



DRINC • DIET AND HEALTH RESEARCH INDUSTRY CLUB

DIET AND HEALTH RESEARCH INDUSTRY CLUB (DRINC) WORKING GROUP REPORT

This document presents the views and conclusions of a Review Panel of experts.
The views expressed are those of the members of the Panel.

November 2011

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Contents

| | |
|---|-----------|
| EXECUTIVE SUMMARY | 3 |
| KEY FINDINGS | 5 |
| CHAPTER 1: BACKGROUND | 7 |
| UK Food Industry | 7 |
| Diet and Health Research Industry Club (DRINC) | 7 |
| DRINC Working Group..... | 8 |
| CHAPTER 2: INTERIM EVALUATION OF DRINC | 10 |
| Introduction | 10 |
| Relevance of research to the food and drink sector and potential impact | 11 |
| Overview | 11 |
| Industry relevance..... | 11 |
| Balance and coverage of the portfolio..... | 12 |
| Research outputs..... | 14 |
| Building capacity in diet and health research..... | 16 |
| Overview | 16 |
| Academic research capacity..... | 17 |
| Skills and training..... | 18 |
| Research capacity in industry..... | 19 |
| Effectiveness of the DRINC mechanism and knowledge exchange | 19 |
| Overview | 19 |
| Club format..... | 19 |
| Industry membership | 20 |
| Knowledge exchange..... | 21 |
| CHAPTER 3: CONCLUSIONS AND FUTURE DIRECTIONS | 23 |
| Overview..... | 23 |
| Research | 23 |
| Skills and training | 24 |
| Mechanisms | 25 |
| ANNEX 1: DRINC RESEARCH CHALLENGES | 26 |
| ANNEX 2: ABSTRACTS OF RESEARCH PROJECTS FUNDED THROUGH DRINC | 29 |
| ANNEX 3: WORKING GROUP MEMBERSHIP | 60 |
| ANNEX 4: PAPERS PUBLISHED OR IN PRESS IN JOURNALS: | 61 |

EXECUTIVE SUMMARY

This document reports the findings of a Working Group set up to provide an expert interim evaluation of BBSRC's Diet and Health Research Industry Club (DRINC) and advise on the need for further support to ensure that the food and drink sector can benefit from the UK biosciences research base.

The food industry is a significant contributor to the economy of the United Kingdom and is the single largest manufacturing sector. It is of strategic importance in enabling the United Kingdom to meet the challenges of providing a nutritious, safe and sustainable supply of food to a growing and ageing population in a world with increasing scarcity of resources.

The food industry, as a whole, is not a research intensive industry and has limited engagement with the academic research community. The DRINC Club has proved itself to be an effective vehicle to address these challenges, by building capacity in the research community and at the same time increasing industry involvement in this strategically important area of science.

This review has established that there have been real benefits from closer links between industry and academia. Twenty five, high-quality research projects of clear industrial relevance have been supported, which promise research outcomes of high impact and researchers who have not previously worked in this field have now expressed an interest in working in the food arena - a direct response to the opportunity of funding through a club mechanism. The grants have supported 60 post-doctoral researchers and technicians and a further 30 PhD studentships have been aligned with the projects, training a new cohort of researchers who have close interaction with industry and will be able to contribute to addressing challenges of diet and health in the future.

However, this development is still in an early stage and the absence of continued funding could lead to these research groups breaking up. The existing fragility of the interactions was demonstrated by the difficulty DRINC has had in engaging with the SME sector. Investments in DRINC are long term and strategic for the benefit of the food industry and its consumers as a whole. Immediate impacts may be perceived as limited which can be challenging for much of the sector.

The DRINC Club has proved itself to be an effective vehicle to address these challenges, by building capacity in the research community and at the same time increasing industry involvement in this strategically important area of science.

The lead BBSRC took in establishing DRINC was welcome and BBSRC should build on the success of DRINC by providing further research funding. DRINC has brought together a range of funders that have added value to the programme by ensuring projects can be effective in meeting the needs of industry without being constrained by the remits of individual funders. A future DRINC should look to build further on the range of funders involved.

DRINC should also seek to increase membership and engagement with a larger number of food and drink companies including innovative SMEs. The Working Group recognise this will be a challenge due to the structure of the sector and will require alternative mechanisms to be

investigated to get them involved in the current difficult financial climate. However, discussions have shown that companies not originally members of DRINC have seen the value of the Club and would be willing to consider membership of a further phase of DRINC.

KEY FINDINGS

1. DRINC is supporting high quality, industry relevant, research projects and is helping to build a stronger academic/industry community.

The standard of the research supported through DRINC is high and is of clear industrial relevance. DRINC projects are producing papers in international journals relevant to the field, generating new intellectual property and producing new products, processes, resources, tools or technologies. The indications are that DRINC research is likely to deliver impacts to the UK food and drink sector now and in the future.

The DRINC remit is industry relevant and generally well covered. However, gaps in the portfolio have been identified in the areas of processing related to diet and health; taste, texture and flavour; and psychology related to food choice.

2. DRINC is helping to build further academic research capacity in the UK in diet and health research and has increased its industry members' capacity to interact with the research base.

Partnerships and networks built through DRINC have increased the ability of the research base to address industrially relevant challenges through multidisciplinary research and aided the development of consortia that can apply to large, multi-funder programmes. DRINC is training a new cohort of people with industry relevant skills related to food and health which benefits from the close interaction with company members. The training provided through DRINC is likely to have a positive impact on the recruitment of skilled scientists by industry. There is potential for greater interaction between industry members and post-doctoral researchers/PhD students.

DRINC has increased its industry members capacity to interact with the research base and identify new research and innovation opportunities. The stronger links developed between the academic and industrial community have led to new partnerships and collaborative projects.

3. The Industry Club mechanism has delivered greater value than the investment in a portfolio of research projects alone.

DRINC provides a sense of identity that both the academic research base and industry can associate with and has developed synergies between projects. It is an effective mechanism in developing both academic-industry and academic-academic partnerships. Creative approaches should be considered to enable SME participation in DRINC.

There is a need to develop a communications strategy for DRINC, to increase awareness of the research more widely within member companies and outside of DRINC.

4. BBSRC should build on the success of DRINC by providing additional research funding through the Club mechanism to further develop the community, involving more academics and engaging with a wider number of companies.

DRINC has produced a vibrant and well connected community. Without further ring-fenced funding the diet and health research the community established through DRINC is at risk and the opportunities for future impact may be lost.

The focus of DRINC should remain diet and health as this is where DRINC funding has begun to establish critical mass. BBSRC should consult widely with the food and drink industry on future research themes within diet and health. BBSRC should also continue to work with other funders to ensure projects can be effective in meeting the needs of industry without being constrained by the remits of individual funders.

The membership subscriptions should be revised to enable a broader range of companies to participate in the DRINC programme (particularly SMEs), including consideration of in-kind contributions in place of membership subscriptions.

5. BBSRC should continue the provision of PhD studentships associated with DRINC grants and increase awareness of existing mechanisms to support knowledge and people exchange

Future support for skills and training should help address the gaps identified by the Working Group, which included: varying knowledge of food industry standards and regulations, learning on how to communicate research to industry, and the sharing of in-house knowledge of companies with researchers.

Opportunities should be created for greater interaction between member companies and students/post doctoral researchers so they have a greater understanding of how their research may be applied in an industrial setting. There are opportunities to improve understanding of the value of research within the food industry.

BBSRC and other funders should also seek to increase awareness and uptake of the variety of mechanisms to support Knowledge and People Exchange and collaborative research between academia and industry.

6. BBSRC should increase engagement around DRINC research and put a Communications and Engagement strategy in place to improve awareness about DRINC and communicate successful outcomes.

A communications Strategy should be put in place to increase awareness of DRINC and its research outcomes in existing company members and non-members. The Research Associations, Knowledge Transfer Networks, relevant industry groups/associations and Technology Strategy Board should be utilised to extend the current reach of DRINC and help demonstrate impact from DRINC research.

CHAPTER 1: BACKGROUND

UK Food Industry

1. The food industry is a significant contributor to the economy of the United Kingdom. It is the single largest manufacturing sector, employing 3.7M people, and accounts for around 7% of GDP. The industry is of strategic importance in enabling the United Kingdom to meet the challenges of providing a nutritious, safe and sustainable supply of food to a growing and ageing population in a world with increasing scarcity of resources.
2. The sector is intensely competitive and, apart from a small number of large companies, it is dominated by small companies operating on low margins. Research capacity is therefore limited and sector spend on R & D totalled £1.13Bn in 2009 ¹. Within the food industry most product development proceeds incrementally, and (outside the very large multinationals) large research centres do not exist. The industry is well served by the Food Research Associations (Campden BRI and Leatherhead) but there is scope for improved linkages with centres of academic excellence coupled with mechanisms to disseminate the results of research back to the industry.
3. Whilst some aspects of the industry, such as plant breeding, have a long history of links with the research community, the engagement of the food industry as a whole with the research community is relatively limited, a consequence of a number of reasons including the small size/profit margins of companies and the lack of intellectual property that research in food related matters can generate. Even amongst larger companies, it is difficult to encourage investment in long term strategic research for the benefit of the food industry and its consumers as a whole where there is limited direct and immediate benefit for the companies involved.

