Group Strategy, Main Achievements & Highlights

Aligned with the overall School strategy outlined above, each individual research group has had its own aims and achievements in delivering on the above key themes, as follows.

Food Chemistry & Biochemistry Group (FC&B) *FC&B* aims to provide underpinning expertise on the identification and quantitative analysis of food compounds, as well as knowledge of the

mechanisms of how these compounds interact with the human body. Research has been funded mainly by: BBSRC, UK Food Standards Agency (FSA), EU and industry. Research has targeted topical new areas, such as the composition of oils and fats during deep frying in the presence of natural antioxidants (**Murray**, **Povey**), as well as increased interdisciplinary research with the 2 other research groups, e.g., emulsion science and quantification of anti-nutritional and toxic compounds in foods (#MH4, #VB1). Highlights include (**Morgan**) development of novel HPLC and immunochemical (#MM3) techniques to quantify allergens or toxicants of growing concern (e.g., cyanogens and glycoalkaloids) and how these are influenced by food processing (#MM1), plus how antigens interact with processing equipment surfaces, linking to *FC&P* research.

Williamson is an ISI 'highly cited author' in agricultural and food sciences, awarded a European Research Council Advanced Grant (POLYTRUE, 2.5M Euros), unique in food science and nutrition, to carry forward research relevant to *FC&B*'s aims and in recognition of *FC&B*'s very strong position in the understanding of absorption, metabolism and biological effects of dietary polyphenols. Such mechanistic understanding is key to underpinning health benefit claims and has involved research on intestinal biochemistry and membrane interactions with phenolics derived from various foods/beverages such as apple, strawberry (#GW2), tea (**Morgan)**, coffee and plant food supplements (**Williamson**, GR477402 (£270k), GR472989 + 479332 (£1.4 M)). Novel roles for transporters in cellular uptake and efflux of conjugated forms of flavonols and phenolic acids have been shown (#GW3, #CO4). *FC&B* strategy has been to examine a wide range of phenolics and determine their potential effects on a wider range of disease risks than hitherto examined elsewhere, to aid *N&PH* in assessing long-term impacts of diet on health. One example is UV-induced skin cancer (**Williamson**, GR474941, £124k). In addition, *FC&B* has pioneered a mathematical predictive model of passive transcellular absorption (**Williamson**) (#GW1), and collaborated with clinicians to perfuse the jejunum to generate a new understanding of *in vivo* metabolism (#GW4). This has led to new insights into the impact of dietary polyphenols and their metabolites on diabetes, cardiovascular disease, prostate cancer and bone health, developed from studies ranging from cell culture to human interventions on healthy and ileostomist volunteers. (**Morgan**, **Williamson**, #GW2). *FC&B* is linking the above findings with assessment of polyphenol intake from diets via methodologies developed in *N&PH* (**Burley** PhD studentship & GR473006, £42k). In addition, the significance of the physical form of insoluble flavonoids is being addressed through collaboration with *FC&P* (#MM2, **Morgan**, **Murray**, **Povey)**.

<u>*Food Colloids & Processing Group (FC&P)*</u> *FC&P* develops knowledge on the physical and microstructural features of food materials that affect product quality and safety as a result of their processing. Systems are investigated via experiment, theory and computer simulation, also involving development of unique instrumentation. Expertise in thermodynamics and statistical analysis (**Holmes**, **Ettelaie,** GR100354, £165k), for example, results in fundamental understanding of how processing affects toxin (#MH4), macro- and micro-nutrient distribution and stability relevant to *FC&B* and *N&PH* work. Research has been sponsored by UK research councils (BBSRC, EPSRC, TSB), EU and large national and international food companies. A strategic aim has been to develop various microscopy (**Murray, Povey**) and ultrasound propagation and scattering techniques (#MH3) (**Povey**, **Holmes**) that can link microstructure with food texture (#JC1), stability and micronutrient release, with a view to on-line process monitoring. For example, ultrasound modulated optical tomography (GR473264 & GR479033, £253k & £88k) was invented by **Povey** and developed in collaboration with Nottingham University, combining the non-invasive imaging of ultrasound with the chemical information from absorption and fluorescence spectroscopy. The ultrasound work has also made important contributions to knowledge of fundamental acoustic properties of matter (#MH2, #MP1, 2), necessary to interpret ultrasound measurements on foods and other materials that are multiphase in nature (e.g., **Povey**, GR484960, £299k).

A new understanding has been reached of the effects of co-adsorption of proteins and polysaccharides via complementary experimental measurements (**Murray**) of adsorbed film properties and their simulation (#RE1). Highlights include demonstration of the vital importance of charge distribution on polysaccharide components adsorbing on top of a protein layer (#RE2). From such research the adsorption behaviour of multicomponent mixtures of polymeric species has been applied directly to industry (FujiFilm & METRC, GR 481217 &GR481155, £19k).

Linkage with *N&PH* is being built via research on food-grade solid particles (#BM1) as Pickering stabilizing agents of emulsions and foams (**Murray**) to potentially reduce the solid (saturated) fat

component of foods. Such particles can greatly strengthen adsorbed protein layers, improving colloidal stability (#BM1, 4). This area has been extended in work with Unilever on the unique nanoparticle protein hydrophobin and also in particle-influenced biopolymer phase separation (#BM3). Interdisciplinary links with *FC&B* have explored flavonoid particles (#MM2), relevant to their delivery and adsorption in humans (**Morgan, Murray** & Nelson (Chemistry)) plus their exploitation as anti-oxidants in oils (**Murray**). Particle research has also resulted in unique instrumentation for testing products and ingredients, e.g., for temperature-dependent foam stability under pressure drop (#BM4); ultralow surface viscosity; Brewster angle microscopy of processed films (#BM2); confocal microscopy of long-term bubble stability. **Akhtar** has pioneered the spinning disk reactor (#MA1–4) to replace separate unit food processing operations, e.g., in chocolate processing and pasteurization with Nestlé (#MA2) and multiple emulsion delivery vehicles (#MA3). **Rappolt**'s work on the structure and dynamics of self-assembling lipid structures (#MR1–4) will forge further links with *FC&B* in understanding interactions with the brush border membrane of polyphenols, lipids & other food molecules that affect their digestion and adsorption.

A major new area linking to *N&PH* has been established in Food Oral Processing (**Chen**). New techniques for monitoring the muscular control of swallowing and its relationship to food texture (#JC3) have been developed in relation to dysphagia and choking (**Chen**, GR311754, £162k and OPTIFEL, GR100883, £165k). Cohort health data from *N&PH* and techniques for monitoring food choice will be complementary to this area in design of foods for at risk groups. A novel *in vitro* gastric digestion device (**Chen**, **Holmes**, **Murray**, **Povey**) has been developed to mimic *in vivo* gastric mixing, in which the inherent hydrodynamics can also modelled (#JC2). This will give insight into how food microstructure affects food digestion and nutrient release, relevant to dietary survey work of *N&PH* and polyphenol availability research in *FC&B*.

<u>*Nutrition & Public Health Group* (*N&PH*)</u> *N&PH* conducts, advances and disseminates nutrition research to facilitate health improvement. This includes incorporation of new information on the content, consumption and processing effects of food components that the other 2 research groups in UoA6 provide. A key strategic aim is to address nutrition throughout the whole life-course ('life-course nutrition'), by extracting new types of information from existing population cohorts as they age and their own children develop. Concomitantly, the aim is to build links with other cohorts to increase the significance of the findings and to extend the research to wider health outcomes and problems. Strategic needs have been addressed in improving collection of dietary data (#JCa3) and food composition data with respect to various minor constituents potentially affecting health.

Important discoveries have consequently been made in, e.g., (a) the relationship between diet and chronic disease such as breast (#VB1, 2) & colorectal (#JCa3) cancer and cardiovascular (#VB4) disease (**Cade**, **Burley**); (b) the impact of nutrition interventions on diet, knowledge and attitude to food (**Cade**, **Evans**, **Burley**); (c) measuring the diet in certain population groups, e.g. children (#CE1, 2) (GR461506, £56k); (d) studying diets of different specific populations (e.g. pregnant women (#NA1–4)); (e) developmental origins of health and disease (**Alwan**, **Cade**).

Dietary supplement intake has been linked to health outcomes in the UK Women's Cohort Study (UKWCS - one of the largest cohort studies of diet and health in the UK) developed by *N&PH*. Such links are revealed only rarely in large cohort studies, due to challenges in coding the data, but this was overcome by *N&PH*.(#JCa2, #NA3) UKWCS has been integrated with the MRC Centre for Nutritional Epidemiology in Cancer Prevention and Survival (CNC), consisting of 7 UK Universities and 5 MRC units, with access to an even larger data-set (>100,000) of individuals. The scale and level of detail this consortium of cohorts contains makes it globally unique and is an important development for the future. Analysis of some of its information has already demonstrated that dietary fibre intake is inversely related to colorectal cancer risk (**Burley**, **Cade**, #JCa3).