Diet and Health Research Industry Club (DRINC)

4. The Diet and Health Research Industry Club (DRINC) was established by BBSRC in partnership between EPSRC, MRC and industry in 2007. In setting up the club, BBSRC aimed to improve linkages between the food industry and academia and support innovative strategic research that would underpin the sector and help it to remain internationally competitive.
5. Through consultation with industry, academia and the public, diet and health was identified as a focus of the club, underpinning the needs of the food industry to deliver healthier foods. Substantial opportunities for innovative research exist across the food supply chain, with diet and health a significant driver for all businesses in the chain, from primary producers to retailers. The research required to address these research opportunities is interdisciplinary in nature and needs to bring together biosciences, physical sciences and engineering.
6. The aims of DRINC are to:
 - Support high quality, innovative, basic research within UK universities and institutes. This research will underpin the development of products that have health and nutritional benefits and help address diet-related health problems in the long-term

¹ [Reference/webpage no longer available – June 2017]

- Help to strengthen and develop the research community in the food area through interdisciplinary research and the provision of training
 - Ensure the transfer of knowledge between the science base and industry through the support of effective networking between the academic groups and companies involved in DRINC
7. The research funded through DRINC addresses the following two themes (described in greater detail at Annex 1):
 - Improved understanding of healthier diets - includes effect of food components on energy intake, and how foods might be designed to have precise nutritional properties
 - Bioactives in foods - includes understanding of how beneficial compounds work and how health claims may be verified
 8. The Club operates by establishing a funding pot to support academic research. 10% of the funding pot comes from a consortium of food companies (Club members). The remainder of the support is provided by BBSRC (principal funder), with support from the Engineering and Physical Sciences Research Council (EPSRC) and Medical Research Council on a project-by-project basis for research that falls within their remits to give a total funding pot of £12.5M over five years.
 9. The Club currently has 13 members: Campden BRI, Coca-Cola, Danisco, Danone, GlaxoSmithKline, Kraft Foods, Leatherhead Food Research, Marks & Spencer plc, National Association of British and Irish Millers Nestl , PepsiCo UK and Ireland, The Sugar Bureau and Unilever
 10. DRINC has provided support for three rounds of grant funding, with 25 research projects awarded (list of projects at Annex 2) and 30 associated PhD studentships. Whilst all of the research funding has now been committed, projects and dissemination activities supported through DRINC will continue to run until 2013.
 11. The Club is managed by BBSRC with the assistance of a coordinator and advice from a Steering Group made up of six industry members (elected from the company members), six academic members and a Chair (appointed by the Research Council funders). The Steering Group is responsible for the assessment of research applications and advising on the strategic direction of the club.
 12. The research and networking activities of the club are facilitated by the coordinator, Prof Peter Schroeder (Biosciences KTN). The coordinators role is to encourage research applications to the club, monitor funded projects, identify opportunities for collaborations within the club and keep industry members updated on club activities. In addition, all research groups funded through the club are expected to attend six-monthly dissemination events which provide a forum to update company members on the progress of research projects

DRINC Working Group

13. With the move of DRINC from funding projects to facilitating dissemination of research outcomes, it was considered timely by the DRINC Steering Group and BBSRC to evaluate the success of DRINC in meeting its aims and advise on the need for further support to ensure that the food and drink sector can benefit from the UK biosciences research base.
14. A Working Group was set up in October 2011 to advise BBSRC and the DRINC Steering Group. The Working Group comprised of industry and academic representatives, who included

members and non-members of DRINC, and representatives from the Technology Strategy Board and the joint funders of the programme (BBSRC, EPSRC and MRC). The members of the group are listed at Annex 3. The Working Group's aims were to:

- evaluate the progress of DRINC against the programme's objectives
- determine what activities are important to ensure the success and impact of BBSRC funded research outputs from DRINC
- provide recommendations on how BBSRC should continue to support research underpinning the food and drink sector and ensure knowledge exchange within the current tight financial environment
- provide a report to BBSRC, EPSRC, MRC and the DRINC Steering Group describing the conclusions of the Working Group and a case for any future activities.

CHAPTER 2: INTERIM EVALUATION OF DRINC

INTRODUCTION

15. The interim evaluation of DRINC was set up by BBSRC and the DRINC Steering Group to determine the success of DRINC in meeting its aims, and advise on the need for further support to ensure that the food and drink sector can benefit from the UK biosciences research base.
16. The objectives of the evaluation were to:
 - comment on the extent to which DRINC is supporting research and training relevant to the UK food and drink sector
 - comment on the extent to which DRINC is building research capacity relevant to the food and drink sector
 - assess the effectiveness of DRINC in promoting interactions, knowledge and skills transfer between academia and industry and potential impacts
 - assess the balance and coverage of the DRINC portfolio and identify any gaps
 - comment on the potential long-term economic and social impacts of DRINC research
 - comment on the value of the club mechanism for supporting research, training and knowledge exchange relevant to the food and drink sector.
17. It was recognised that it would be too early to draw final conclusions regarding the outputs of the research projects due to the early stage of most projects.
18. The evaluation was conducted by the Working Group with evidence drawn from:
 - **Funded grant holders:** A questionnaire was sent to all 37 Principal Investigators (PIs) who had been awarded funding through DRINC (33 responses). The questionnaire covered topics including the success of the grant, previous research experience in the areas funded through DRINC, interactions with industry, research outputs and outcomes, networking and knowledge exchange, and views on Research Council support for collaborative diet and health research with industry.
 - **Unfunded applicants:** A questionnaire was sent to 33 academics whose research proposals had made it through the outline application stage but had not been successful in obtaining DRINC funding at the full application stage (15 responses). The questionnaire covered topics such as the applicants previous research experience in the areas funded by DRINC, the value of the launch workshop and application process (including any interactions with industry) and views on Research Council support for diet and health research through DRINC.
 - **Industry members:** A questionnaire was sent to the 13 industry members involved in DRINC (11 responses). The questionnaire included questions on the company's motivation for becoming involved in DRINC, the level of satisfaction with respect to the return on their

investment, links formed between industry members, contributions to DRINC activities, the value of the training provided to early career scientists and views on Research Council support for diet and health research.

- **Employees on DRINC grants:** A questionnaire was sent out to 20 postdoctoral researchers working on DRINC grants (16 responses). The questionnaire covered topics including their previous research experience, training and other DRINC opportunities, interactions with industry partners and future career interests.
 - **BBSRC data:** Relevant funding data were collated from BBSRC databases.
 - **Outputs of DRINC grants** collated from Annual Report forms.
19. The following chapter reports the conclusions of the Working Group's evaluation under the following headings:
- Relevance of research supported through DRINC to the food and drink sector and potential impacts
 - Building capacity in diet and health research
 - Effectiveness of the DRINC mechanism and knowledge exchange

RELEVANCE OF RESEARCH TO THE FOOD AND DRINK SECTOR AND POTENTIAL IMPACT

Overview

20. DRINC was launched in 2007 to support innovative academic research that would underpin the needs of the food industry to develop and deliver new foods of benefit to the consumer. It is supporting 25 industrially-relevant research projects, allocated competitively through three funding calls. The rigorous assessment process has ensured the projects funded are of clear relevance to industry in addition to being of high-quality. Despite most research projects being at an early stage there is evidence of a variety of outputs which will benefit the food and drink industry. Early indications are that DRINC is likely to deliver significant impacts to the food and drink sector.
21. The Club has a well balanced portfolio which is of relevance to the wider food and drink industry outside of DRINC's membership. The Steering Group has directed the calls effectively to ensure a balanced portfolio covering most critical areas. Three areas have been highlighted where there are gaps in the portfolio: The effects of processing technology on diet and health; understanding the biological, chemical and physical basis of taste, texture and flavour; and the psychology and biology of factors which influence food choice. These areas were highlighted within the funding calls but lacked sufficiently competitive applications for funding.

Industry relevance

22. The Working Group considered that the DRINC projects were addressing key challenges for the food and drink industries. All of the company members which responded to the survey considered that the research funded through DRINC was more relevant to the food and drink sector than wider research council-funded research. Eleven of the 13 company members that responded considered the research to be relevant or very relevant to their company, with the remaining two considering it to be somewhat relevant.
23. The role of the industrial members in shaping the research agenda and deciding which projects should be funded, as well as the inclusion of industry relevance in the assessment procedure, ensured the industrial relevance of the funded projects. Whilst the particular

interests of the companies present in DRINC had influenced the projects receiving funding, through the scoping of the calls for proposals, the Working Group considered that the research supported was broadly applicable to the needs of the wider food and drink sectors.

24. The industry relevance of individual projects appeared to be greatest where there were links to companies. Closer links between academics and industry provided greater opportunities for detailed discussions about the research and how to take forward the findings. The Working Group emphasised the importance of academics visiting industry so that they could fully appreciate the industry environment and context for their project.
25. DRINC has enabled industry members to identify new opportunities in research areas they had not previously considered as having relevance to them, especially within theme 1, highlighting the value of the mechanism in enabling industry engagement in more risky and speculative projects. The following comments were made by company members:

'It has been a showcase for UK quality science to an international company that conducts most its research outside of the UK.'

'I have seen some first class science and some industrially relevant applications. I really think we need a DRINC 2 to build on this wonderful achievement.'

'It has been very useful having access to the academics'

Balance and coverage of the portfolio

26. The DRINC portfolio was considered to be generally well covered, with a good split between the research themes: Theme 1: Research leading to an improved understanding of healthier diets, and Theme 2: Research relating to bioactives in food that benefit health (Table 1). The Working Group noted that the assignment of projects to categories was not an exact science and some projects spanned several categories.