Research into life-course nutrition via a Wellcome Trust Training Fellowship to **Alwan** & **Cade** (GR472859, £27k) has established a relationship between total iron intake (#NA3) (from food and supplements) in early pregnancy (#NA2) and birth weight (GR480664 & 476006, £154k), incorporating new methods of measurement (brachio-femoral pulse wave velocity at ca. 4 weeks of age) and forged collaborations the School of Medicine at UoL and other institutes (Universities of Bristol, Southampton and the Rowett Institute). To investigate how life-course nutrition might be changed, 3 large randomised controlled trials have been implemented to support positive dietary behaviour change in children (#CE2), including the first full trial funded by NIHR Public Health

(**Evans**, **Cade**) (GR478389 & 480670, £187k). With respect to food intake assessment, a major achievement has been the first proper evaluation of a dietary self-monitoring app for smartphones, My Meal Mate (#JCa4) (GR477190 & 480662, £129k). *N&PH*'s short-form food frequency questionnaire (GR481888, £31k) has featured in a National Obesity Observatory report (03.2011). Recently an on-line 24h dietary recall tool (MRC funded, GR481582, **Alwan**, **Cade**, **Evans**, £366k) was developed, the first of its kind in the UK, plus the Child And Dietary Evaluation Tool (CADET) (used in 3 major trials by other Universities). *N&PH* is active in consultancy, formulating key health messages from scientific findings and providing a literature review service. Highlights include the Caffeine and Reproductive Health study resulting in UK government advice (11.2008) to pregnant women to limit daily caffeine intake (#JCa1).

Laboratory-based *N&PH* research has been expanded to improve food composition knowledge (**Orfila**) and the effects of proteins and carbohydrates (polysaccharides, oligosaccharides and sugars) on plant cellular structure in relation to food texture, quality and nutrition (**Orfila**, #CO2, 3). Linking with *FC&B* research, **Bosch** has investigated anti-inflammatory properties flavonoids and their metabolites, via micro RNAs (miRNAs) as posttranscriptional gene regulators (#CB1, 2). Such work has also stimulated statistical modelling (with *FC&P*) of the distribution and potential benefits and risks of such food components consumed (**Holmes** & **Burley**). **Burley** has conducted a major systematic review of clinical trials and observational studies of such dietary carbohydrates in relation to stroke (#VB2), heart disease, Type 2 diabetes and obesity for the Dept. of Health (GR477663 & 480666, £226k). The carbohydrate work has thus benefited from links with both *FC&B* and *FC&P*, i.e., taking into account methods of composition analysis and food microstructure effects and led to a major EU project (PATHWAY-27, **Orfila**, GR479837, £ 310k) linking microstructure with nutritive value. Other key achievements include identification of acetylated homogalacturonan as an important regulator of tuber hardness (#CO1), leading to funding by The Potato Council (GR479341, £112k) and Heinz into problems with two major UK staple foods: bruise susceptibility in potatoes and texture quality of beans, respectively.

c. People, including:

i. Staffing strategy and staff development

In order to implement the research strategy outlined in Sects. a and b above, carry this forward into the future, plus take account of recent and future retirements, new staff have been recruited. All staff and student representatives play a role in recruitment of academic staff.

Orfila and **Bosch** were appointed in 2009 and 2013, respectively, to strengthen nutrition expertise. **Cade** and two new lecturers (**Burley** and **Evans**) and their associated research group were brought from UoL Medical School to complete the new *N&PH* research group. In 2010 **Holmes** and **Akhtar** were appointed to expand the food physical, processing and industrial liaison activities. These appointments are key in bringing classic food science and processing closer to the wider nutrition and health issues. In addition, **Rappolt** was appointed (01.04.13) to a UoL 'Leadership Chair' (in Lipid Biophysics) to further strengthen physicochemical research. The UoL-supported (> £ 1 M) aim is for this Chair is to integrate research activity in lipid biophysics within UoA6 and across UoL as a whole, to promote its internationally leading position in food research.

UoA6's policy on staff training & development is that stated in www.sddu.leeds.ac.uk, which includes a *Next Generation Researcher* programme, developed in association with the national Researcher Development Framework (RDF). The MaPS Training Hub is used to provide training and development for research staff and students. UoL is an accredited Investors in People organization and was one of the first UK Universities to be awarded (in 2010) the HR Excellence in Research Award by the EC, in recognition of such initiatives, and renewed in 2013.

UoA6 delivers a supportive and professional working environment for all staff. Equality issues are central, supported by a MaPS Faculty Diversity Champion and representation on the University's Equality and Diversity Committee. UoA6 and UoL strongly support development of women's careers in Science, Technology, Engineering and Mathematical (STEM) disciplines, as evidenced by a steady increase in the proportion of women applying for and obtaining academic posts in UoA6 in recent years, and recognized in an Athena SWAN Silver Award (2012) to UoA6's Faculty. UoL's and UoA6's support program for staff returning from long term absence, in particular Maternity Leave, has been commended. The staffing strategy has resulted in an appropriate change in research activity to achieve UoA6's vision whilst reaching a more equal gender balance

overall (% of female academic staff has increased from 12 % to > 40 % since 1.1.08).

UoA6's staff review & development scheme (SRDS) is a formal 2-way review process monitoring research progress and planning appropriate training where appropriate for staff at all levels. Junior staff are mentored by more senior staff, particularly in developing grant proposals. All proposals are viewed by both junior and senior colleagues before submission for constructive feedback and sharing of good practice. Few proposals have single authors; > 90% have co-investigators within UoA6, elsewhere in UoL or from other Universities. **Williamson** chairs the joint Faculty MaPS/Engineering Ethics Committee and advises on ethical aspects.

ii. Research students

UoA6 has successfully collaborated with industry via Industrial CASE awards, aiding technology transfer to industry and giving students industry experience. Examples include: Acoustic model of particle mixtures (**Povey** & Proctor & Gamble); Nanoemulsion preparation (**Povey** & Proctor & Gamble); Hydrophobin-stabilized bubbles (**Murray** & Unilever); Paraffin wax formulations (**Murray** & GSK); Starch-based adhesives (**Chen**, **Ettelaie** & National Starch). Major companies have also fully funded some students, e.g., since 1.1.08, 8 students by Nestlé to **Williamson** (GR472989 & 479332, £1.4 M); 2 by Unilever to **Murray**, (£ 60 k); 1 by National Starch to **Chen** & **Ettelaie**, (£ 65k), 1 by McCains to **Povey** (£ 85k); all indicating significant industry support. Of UoA6's total journal publications > 15% have industrial co-authors.

UoA6 and UoL's Postgraduate Development Record System (PDRS) provides a training needs analysis tool for all PhD students and a record of supervisor meetings (10 p.a. minimum) and outcomes. Staff are trained in supervision. Students complete a minimum of 10 days of skills training p.a. and attend appropriate BSc & MSc lectures that will aid their development. All students are assigned an independent staff advisor. Students submit reports at 9 and 24 months; a transfer *viva voce* takes place at 11 months with 2 independent assessors. As part of their training & development, PhD students organize their own conference each year, presenting their work and leading the discussion. External oral presentations are expected, particularly in their final year, for which some students have won prizes, e.g., Diane Threapleton (*N&PH*) from the UK Nutrition Society (2012 & 2013), Fraser Courts (*FC&B*) from IFST (2009) - subsequently selected by the Society of the Chemical Industry as a Science Ambassador. UoA6 pays for student conference contributions out of general revenue if funding is short. All UoA6 research facilities are made available to students (providing facilities demand and consumables costs are considered), plus UoL is part of the N8 Shared Equipment initiative (http://www.n8equipment.org.uk/).

d. Income, infrastructure and facilities

Major infrastructure investment strategy is decided through discussions of UoA6's Senior Management Group, representing each of the 3 research groups. *FC&B* laboratories have excellent cell culture and state-of-the art analytical facilities including: normal and fast high resolution chromatography with diode array and CoulArray, PAD, ELSD and fluorescence detectors; LC-MS; GC-MS equipment; ELISA plate readers. *FC&P* has a unique equipment base in: specialist bulk and interfacial rheometry (shear, dilatational & extensional); texture, surface friction and swallowing analysis; microscopy (Brewster angle, atomic force, confocal laser scanning, ultrasound); Split Post and Single Post Dielectric Resonators (SPDR, SPR) for thin film dielectrics, surface resistivity and reactance; specialist homogenization equipment. UoL is investing £ 0.64 M in SAXS/WAXS facilities for **Rappolt**. UoA6 provided completely refurbished office space with secure personal data storage facilities for the *N&PH* staff from Medicine, plus a database manager and research support assistant, to improve data management and security.

All 3 research areas benefit from access to the pilot plant food processing equipment in the Food Technology Laboratory and its associated taste panel suite. Unique within UoL, this allows direct incorporation and testing of research findings on real food products and has aided collaboration on short and long term processing and formulation problems faced by industry, for example, through **Akhtar** linking academics with industry (see Sect. b above). Partnership in the White Rose High Performance Computer initiative has allowed access to the state of art computing facilities for simulation work in *FC&P*, further exploited in application of Monte Carlo methods to dietary data for prediction of likely contaminant and toxin exposure in foods, joint with *N&PH*.