Table 1 Balance and coverage of the DRINC portfolio

| Sub theme | Category | Number of grants | Percentage of portfolio |
|--|---|-------------------------|--------------------------------|
| Theme 1: Research leading to an improved understanding of healthier diets | | | |
| A | Understanding the biological, chemical and physical basis of taste, texture and flavour | 0 | 0 |
| B | Understanding the functionality of food and drink components | 1 | 4 |
| C | The role of food constituents/food viscosity on energy intake | 5 | 20 |
| D | An understanding of food structure and its influence on human physiology | 6 | 24 |
| Theme 2: Research relating to bioactives in food that benefit health | | | |
| A | Production, formation and separation of bioactives | 2 | 8 |
| B | Processing and delivery | 2 | 8 |
| C | Efficacy, mechanism and best practice for proving action | 9 | 36 |
| | | 25 | 100 |

The scope of the sub-themes is outlined in Annex 1

27. Funding for the first call was dominated by research on bioactives. However, subsequent calls were adjusted to focus on other areas of research within DRINC's remit, such as diet-GI interactions and the modification of primary raw materials, to try to ensure a balanced portfolio.
28. The majority (80%) of industry partners questioned in the evaluation survey reported that there was good coverage of the remit by the funded grants, with no significant gaps in the research supported by the programme. Only three industry members identified specific areas requiring more support. There was also evidence from the industry responses that they were not fully aware of the wider Research Council funding relevant to their interests.

'Support for areas at a good level. If there was significantly more, I feel the research quality would suffer. An area at the periphery that was not addressed fully was how we can breed/grow plants with higher nutritive content, what effect this could have on human health and how we could persuade farmers to grow and people to consume.'

'Satiety could be better funded.'

'Biomarkers for health – still a lot of scope. Bioaccessibility of nutrients. Effects of food processing on diet and health.'

29. In contrast to the industry members, the majority of grant holders (64%) considered that there were areas within the DRINC remit requiring more support. However, there was limited feedback on the areas requiring more support and little consensus on the areas that were poorly served. Comments included:

'Appetite and food choice/consumption are very poorly provided for, other than DRINC. The social/population elements need major attention, not just biology/psychology.'

'Food engineering. Food manufacturing is the biggest industry in the UK and gets virtually no Research Council support. This part of the research community will not exist soon.'

'Flavour perception and basic sensory processing..., which is clearly critical to consumer behaviour.'

'Biomarkers for assessing early decline in metabolic and vascular health.'

'Limited support on major commodity crops as opposed to high value crops and tools.'

'Very little strategic research on animal derived foods and health unlike the situation with the plants.'

'Studies investigating molecular actions of food components at the cellular level.'

30. The Working Group considered the following areas of DRINC's remit as having limited or no projects funded despite being highlighted within the research calls and being of importance to the industry:

- The effects of processing technology on diet and health
- Understanding the biological, chemical and physical basis of taste, texture and flavour
- The psychology and biology of factors which influence food choice

The effects of processing on diet and health

31. DRINC received quality applications involving process science (the physics, chemistry and biology that underpins food processes) and a number of these applications were funded. However, it received very few proposals involving either process or mechanical engineering even though there are a number of internationally recognised academic groups in these fields in the UK.

32. Possible explanations include that:

- some groups may have assumed that a BBSRC-led research call was not applicable to them
- there may be a lack of understanding amongst researchers about the potential value of this type of research
- the UK manufacturing base for food processing equipment is now quite small and was not engaged in DRINC.

Understanding the basis of taste, texture and flavour

33. In order to tackle major issues such as fat, sugar and salt reduction, DRINC members believed it was important to have a better understanding of the physical, chemical and biological factors that affect the perception of taste, texture and flavour. The Working Group highlighted the lack of successful applications in this area and considered that it was likely to be due to the relative lack of people with relevant expertise entering academia and industry to work in this area.

Psychology and food choice/satiety

34. Understanding the links between the psychological and biological influences on food choice and satiety has a massive potential in the food industry. Good applications were received in this area: four were funded and a similar number narrowly missed out on funding. There are a limited number of academic groups in the UK able to contribute to the psychology of food choice, especially when they are required to work closely with basic biological science. To be successful, projects in this field also need strong industrial links.

Research outputs

35. The data for the evaluation was collected at the beginning of 2011 when the research projects funded through the first two funding calls were well underway, but had not yet been completed; and research projects from the third call had only just started. It was therefore recognised that many of the projects were at an early stage and that it was too early to fully evaluate the outputs from the programme.

36. However, the Working Group recognised the rigorous and competitive nature of the assessment process that had been set up to ensure that the projects funded through the DRINC programme met the high scientific and industrial relevance requirements of the Research Councils and industry members. All but one of the twenty five research projects were considered to be making good progress on the basis of annual report assessments and presentations at dissemination events. As a result of the selection process and progress to date there are expected to be a variety of significant, quality impacts from the DRINC projects in the longer term.

37. All of the projects had, or are expected to, generate papers for international journals relevant to the field and present at local, national and international meetings in the short to medium term. In addition, it was anticipated that many of the projects would produce other valuable outputs, including new processes, products, technologies and resources; intellectual property;

further grant applications and partnerships; and training. Whilst some of these outputs are possible within the short to medium term, it was acknowledged by the Working Group that the majority of these outputs would be realised in the medium to longer term and that these would need to be tracked to fully evaluate the impact from DRINC. The new Research Councils Research Outcomes System should enable the collection of these impacts over the longer term.

Publications and presentations

38. The grant holder surveys and annual reports demonstrated that a number of high quality publications had been produced (or were in development) for academic journals relevant to the field (Table 2 and Annex 4)

Table 2: Journals published in by DRINC grant holders

| | |
|--|--|
| Agro Food Industry Hi-Tech | Free Radical Research |
| American Journal of Physiology-Regulatory Integrative and Comparative Physiology | Handbook of Diet and Behaviour |
| Appetite | Handbook of Food Addiction |
| British Journal of Nutrition | International Journal of Behavioural Nutrition and Physical Activity |
| British Journal of Sports Medicine | Journal of Addiction |
| Cell Metabolism | Journal of Obesity |
| Cereal Chemistry | Neurogastroenterology and Motility |
| Current Opinion in Clinical Nutrition | Nutrition Research Reviews |
| European Journal of Biochemistry | Proceedings of the Nutrition Society |
| Food Hydrocolloids | Sports medicine |

39. All of the projects had provided presentations at academic conferences and dissemination events, and the majority of grant holders funded through the first call had met industry members to discuss their research.

Research groups have been invited by industry members to attend meetings and conferences, including visits to Campden BRI, Leatherhead Food Research; Unilever, Vlaardingen; Danone, Paris; Nestle, York; GlaxoSmithKline; European Steering Council of Coca Cola in Brussels (October 2009); US-Ireland functional foods meeting (March 2010); and the 69th Nestle Nutrition Institute workshop (October 2010).

New products, processes, resources, tools and technologies

40. Fifty six per cent of grant holders said that they had or were likely to develop new products, processes, resources, tools or technologies as a result of the grant, and two grant holders had completed tools. Twenty eight per cent of respondents said that they had or were likely to apply for some form of intellectual property (IP) protection, and four respondents had applied for IP rights to date. None of the IP generated from the DRINC projects had yet been licensed or yielded any income, but there was some confidence that the IP would be licensed by a DRINC company member.

Work associated with projects at Newcastle University and Birmingham University have led to patents being filed with the GB Intellectual Property Office:

"Inhibition of Pancreatic Lipase" was filed on 25 November 2010? Patent Application Number 0920633.5 (Newcastle)

"Comestible product" (appetite suppression) was filed on 21 April 2010. Patent Application number GB1006628.0 (Birmingham)

Matthew Wilcox was awarded and completed a RSE/BBSRC enterprise fellowship to drive forward the commercialisation of research outcomes associated with a project funded at Newcastle University and won an award for his business plan in the RCUK business plan competition in 2010.

41. It was noted that the food industry tends to protect its new products, processes, tools and technologies by know-how rather than formal IP. The Working Group commented that the focus should not just be on IP when evaluating outputs, as the collaborations developed through DRINC can bring greater benefits than IP alone.

Spin-out companies

42. Whilst spin-out companies are relatively rare in the food industry, one researcher stated that a spin-out company was a likely result of their research.

Further funding

43. It is too early for the majority of grant holders to have secured further funding. However, DRINC appeared to have increased the number and quality of applications to the TSB Nutrition for Life call, and some grant holders have been successful in obtaining further funding to continue their research.

Scientists at Birmingham University and the University of Warwick have been successful at obtaining funding in collaboration with industry from the TSB's Nutrition for life call and BBSRC's Industrial CASE competition:

"ePET (edible Pickering Emulsion Technology)" Led by Cargill, with Birmingham University; and "Reduced-Salt Emulsion Technologies (Re-SET)" Led by PepsiCo

"Identification & characterisation of dietary inducers of glyoxalase-1 for prevention and early-stage alleviation of age related health disorders through functional foods." Led by Unilever, with University of Warwick.

Scientists at the University of Warwick have been successful in at obtaining an Industrial CASE studentship with Unilever. "Anti-stress gene response in cell and tissue ageing: role of transcription factor NF-E2-related factor-2 and effect of dietary activators."

BUILDING CAPACITY IN DIET AND HEALTH RESEARCH

Overview

44. The food industry is not a research intensive environment and its research capacity has been further reduced in recent years. DRINC is helping to re-energise the links between the research base and industry by creating an identity for research relevant to the food and drink industry and developing an academic industry community. DRINC has encouraged new

researchers into the field and has helped to develop a number of partnerships that will enable the community to effectively address industrially relevant challenges. The Club provides a valuable training environment for post-doctoral researchers and PhD students but more interaction with industry should be encouraged.

Academic research capacity

45. The Working Group recognised that the establishment of DRINC itself had a positive impact on the academic research capacity in diet and health even at an early stage. They acknowledged that DRINC, through being a managed programme of research (including ring-fenced funding, a Steering Group, programme Coordinator and dissemination events), had led to the development of a community and research capacity that would be difficult to achieve through Responsive Mode funding. It was believed that the development of the DRINC community had also produced a cohort of funded and unfunded groups that would be better prepared to respond to future research funding opportunities.
46. DRINC has encouraged new departments, groups and people to come into the area of diet and health research. 18% of grant holders had not previously worked in the field of diet and health and a further 27% had been working in the area for less than five years. In addition 12% of employees on grants were new to the field.
47. DRINC has also succeeded in bringing together different disciplines, in particular nutrition, food science and psychology, which have been valuable in addressing industry relevant research challenges and has been seen as a particular benefit by industry members. Feedback from the evaluation surveys indicated that DRINC had built new links between researchers. Five grant holders named 36 individuals, groups and institutions with which they had formed connections through DRINC. The annual reports also indicated that DRINC had been important for the development of new academic partnerships through directly facilitating networking and information sharing at dissemination events and the identification of synergies between projects.

Scientists supported through DRINC are exploring bringing together interested members and projects to add value to DRINC's investment in the areas of 1) Diet and the Gastro-Intestinal tract and 2) Bioscience and behaviour. These activities, brought about by synergies identified through DRINC, will enhance opportunities for integration and aid the development of new ideas for collaboration.

Partnerships developed through DRINC also contributed to the development of the successful Food Quality and Health Advanced Training Partnership (ATP) application, led by the University of Reading, with University of Birmingham, Rothamsted Research and Leatherhead Food Research.

48. Partnerships and networks built through DRINC have also aided the development of consortia that can apply to EU and other large multi-partner programmes.

DRINC research at the University of Leeds has formed the basis for successful involvement as a major partner in EU FP7 'Full4Health' co-ordinated by the Rowett Institute, University of Aberdeen, and submission of further EU FP7 applications: 2 under (KBBE.2011.2.3-04 - Satiety control through food structures made by novel processing); one under FP7-PEOPLE-2010-ITN; and one KBBE under development on Lifestyle Nutrition and the elderly.

*Work on food hedonics (liking and wanting) at the University of Leeds has also been taken up in 2 large NIH collaborations (09-DK-0081- Selective Reduction of Dietary Carbohydrate versus Fat: Differential Effects on metabolism, Endocrine Physiology, Regional Brain Activity and Reward Circuitry, NIDDK, Bethesda, MD *nominated for NIH Director's Choice Prize) and (R01-HL-079478 Worksite Environmental Interventions for Weight Control, Minneapolis, MN).*

Scientists at the University of Warwick have been successful in obtaining funding from the EU FP7 Large-scale integrating project (with Prof. Dr. Andreu Palou and others), with a project on 'BIOmarkers of Robustness of Metabolic Homeostasis for Nutrigenomics-derived Health CLAIMS Made on food (BIOCLAIMS)', 01/04/2009 to 31/10/12

Skills and training

49. An objective of DRINC is to produce trained students and post-doctoral researchers, and increase the number of skilled professionals within the food and drink sector. DRINC is training a new cohort of people that will be able to contribute to the challenges around food and health within an industrially relevant context. DRINC is supporting 30 aligned PhD studentships and over 60 post-doctoral researchers and technicians on grants.
50. The focussed allocation of studentships was considered to make a valuable contribution to the industry relevant skills needs of academia and those of the food and drink industry and had the potential to have a positive impact on future recruitment. Comments from the industry survey included:

'post docs and PhD students will be a future resource for the industry'

'I think it is very important to promote young researchers in this area – and to afford them opportunities to meet industry contacts to better understand the different perspectives.'
51. The DRINC projects themselves also provide an opportunity for training, and there is value from the exposure to companies within the programme and the industry context of the research. Projects with direct links to industry were considered to be particularly beneficial in providing training in industry relevant skills. There is scope to improve engagement between researchers and industry, especially on projects without direct industry links to provide increased training opportunities.
52. The dissemination events provide an opportunity for post-doctoral researchers and students to present their work through presentations, posters (judged by a panel) and networking. This provides valuable learning on how to apply and communicate their work to industry, and an opportunity for feedback from academic and industrial members. The dissemination events also provide an opportunity for all of the students to meet together, creating a cohort which the Working Group considered valuable for training.
53. Presentations from company representatives at dissemination events about their research interests have provided insight for researchers into the food and drink industries. This was demonstrated by the respondents to the survey which showed evidence that DRINC had increased awareness of industry challenges in the academic community and influenced the future direction of a number of academic research programmes.
54. It was acknowledged that increased industry attendance at dissemination events would improve the opportunities for engagement between students/post-doctoral researchers and industry, and time allocated to networking/impact activities within the dissemination event could be increased to optimise their training value.

55. Researchers and students on projects had varying knowledge of food industry standards and regulations. This could be improved through relevant training and closer interactions with industry. There was also an opportunity to bring together the in-house knowledge of companies, e.g. expertise about their consumers, with the understanding gained by the research groups, to bring a useful context to the academic researchers and bridge the gap between underpinning science and understanding of consumers.

Research capacity in industry

56. The food industry is not a research intensive environment. It has been further reduced over recent years due to consolidation and other business pressures and become more short-term in nature. DRINC has increased academic research capacity, which can support industry and increase industry engagement with the research community. It has also proven to be an effective mechanism to bring both academic and industry groups together and has extended the research opportunities of industry through the funding of early stage, industrially relevant research, which would otherwise may not be supported to such an extent. However, DRINC alone should not be expected to address the structural issues within industry that limit research potential.

57. Importantly, DRINC has improved engagement and partnerships between industry and academia. Twenty four (out of 25) of the DRINC grant holders identified 77 links with industry: two thirds of the partnerships were informal and one third formal. DRINC was said to be important for the development of 58% of the partnerships. The DRINC grant holders and industry members reported that important lessons had been learnt about communication/engagement between academia and industry, and who to contact within the research and industrial communities. The increase in partnerships had also led to joint industry-academic funding applications to the Technology Strategy Board (see Further Funding section above) and other new project opportunities between academia and industry.

58. The Working Group also recognised the potential for DRINC to underpin future recruitment of scientists into the industry with 60% of employees on grants stating that they would consider a career in industry to pursue diet and health research.

EFFECTIVENESS OF THE DRINC (CLUB) MECHANISM AND KNOWLEDGE EXCHANGE

Overview

59. In addition to supporting industry-relevant research, DRINC has also supported a wide range of other activities which have had a positive influence on bringing together the academic and industry research communities. It has fostered the development of new partnerships which have benefited the research programmes and has also started to seed wider collaborations. These benefits could not have been achieved through Responsive Mode funding. Due to the nature of the sector, the industry membership is narrow; wider engagement, particularly with SMEs, should be encouraged as the research projects progress. A communications strategy should be developed to underpin these activities.

Club format

60. The Club format was considered to deliver benefits that could not be achieved through responsive mode funding alone. DRINC has provided added value above a portfolio of research projects by creating an identity for diet and health research in the UK which has been valuable in bringing together the academic and industry community to address research and

training challenges and enable knowledge exchange. It was considered that the industry involvement had helped to validate the importance of the area to the wider sector and society.

61. The defined pot of funding available through the DRINC, and focus on diet and health, was valued by the academic applicants to DRINC. The club mechanism was considered more effective for supporting strategic research compared to Responsive Mode calls, due to the level of involvement of industry, but maintained the high academic rigour required by the research councils and DRINC Steering Group. The number and variety of projects would have probably been reduced if the research had been supported through Responsive Mode.
62. The two stage funding process, with an outline and full proposal stage, was also considered beneficial as it meant that applicants could produce a shorter proposal at the outline stage and had the opportunity to incorporate feedback from the DRINC Steering Group into the development of a full proposal. Particular value was attributed to the role of the Coordinator in encouraging applications, providing feedback on proposals and annual reports, and providing support to grant holders during the course of the programme.
63. The coordinator role has also enabled some wider dissemination of DRINC's activities including through the Research Associations.
64. The Steering Group, comprising of academic and industry representatives, plays an important role in the Club structure. The Steering Group's role includes the development of funding calls, assessment of proposals, monitoring of annual reports and providing feedback to the grant holders. It was recognised that industry members on the Steering Group had a better feel for the overall approach and work done in the programme compared to those who did not sit on the Steering Group but were members of DRINC. Opportunities to address this are outlined in the Knowledge Exchange section below.
65. It was also recognised that the Club mechanism helped bring together and align the interests of different research councils in specific research areas. The involvement of MRC and EPSRC in the programme, and the additional co-funding available, was considered important in attracting different disciplines and skills to the programme.

Industry membership

66. The Working Group noted concerns that the Clubs tended to be dominated by a small number of large industry players and lacked significant SME involvement. This was not considered to be surprising given the structure of the food industry and the fact that it is the larger companies that have the resource, expertise and longer term strategic horizons both to create ideas and to fully optimise the outputs from the DRINC programme.
67. Other structural factors influencing the membership are that even relatively small financial contributions are particularly hard for the smaller companies to find when set against the time horizon of the research programme, exacerbated further in the current economic climate. Attitudes to basic research also differ widely across a fragmented and diverse industry and the precompetitive nature of the research and the lack of IP also presented issues to company involvement in certain cases. This was to be expected given the nature of DRINC in supporting underpinning research. However other complementary sources of funding for more applied and closer to market research exist through the Technology Strategy Board.
68. A particular issue was highlighted around SME participation in DRINC where contributions should not always need to be purely financial. Contribution can also consist of company involvement in research calls, assessment of applications and reports, site visits and dissemination events. The Working Group thought that the role of the Research Associations and the Knowledge Transfer Networks in particular should be utilised more fully to assist SME

participation because they were uniquely well placed through their membership to educate, communicate and coordinate.

69. Whilst Research Council support for DRINC is seen as positive, the Working Group believed that the Club mechanism should not be the only mechanism used to support diet and health research relevant to industry. Opportunities exist to exploit and optimise other collaborative research mechanisms (e.g. BBSRC IPA and LINK and Technology Strategy Board mechanisms) and use successful elements of the Club format to support research outside of the Clubs.