Research overheads and consultancy have been used for equipment update and investment,

particularly for more recent and junior staff. For *FC&P* in 2009 this allowed purchase of a new Malvern NanoSizer (£30k) for particle size and zeta potential measurement, plus a new Malvern Kinexus shear rheometer; for *FC&B* and *N&PH* investment (£ 100k) in HPLC and LCMS systems and general refurbishment (£ 44k) of bench-space; for *N&PH*, purchase of Texture Analyzer equipment (£ 10k) for cell wall studies, real-time PCR & chromatography equipment with PAD detection for carbohydrate analysis, part-funded by Yorkshire Agricultural Society. This has led to further support for PhD students, e.g., for **Orfila** (from the Potato Council). For *FC&B*, state of the art UPLC-MS (£200k) and refurbishment of new lab space has been provided and a mini computer cluster, partly from matching UoL funds. Significant equipment donations have been received from industrial collaborators, e.g., spinning drop tensiometer (£20 k) and jet homogenizer (£10 k) from ICI/Henkel; drop profile tensiometer from Unilever (£ 25 k); Proctor & Gamble acoustic sensing rigs (GR482479, £40k). Such facility upgrades have aided UoA6 in providing service to other Schools at UoL, other Universities and industrial partners, e.g., in: bulk rheology, surface tensiometry, confocal microscopy, emulsion preparation and characterization, contact angle and ultrasound measurements. At the same time, UoA6 also makes good use of specialist facilities elsewhere in UoL, e.g., in electron microscopy, X-ray tomography, NMR, DSC and rapid protein analysis.

The funding landscape accessible to UoA6 has substantially expanded due to the research and staffing strategy described above, e.g., to TSB, MRC and health charity organizations. Charity funded research (although reducing average research recovery per FTE) has substantially increased global exposure of UoA6 research, which is now highly distinctive in covering such a broad range of science relevant to food and nutrition.

e. Collaboration or contribution to the discipline or research base

Staff are encouraged to promote their research discipline and engage with the wider stakeholder audience. The staff workload model allows for this. Examples include the following.

- Visiting Professorships to Universities of: Surrey (**Williamson**), Harbin (**Williamson**),Jiliang (**Chen**),Tianjin (**Chen**).
- Editorship of journals, e.g., *Food Hydrocolloids, Food and Function, Food Texture*, *Food Digestion, Food and Agricultural Immunology*.
- Scientific Advice to industry, e.g., Nestlé (Lausanne), ICI; Nestlé Nutrition Institute.
- Service on organizing committees of conferences, e.g., 4th Int. Conference on Polyphenols and Health (Leeds, 2009), with > £70k industry sponsorship); 1st Food Oral Processing (Leeds, 2010) now a biennial series (Beaune, 2012; Wageningen, 2014); Food Colloids; Faraday Discussions; Food Structure and Functionality Forum.
- Activity in scientific societies, e.g., IFST (including the IFST Young Scientist Competition); RSC Food Group committees; Complex Fluids Group of Institute of Physics.
- Service on Government and EU commissions, advisory and grant awarding committees, e.g., EU Research Council Advanced Grants; European Assoc. on Food Composition; FP7 REFRESH and REGPOT projects; Committee of Toxicity of Chemicals in Food, Consumer Products & the Environment (COT); Association for Nutrition Registration Committee; World Cancer Research Fund International Regular Grant Programme Panel, British Nutrition Foundation Scientific Advisory Panel, Max Planck Institute Hahn Research Medal; BBSRC working group on Nutritional Enhancement of Crops; research assessment panels for Universities of Cork and Wageningen.
- UoA6 staff are also active in increasing public awareness of science and food issues, for example: the Wellcome-funded project “You are what you ate”; promotion of food science and nutrition in local schools by providing food & nutrition workshops relevant to their curricula; The Ministry of Food Initiative (**Cade**, GR481006, £6k) and various informal talks at Science Cafés and public institutes in the region. Promotion of their research discipline is encouraged for all staff and aided via mentoring of junior staff by senior staff.
- Strong collaboration between academics in the different research areas within UoA6, leading to joint publications, PhD studentships and grant proposals. (See Sect. b)
- Collaboration with external bodies, for example: **Williamson** with Nestlé Research Centre; **Cade** with the FSA resulting in new advice to pregnant women to limit caffeine intake; **Evans** with the FSA, British Nutrition Foundation, School Food Trust, NHS and several Education authorities in incorporating research results into policy documents regarding school children's packed lunches, including the Government's newly announced (09.2013) £ 600M School Food Plan.