Knowledge exchange

70. The Working Group believed that the opportunities for knowledge exchange between participants were real strengths of the DRINC programme and there was evidence that this was helping to maximise the impacts of the programme by building on synergies between projects. The responses to the evaluation survey identified 77 links with industry: two thirds of the partnerships were informal and one third formal. DRINC was indicated as important for the development of 58% of the partnerships.
71. Five of the grant holders questioned in the survey cited academic links that had developed as a result of DRINC, naming 36 individuals, groups and institutions with which they had formed connections. Other partnerships have subsequently developed through networking and information sharing at dissemination events. The identification of synergies between projects had also led to the development of proposals for workshops to bring projects, researchers and industry with similar research interests together.
72. The dissemination events were seen as an important and successful mechanism for enabling training (see skills and training section above) and the development of a network of academics and industry members involved in diet and health. There is however a need for more one-to-one interactions. At Principal Investigator level the dissemination events were considered useful for developing relationships between industry and academia, but at post-doctoral researcher and PhD level 1:1 interaction with industry were considered more limited and variable.
73. The Working Group considered the format of the dissemination events and the challenge of responding to a large number of projects and a dynamic programme. There is potential to reconsider the format of meetings and the frequency of the events, whilst maintaining the relevance and accessibility to industry members.
74. There is a need to increase levels of networking outside of dissemination events. Industry visits to research groups can provide opportunities for detailed discussions about the research and how to take forward the findings and increase impact, but the amount of visits varied considerably between projects. All projects are required to present their research towards the end of the project to interested industry members, but the Working Group considered there would be value in increasing the number of visits between academics and industry representatives during the course of the projects. Providing additional funding for visits could improve links and understanding on both sides. The Working Group acknowledged that that whilst time pressures constrained industry representative s ability to participate in meetings it was important that they can devote sufficient time to enable knowledge exchange. It was also recognised that there might be more informal interaction than recorded through the survey or annual reports
75. It was acknowledged that the programme is still at a relatively early stage to fully communicate the outputs and impacts from the funded research. However it was considered timely to put a communication strategy in place targeted both at improving awareness and communicating

successful outcomes and including the identification of who will do the communication and the appropriate vehicles for dissemination.

CHAPTER 3: CONCLUSIONS AND FUTURE DIRECTIONS

OVERVIEW

76. DRINC has demonstrated the opportunity to begin to address the limited links between the food and drink industry and academia and the capacity of the industry to take up innovations from the research base. The Club has proved itself to be an effective vehicle to address these challenges, by building capacity in the research community and at the same time increasing industry involvement in this strategically important area of science.
77. This review has established that there have been real benefits from closer links between industry and academia, valuable projects have been identified, indications are that research outcomes will be of high quality and researchers who have previously not worked in this field have now expressed an interest in working in the food arena - a direct response to the opportunity of funding through a club mechanism.
78. However, this development is still in an early stage and the absence of continued funding could lead to these research groups and the community that has been established breaking up. The existing fragility of the interactions was demonstrated by the difficulty DRINC has had in engaging with the SME sector. Investments in DRINC are long term and strategic for the benefit of the food industry and its consumers as a whole. Immediate impacts may be perceived as limited which can be challenging for much of the sector.

RESEARCH

79. BBSRC should build on the success of DRINC by providing additional research funding through the mechanism to further develop the community involving more academics and engaging a wider number of companies.
80. It is currently unlikely that this community will be sustained through Industrial Partnership Awards and LINK projects awarded through BBSRC Responsive Mode alone. However, the long-term challenge is to enable the food industry to become engaged in a wider range of funding mechanisms and for the community to eventually become sustained without ring-fenced funding
81. The focus of DRINC should remain diet and health as this is where DRINC funding has begun to establish critical mass. BBSRC should consult widely with the food and drink industry on future research themes within diet and health. Themes could include understanding nutrition across the life course in addition to the research areas within DRINC's current remit which have not yet been addressed:
 - The effects of processing technology on diet and health
 - Understanding the biological, chemical and physical basis of taste, texture and flavour
 - The psychology and biology of factors which influence food choice
82. The lead BBSRC took in establishing DRINC was welcome and BBSRC should continue to work with other funders to ensure projects can be effective in meeting the needs of industry without being constrained by the remits of individual funders.
83. Particular areas where working in partnership with other research councils will be important include:

- Process engineering with EPSRC
- Food choice with ESRC
- Links between diet and disease with MRC

SKILLS AND TRAINING

84. DRINC is playing an important role in training a new cohort of researchers who will contribute to addressing research challenges around health and food in an industrially relevant context.
85. It is important to maintain and build a skilled academic and industrial community that can contribute to the challenges of the food and drink sector in the area of diet and health. The focussed provision of PhD studentships by the DRINC programme has made a valuable contribution to the industry relevant skills needs of academia and the food and drink industries, and has the potential to benefit future recruitment within industry. BBSRC should continue the provision of PhD studentships associated with DRINC grants.
86. Future support for skills and training should help address the gaps identified by the Working Group, which included:
- Varying knowledge of food industry standards and regulation by students and researchers. This could be improved through relevant training and closer relationships with industry.
 - Opportunities to increase the sharing of in-house knowledge of companies with researchers to provide context and bridge the gap between underpinning science and understanding of consumers.
 - Increasing the number of studentships and postdoctoral positions in the areas of processing related to diet and health; taste, texture and flavour; and psychology related to food choice; and hence opportunities for skills development and training.
87. Exposure of students and researchers to companies within the programme and the industry context of the research are valuable features of DRINC. The dissemination events provide an opportunity for postdoctoral researchers and students to communicate their work through presentations, posters and networking. However, there is still potential to provide learning on how to communicate research to industry, particularly where industry representatives are not specialists in the area of research. In addition there is the opportunity to provide greater interaction between companies with students and post doctoral researchers so they have a greater understanding of how their research may be applied in an industrial setting. Mechanisms to address this include:
- Encouraging more formal and informal links between projects and companies.
 - Increased attendance and industry input at dissemination events
 - Increased networking and impact activities within and outside of dissemination events
 - Involvement in Research Council and TSB People and Information exchange schemes such as the Industry Interchange Programme, Knowledge Transfer Partnerships (KTPs) and Industry Fellowships scheme.
 - Participation in the Advanced Training Partnership (ATP) programmes
88. There are opportunities to improve understanding of the value of research within the food industry. Whilst it is recognised that there are barriers to industry engagement in research, there is potential for the clearer and wider communication of DRINC funded research, including its potential impacts. There are also opportunities for increased industry involvement in research projects and dissemination events to improve understanding by industry and

academia. Outside of the programme, industry members should be encouraged to participate in People and Information exchange schemes, which enable industrial and academic researchers to exchange ideas and experience by moving between industry and academia and enable access to facilities and equipment.

MECHANISMS

89. BBSRC should increase engagement around DRINC research and put a Communications and Engagement Strategy in place to improve awareness about DRINC and communicate successful outcomes. The strategy should address the need to improve the documentation and information available to communicate DRINC activities to a wider range of employees in member companies e.g. through the use of case studies and tailored communications. In addition, creative approaches should be adopted to encourage wider engagement with industry and academic communities outside of the club, in particular with SMEs, although the challenge inherent within this should not be underestimated. The Research Associations and Knowledge Transfer Networks, which have a wide industrial membership, should be utilised to extend the current reach of DRINC communications and help demonstrate and offer a route to impact from DRINC research. Other channels should also be considered, including other industry groups, trade associations and the TSB.
90. Membership fees could be a barrier to some companies joining a future phase of DRINC, particularly small companies or companies with limited external research budgets. The existing sliding scale of membership was welcome but had not fully addressed this issue. Alternative mechanisms should be considered to enable a broader range of companies to participate in the programme, including consideration of in-kind contributions in place of membership subscriptions and opportunities to off-set contributions to Industrial CASE studentships against membership fees.

ANNEX 1: DRINC RESEARCH CHALLENGES

RESEARCH AREA 1 – Improved Understanding of What Constitutes Healthy Food and Drink

Producing healthier foods may be achieved through the alteration of components such as fat, sugar, carbohydrate and salt. However, this response has been seen as too narrow in scope and greater vision is needed. The challenge facing the food industry is making such foods as palatable to consumers as their conventional counterparts. There is also a need to understand how to deliver enhanced micronutrient content or beneficial components such as pre- and pro-biotics, in an effective manner. Sometimes modification or fortification of foods is straightforward for example enhancing omega-3 fatty acids in milk by changing the feed of the cattle. Some products, such as probiotic yoghurt and vegetable drinks, claim to deliver benefit; few do it within a conventional food. There is a need for high quality research to deliver these challenges where the following research topics should be considered;

- Understanding the **functionality of food and drink components** so that the impact on food safety, processing and bioavailability of reducing those components potentially detrimental to human health or increasing beneficial components can be understood. For example, the reduction of salt whilst beneficial to health may have an effect of enabling the level of micro-organisms within the food to increase.
- Understanding ***the basis of taste, texture and flavour*** at a fundamental level enabling reduction/ fortification in food and drink components without adversely affecting consumer reaction. This requires a combination of disciplines. For example, there is a need to understand how texture is developed through processing and break down in the mouth, and how flavours are generated, move to receptors and are perceived. This combines biochemistry, food science, physiology and physical science, as well as the olfactory psychology of perception and the development of mathematical models for the processes developed.
- An understanding of ***food structure and its influence on human physiology and nutrition***. It is now recognised that particle size and the proportion of amylose and amylopectin in foods can have a significant impact on blood glucose levels when the food is ingested. A better understanding of food structure may enable us to design new food or drink with precise nutritional and physiological properties. Over the years, food science has concentrated on understanding the physico-chemical properties of foods in relation to food texture, viscosity or heat transfer properties. The future challenge is to investigate and understand the role food structure plays in influencing human physiology. The research could enable for example the design of food and drink aimed at lowering the prevalence of chronic diseases such as type 2 diabetes, cardiovascular disease and cancer.
- ***The role of food constituents/food viscosity on energy intake***. Little is known about the mechanism of satiety. Food and drink components have been shown to have independent

effects on satiety. A clear understanding of how minor food and drink components (e.g. polyphenols, flavanoids, catcechins and epigallocatechin gallate) may influence energy intake via an impact on satiety is an important research theme. More generally, our understanding of how the type and composition of food components influence satiety and interact with individual learned behaviour are important and challenging areas of research.

RESEARCH AREA 2 – Bioactives for health benefit

Health provision by bioactives* is a fast growing market. For bioactives to be marketed effectively their actions must be fully understood and verified. To achieve this there is a need to address the following areas:

- **Production, formation and separation of bioactives**
The bioactive composition of both crop plants and farm animals is important in their impact on human health. The provision of bioactives can be facilitated by direct genetic intervention, changes in animal feed, by seed choice and plant and animal breeding regimes or by recovery from existing by-products and for example food processing micro-organisms. This research area will address the intrinsic properties of crops and food animals to provide the evidence base for breeding crops and animals with improved properties for producing bioactives and non-food processing micro-organisms. In addition the study of the metabolome and fluxome of crop plants and farm animals, together with improved methods in separation science, is required to optimise the level of useful bioactives in food. Commercial success will involve operational efficiency on a large scale.
- **Processing and delivery**
The bioactive must survive processing to reach the consumer and must be delivered in an appropriate way to benefit health. Protection and delivery technologies will therefore play a major role in healthy food and drink development. The physical nature of food stuffs is important in the technologies that need to be applied in processing the raw materials and the delivery of bioactives. It has become increasingly apparent that the fine structure of food at the nano- and micrometre scale is important in defining its physical, chemical and biological properties. This affects food processing, has a major impact on delivery of bioactives, yet is relatively poorly understood. Having suitable physico-chemical models for foods will better enable their modification to have desirable properties, conferring health benefits with optimal processing conditions and costs. In addition work on technologies (e.g. encapsulation) is required to improve shelf-life, delivery and to mask taste.
- **Efficacy, mechanism and best practice for proving action**
There is a need to understand the biology underlying the mechanism of action of bioactives on health and to establish the tools and technologies to measure bioefficacy through, for

example, the use of biomarkers. This should aim to deliver best practice methodologies for demonstrating health benefits. A greater understanding of bioactives may also lead to the development of personalised nutrition where food complements could be introduced.

* For this research area, bioactives are defined as naturally occurring food components having functional benefit, contributing to human health and well being, which may exist intrinsically in a food/drink or may be added as an enhancement, derived or recovered from natural sources, and delivered in an appropriate format to promote efficacy and availability in the diet.

Intervention studies

To support research in both areas there is a need for dose response, quantification and intervention studies on consumer groups of the population to generate convincing data for consumers, regulators and public health. For example, there is an assumption that low fat food and drink will reduce obesity but eating behaviour is complex and there is a need to understand the effect that individual food components have on psychology of appetite and food choice. Whilst it would not be the intention to support under the Club product specific studies, there may be scope, within the Club, for the study of generic classes of compounds, where instigating studies to demonstrate behavioural or health benefit could be of wider value.

ANNEX 2: ABSTRACTS OF RESEARCH PROJECTS FUNDED THROUGH DRINC

APPLICATIONS FUNDED THROUGH DRINC 1ST CALL JUNE 2008

| Self structuring foods with slow burn for control of satiety | | |
|---|--------------------------|-------------|
| Ian Norton | University of Birmingham | £350,943.23 |
| Number of PhD studentships awarded: 1 | | |
| <p>There is a need to control energy intake of consumers. A problem is that foods have become softer and more easily digestible and are less satiating. This leads to the individual feeling hungry more quickly and wanting to eat again often between meals. It has to be recognised that the consumer however, wants to have foods that are convenient, good tasting and easily prepared. The technical need is therefore to find ways to structure the food so that it is stable during storage and distribution is convenient and tastes good but then is slowly digested resulting in calories being released over hours.</p> <p>One potential way of achieving this is to produce foods that respond to the environment they find themselves in. So a food that is structured with a hydrocolloid that is sensitive to pH and is designed to structure the contents of the stomach (e.g. forms a gel that occupies the whole stomach) is potentially capable of slowing the stomach emptying process. Initial work has shown that this is possible and that the onset of hunger can be delayed by several hours. We intend to extend these initial findings and produce and investigate a range of alginates to control the gelation rate and gel properties under conditions; acidity, salt, temperature corresponding to the stomach. Having developed an understanding of the fine structure control of alginate we will study alternative materials that are acid sensitive (eg pectin, gellan etc) as well as investigating mixtures of these materials with each other and non acid sensitive hydrocolloids for specific kinetic and rheological control. There is a requirement to have temperature and time stable structures so that they can be transported and used in cooked products so we will investigate the use of sheared gels.</p> <p>A significant challenge will be to have materials included that will modulate the energy delivery and slowly release calories after the meal (slow burn) and still be organoleptically acceptable to the consumer. In order to do this we will include starch in different states; which are known to be digested at different rates and so delivers energy to the body over different timescales from minutes to hours. Starch which is highly crystalline can result in sandy or gritty textures in the mouth, particularly as the retrogradation process is not controlled in the manufacturing process. This has in the past limit the applicability of controlling energy release in soft foods using retrograded/resistant starch. We will investigate ways of including starch in other biopolymer and sheared biopolymer systems including 'hydrocolloid shells'. The shell will be designed to protect the starch against the amylase in the mouth and slow down the acid action in the stomach. This may well require a double or even triple shell to be produced with different hydrocolloids making up the shells. The overall dimensions of the particles will be less than ten microns to avoid oral</p> | | |

detection. In addition, starch in plants is more slowly digested than raw starch and we will investigate the separation and inclusion of cellular materials that are texturally and orally acceptable.

Having investigated routes to obtain self assembling structures and the way to include and modulate breakdown to control calorie release, we will then use our engineering skills to find ways to produce these materials at scale. As we do so we will be aware of potential problems of use in storage and transportation i.e. breakdown of the structures at elevated temperatures or self structuring occurring on storage before the product is used by the consumer. We will develop cyclised hydrocolloid networks, fluid gels (i.e. calcium cross linked alginate) which are temperature and time stable but dissolve at acid pH's and restructure into acid gels in the stomach. Fluid gels will be constructed by gelling the hydrocolloids or mixed hydrocolloids under well controlled flow fields and temperature profiles e.g. temperature ramped turbulent flow.

The overall objective is to produce a liquid like food which is enjoyable and pleasant to eat while controlling and manipulating the desire to re-eat or snack between meals.

The key hypothesis is that self structuring systems (which respond to the environment of the GI tract to form solid like structures after consumption) containing complex microstructural elements (with encapsulated macronutrients) to deliver a sustained release of calories over long times (hours) that satiation will be sustained between meals.

Enhancing delivery of minerals using multifunctional carriers

| | | |
|----------------------|----------------------------|-------------|
| Roger Parker | Institute of Food Research | £356,533.05 |
| Sue Fairweather-Tait | University of East Anglia | £34,022.38 |

Number of PhD studentships awarded: 1

The intake of many minerals and vitamins has fallen in recent years, due to reduced energy intake associated with a more sedentary lifestyle. It is also recognised that requirements of these nutrients for optimal health and reduction in the risk of chronic diet-related diseases may be higher than those recommended to avoid deficiency disorders. In industrialised countries such as the UK, iron deficiency is still a relatively common nutritional disorder, especially in individuals with a high requirement due to growth, blood loss or in old age. The absorption of minerals such as iron, calcium, zinc and magnesium is often reduced due to binding with other dietary constituents such as phytates and tannins, or oxidation into insoluble forms which severely reduce uptake. Therefore the absorption and uptake of minerals are strongly dependent on the form they are in.

Therefore if it is possible to design a system that will protect the mineral during processing, storage and the early stages of digestion (stomach), and then release the mineral into the small intestine, where it is absorbed by the body, we should be able to enhance mineral uptake.

The aim of this project is therefore to develop a novel delivery structure for water soluble minerals that is sensitive to changes in pH that are associated with the digestion process. The mineral (in this project we will focus on iron) is housed in small gel micro-beads (approx. 0.1mm diameter).

These beads are coated in layers of biopolymers and an impermeable layer of lipid or wax. The biopolymers are commonly used food ingredients such as pectin and proteins, and when assembled in these structures, become sensitive to pH changes. We have shown that they are stable at the acidic pH encountered in the stomach, but can degrade when they pass into the higher pH associated with the small intestine. The impermeable lipid layer will be degraded by enzymes in the duodenum, thus enabling the release of the iron from the micro-bead, and thus be available for absorption.

The project has been divided up into tasks that will address the following main objectives.

1. Create and characterise the pH and environmental sensitivity of the biopolymer layers. Using techniques that can measure the mass and composition of these molecular layers, we can determine how the layers respond to changes in pH and select suitable systems.
2. Assemble micro-beads and coat in selected biopolymer layers. Here we will develop methods that will allow us to encapsulate iron loaded microbeads in the impermeable biopolymer layers.
3. Determine stability, encapsulation efficiency and iron release properties. We will measure how much iron escapes from the microbeads during typical processing and storage conditions, and during simulated digestion to ensure they will release the iron under appropriate conditions. We will also use cell culture studies to see if the iron that is released is in a form that can be absorbed by cells lining the small intestine.
4. Determine rates of iron uptake from the coated microbeads. Foods loaded with the microbeads will be fed to human volunteers and their plasma iron concentrations will be monitored. This will reveal exactly how effective these structures are for enhancing the delivery of iron.

If successful the results of this project could be applied to other minerals and water soluble nutrients where fortification is a problem. These approaches could be used in a wide range of foods thus helping to increase the intake of these vital dietary components.

Dietary activators of antioxidant response element-linked gene expression for good vascular health

| | | |
|-----------------|-----------------------|------------|
| Paul Thornalley | University of Warwick | £634276.92 |
|-----------------|-----------------------|------------|

Studies of human populations and their eating habits have shown that increased consumption of vegetables and fruit is associated with decreased risk of heart disease and stroke. This suggests these foodstuffs keep major blood vessels in a good state. Fruit and particularly Brassica vegetables (broccoli, cabbage, cauliflower and Brussel sprouts) are important components of a healthy diet because they have high levels of compounds linked to low risk of heart disease. The key to their benefit is probably their ability to induce and increase endogenous defences against blood vessel damage and counter the development of high cholesterol and lipids in the body.

Good health of blood vessels is associated with a high production of proteins encoded by a battery of genes associated with maintenance of good blood vessel structural and function. The

protective genes are regulated through interactions with at a section of their DNA called an "antioxidant response element (ARE)". Increased production of protective proteins is achieved by stimulating a protein called "nrf2" that normally resides in the cell but outside of the cell nucleus to move into the nucleus. In the normal state, nrf2 is held predominantly outside the nucleus; on stimulation, it moves into the nucleus, binds protective genes and makes them produce more of their encoded protein. Increased levels of ARE-linked gene proteins provide for increased protection against spontaneous damage in the blood vessels / by reactions with oxygen, reactive nitrogen species and sugars - preserving the structure and functions of proteins and lipids within the blood vessels. A further remarkable property of nrf2 is its ability to switch off certain ARE-linked genes / particularly those associated with the excessive production of cholesterol and lipids. Minor components in fruit and vegetables can stimulate nrf2 to do this. We think the most important components are: products derived from so-called "omega-3 fatty acids" found in vegetable oils ("Canola"), carotenoids / compounds traditionally found in carrots but also in other vegetables, glucosinolates / compounds found in Brassica vegetables and also in increasingly popular "Rocket" salad, polyphenols / compounds found in grape juice and also in onions, and alkyl disulphides / compounds found in onions and garlic. It is not clear currently which of these groups of compounds and members thereof are most effective in enhancing the ARE-linked protective responses in blood vessels.

The aim of this project is to use two human cell lines / cells originating from human tissue but now grow continuously in culture, a cell typical of those found in blood vessels and one typical of liver cells (where cholesterol and lipids are made) / that have been genetically modified to produce nrf2 with a green fluorescence. We can then study nrf2 movement into the nucleus in response to compounds from fruit and vegetable under the microscope and make a time-lapsed video. Compounds from fruit and vegetables will be studied for their ability to produce strong and prolonged activation of nrf2 and associated cell protection from damage and accumulation of lipids. Compounds from many plant varieties will be studied to find the plants best for enhancing cell health. Mathematical models of the nrf2 effects will be refined to predict health benefits from fruit and vegetable consumption. Finally, we will study the health of blood vessels in healthy human volunteers during periods when we supplement their diet successively with vegetable oil, tomato juice/paste, broccoli and Rocket salad. Successful completion of this project will reveal the varieties of common fruit and vegetables that are likely most beneficial in maintaining blood vessels in a good state and also which fruit and vegetables have the ability to decrease bad cholesterol and lipids and raise good cholesterol, and likely beneficial if include in our diets for current and future generations.

Defining the gut to brain signalling mechanisms underlying responses to nutrients

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|--|--------------------------|-------------|
| David Thompson | University of Manchester | £588,994.95 |
| Number of PhD studentships awarded: 1 | | |
| The ways in which food intake is controlled need to be better understood if we are to combat the rising problem of over-eating and obesity. These are posing major threats to human health and prosperity. Many different factors are involved in weight gain, but meal size is an important factor. | | |

During the course of a meal and after eating, the digestive system sends multiple signals to the parts of the brain responsible for controlling how much food is eaten, and how hungry or full the eater feels. These signals are most powerfully triggered by the detection of food molecules by specialised cells in the lining of the small intestine. These cells then release 'gut hormones', messenger molecules which signal to the brain. The hormones (eg CCK, GLP-1) are believed to work principally by acting on nerve fibres linking directly from gut to brain, termed the vagal afferent pathway. The hormones may also travel in the bloodstream to the brain. These subconscious signals are then integrated by the brain centres which control food intake, most importantly by areas known as the medulla and hypothalamus.

How the nutrient molecules are initially detected in the gut is only now becoming clear. An exciting series of recent discoveries has shown that the sensing mechanisms that detect sugar molecules in the gut may be identical to the taste bud receptors which recognise sweet tasting substances in the mouth. It is also known that sugars in the intestine send 'fullness' signals to the brain, and slow down the speed with which the meal empties from the stomach. These two responses thereby limit further food intake. It is now essential to fully understand these mechanisms, since they can potentially be targeted by redesigning the composition of food products in order to induce fullness and reduce food consumption. We will undertake a series of studies designed to precisely determine the sensing and signalling pathways involved. Using a representative panel of sugars and sweeteners placed in the gut or the mouth, we will assess the whole 'control circuit'. This will be achieved by (i) determining the effects of sweet molecules on the speed at which the stomach empties, (ii) measuring the release of key gut hormones and using drugs that block their effects, and (iii) identifying the regions of the brain that are activated by sweet molecules in the gut and/or mouth. The studies will all involve monitoring key sensations of fullness or hunger throughout.

We have all the necessary research infrastructure and expertise required. A key technique involves a non-invasive measure of stomach function using breath testing technology. We also host a state-of-the art brain imaging facility using functional magnetic resonance imaging: this allows us to directly visualise the precise areas of the brain activated in response to nutrients.

Finally, we hope to extend the importance of these studies by collaborating with colleagues in Nottingham who are conducting research into the genetic basis for differences between individuals in the key sweet tasting responses and receptors present in the mouth and gut. Understanding these pathways will permit scientific researchers and food companies to work together to design and develop food products with positive health benefits for the population. Quality of life and prosperity are now under serious threat as a consequence of over-nutrition, a problem enhanced by the widespread availability of energy dense foods. Understanding the mechanisms by which nutrients/foods signal from the gut to the brain to influence food intake is critical to the development of novel satiating foods.

As a basis for strategies to prevent and/or treat obesity we will explore, in humans, the gut-to-brain signalling mechanisms involved in the regulation of appetite and energy intake by nutrients, particularly sweet substances. A key hypothesis is that the sweet taste receptors expressed in the mouth are also responsible for sensing in the gut, and therefore should be activated in a similar pattern.

The effect of dietary bioactive compounds on skin health in humans in vivo

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|-----------------|--------------------------|-------------|
| Lesley Rhodes | University of Manchester | £314,701.86 |
| Anna Nicolaou | Bradford University | £58,721.56 |
| Gary Williamson | University of Leeds | £127,847.84 |

Number of PhD studentships awarded: 2

The skin is the largest organ in the body and is readily visible. The consumer is often very aware of his/her skin and it is a sign to the outside world of health status. Ultraviolet (UV) radiation in sunlight is an important environmental agent that is responsible for short and longer-term negative aspects of skin health, including sunburn and most of the features associated with skin ageing. Behavioural changes have resulted in exposure to higher levels of UV, such that related health issues are increasing, and anticipated to increase further due to predicted climate change. Many previous studies have examined negative effects of food on skin, for example allergy or other diseases, or vitamin or mineral deficiency. There is also a substantial body of evidence showing beneficial effects of drugs and some nutrients on animals and when applied topically to the skin. However, there is surprisingly little information on the effect of orally taken bioactive compounds on skin in humans clinically, despite much supporting evidence for an effect from cell culture, animal, topical and mechanistic studies. The range of expertise provided by our 3-centre collaboration makes us ideally placed to address this area. To underpin the concept of nutrition for a healthy skin, we propose to examine the effect of bioactive compounds for which information in other systems is already available, on humans in vivo using state of the art techniques for measuring biomarkers of skin health directly in the skin, and further to measure nutrient uptake into the skin. Specifically, the data from laboratory studies on human skin cells shows that the compounds in green tea protect very efficiently against UV radiation stress. In addition, a large number of pre-clinical studies on rats and mice have shown a protective effect of green tea against cancers of many types. There are also many papers that report a protective effect of green tea against inflammation when applied directly (topically) to the skin. Taken together, this evidence suggests that a human study where the green tea is given orally is urgently needed and very timely. The importance of vitamin C to skin and connective tissues has been known for a long time. During UV and other stresses, the requirement of vitamin C increases. The study will be conducted over 3 months since the skin takes several months to replenish itself (turnover). The study has been designed to demonstrate a protective effect, and, if results are as expected, the study will be useful to both consumers and industry since it will validate the use of green tea in oral skin care formulations, and also provide the consumer with a choice to drink green tea for improving skin quality and even slowing ageing. It is anticipated that the results will also receive substantial press coverage with good publicity for the researchers and for the BBSRC DRINC programme.

The impact of cocoa processing on flavanol content, absorption and health effects

Jeremy Spencer

University of Reading

£330,727.74

Number of PhD studentships awarded: 1

Representing one of the most important lifestyle factors, diet can strongly influence the incidence of cardiovascular disease and thus a healthy diet is crucial for healthy ageing. Recent dietary intervention studies, in particular those using wine, tea and cocoa, have demonstrated beneficial effects on reducing cardiovascular disease risk, including an ability to lower blood pressure and to prevent blood vessel ageing. While such foods and beverages differ greatly in chemical composition, nutrient content and calories per serving, they have in common that they are amongst the major dietary sources of a group of plant compounds known as flavanols. The beneficial effects of flavanols have been attributed to their potential to be absorbed into the blood and to exert direct actions on blood vessels.

Whilst flavanol-rich foods can be regarded as being protective against cardiovascular disease, the content of active flavanols is significantly reduced during industrial processing. This is because during heating and storage, the flavanols react with to varying degrees with sugars to form new products known as flavanol-Maillard conjugates. At present, information regarding the absorption of these new conjugates and whether they possess similar beneficial properties to native flavanols is lacking. This proposal is designed to address these questions and to unravel the significance of industrial food processing on their inherent health properties. On completion of the proposal, we will be in an excellent position to advise manufacturers of flavanol-rich foods on the best processing conditions required to produce foods with optimum beneficial cardiovascular effects.

Building on existing human work conducted in our laboratory, this multidisciplinary study is designed to: 1) investigate the formation of flavanol-Maillard products during the processing of a common flavanol-rich food, namely cocoa; 2) determine the fate of these compounds in the human stomach, small intestine and large intestine; and 3) assess their ability to exert beneficial effects human cells. The first objective will inform us of the major flavanol-Maillard conjugates formed in the flavanol-rich foods during the processing, in this case heating of the cocoa beans during roasting. Although we will study cocoa, heat processing is relevant to many other flavanol rich-foods and therefore will have wider relevance. Secondly, we will examine the absorption of these conjugates, along with native flavanols by feeding processed cocoa to human and measuring them in blood. This will tell us whether heat processing reduces the absorption of native flavanols and also whether the flavanol-Maillard conjugates are absorbed by humans. We will also investigate their metabolism in the large intestine and whether they have a beneficial effect on the balance of the gut microflora, akin to changes seen with pre-biotic functional foods. Lastly, we will examine the beneficial effects of the conjugates in cellular models of human colon cancer and cardiovascular disease using state-of-the-art molecular techniques.

We predict that this proposal will help determine the optimum industrial processing conditions required to generate flavanol-rich foods capable of exerting the strongest cardiovascular protection. It will inform both industry and the consumer and will help us develop future strategies to maximise flavanols in our foods. The proposal will broaden understanding of the role that diet plays in the prevention of cardiovascular disease and will help provide evidence for new and promising dietary

strategies for tackling cardiovascular disease. The results of this study therefore have important implications for an ageing population where an improvement in healthy ageing is greatly desired. Moreover, the potential benefits in terms of quality of life are relevant to the population as a whole, as are the potential savings in health care costs.

Drivers of eating behaviour during chronic overconsumption

John Blundell

University of Leeds

£554,605.23

Number of PhD studentships awarded: 1

This project will investigate the drivers of eating behaviour that occur during a prolonged period of overconsumption (excess intake of calories). Overconsumption is important as a major cause of weight (re)gain and obesity.

The type of society which exists in many developed countries is said to represent an 'obesigenic' environment. This type of environment facilitates a high consumption of food (as well as encouraging sedentariness) and generates rapid weight gain that leads to obesity. The obesigenic environment 'offers' the possibility for people to overeat. People are able to eat too much of some foods because of excessive activation of hedonic (pleasure related) processes, or because of a defect in homeostatic processes. Firstly this means that people will eat more because of elevated sensations of pleasure during eating or heightened motivation to obtain a looked-for food. These (hedonic) processes are termed 'liking' & 'wanting'. Secondly, people will eat more because their physiological systems fail to shut off eating quickly (leading to large meals) or because food fails to suppress their hunger after eating. These last two processes are called 'satiation' and 'satiety'.

The pleasure of eating can be divided into two components /'liking' & 'wanting'. Although these terms often occur together, they are quite different. Sometimes we do not have a strong wanting for foods that we like a lot; at other times we have a strong wanting for foods that are not especially liked (e.g. potatoes/food staples). Importantly, we have developed procedures that measure both the liking & wanting of foods. It is not known if overconsumption results from an increase in liking for certain foods, or from an increase in wanting for those foods. We will identify the types of foods selected during a prolonged period of overeating and whether this is driven to a greater degree by increased liking or wanting.

At the same time it is important to be able to measure the actual changes in processes that control meal size (satiation) and which lead to the reduction of hunger after eating (satiety). We will identify which aspect of eating plays the major role in allowing overeating /a large meal size, or weak suppression of hunger. This will inform us how to use specific foods to control these two aspects of eating.

It is important to be able to relate changes in sensations and behaviour to underlying physiological processes. This means measuring chemicals in the blood that are known to be involved in appetite control. Some of these chemicals are thought to be involved mainly in hunger (ghrelin) or in satiety (GLP1, CCK) or in both hunger/satiety, liking & wanting (leptin). We will therefore assess the particular ways in which these signals influence overconsumption.

Generating overconsumption in the long term leads to a gain in weight which may never be lost again and could impair health. We have therefore developed a 'safe' model of overconsumption that has arisen from a BBSRC project just finished. When overweight and obese people volunteer for a 12 week programme of supervised daily exercise (of fixed energy expenditure) some individuals lose weight and others do not. However, independent of weight loss all volunteers show decreases in heart rate, blood pressure, and an increase in fitness (key to becoming healthy). The reason behind this variability in response is that the poor responders who do not lose weight have increased their food intake to negate the energy lost. This increase can be interpreted as overconsumption and amounts to ~290 kcal/day. In absence of exercise this would lead to a dramatic weight increase of more than 6kg over a year. Therefore we can use this 'safe' form of overconsumption to examine changes in underlying behavioural drivers /liking & wanting, satiation and satiety/ and their association with signalling peptides. This provides a relevant long term method for investigating the drivers of food behaviour.

Understanding decisions about portion size: The key to acceptable foods that reduce energy intake?

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| Jeffrey Brunstrom | University of Bristol | £389,486.70 |
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Number of PhD studentships awarded: 1

Researchers have long been interested in the prospect of developing enjoyable foods that are filling yet low in calories. In almost all studies the critical dependent measure has been 'amount eaten' or some other assessment of feelings of hunger and fullness after a particular test food has been consumed. The logic here is that the amount eaten is normally determined by psychological and physiological effects of eating that take place during and towards the end of a meal. This project will 1) challenge this fundamental assumption and 2) show how an understanding of portion-size decisions can help us to identify palatable foods that promote lower energy intake.

The first phase of this project will seek evidence that on occasions when we have control over meal size (which we suspect is very often), the most important determinant of food intake is the decision-making that underlies how much is chosen before a meal begins. In so doing, we aim to provide 1) evidence that 'traditional' methods are not best placed to develop foods that reduce energy intake, and 2) a justification for a new approach for asking questions about food characteristics and their effect on decisions about portion size.

After establishing the importance of portion-size decisions, phase two will explore the basis on which decisions about portion-sizes are made. Particular emphasis will be placed on modelling the relative importance of liking for the test foods and expectations about how filling they are, focusing on how these factors combine in the mind of a consumer. In so doing, we will be able to propose particular foods that may help to reduce energy intake, and we will deliver new methods that can be used to explore many other foods in future.

Finally, it is important to say that we are not proposing that physiological effects of eating play little or no role in influencing energy intake, merely that their role is secondary to portion-size

decisions during individual meals. In the longer term, physiological feedback of this kind could be very important. Indeed, we suspect that portion-size decisions are, in part, learned from previous experiences of the filling effects of different foods. The final phase (phase 3) of this project will test this proposition. This research will inform our understanding of the origin of portion-size decisions. This may explain changes that can occur in the acceptability and use of low-energy 'diet foods' after they become familiar to a consumer, and it will highlight ways of 'protecting' against a decrease in acceptability over time.

| Bioactive alginates and obesity | | |
|--|----------------------|-------------|
| Jeffrey Pearson | Newcastle University | £412,059.92 |
| Number of PhD studentships awarded: 2 | | |
| <p>Obesity is one of the fastest growing medical issues across the western world and it is fast becoming one of the leading causes of mortality worldwide. At least one in thirteen annual deaths in the European Union are likely to be related to overweight. That is 337,000 deaths/year and Britain leads the E.U. table of deaths related to excess body weight. Half the adults in the U.K. are overweight and around one in four is obese. Obesity increases the risk of high blood pressure, heart disease and late onset diabetes with an estimated cost to the economy of £2 Billion/year.</p> <p>In general, women have a greater body mass index (BMI) distribution and higher obesity rate compared to men. Obesity is a condition associated with poverty and a poor diet in both the developed and developing nations. It is therefore particularly important that if treatment/prevention is delivered via diet that the foods should be affordable and acceptable e.g. bread, the vehicle we intend to trial.</p> <p>Because eating is a pleasurable experience and humans tend to over eat if food is available in excess, in particular high energy foods which are often rich in fat. Reducing fat metabolism and uptake is one approach to reducing weight gain. Therefore chemically synthesised inhibitors of the fat digesting enzymes, lipases are currently being used to treat obesity. At present the major lipase inhibitor available on prescription in the U.K. is orlistat (Xenical) which will reduce fat absorption by up to 30%. However side effects such as oily stools, flatulence and diarrhoea have meant reduced acceptability. Interestingly these side effects can be significantly reduced if the lipase inhibitor is taken with a dietary fibre supplement. Therefore a good solution would be a dietary fibre with lipase inhibitory activity. Alginate, a natural fibre from seaweed has these properties.</p> <p>We have demonstrated in our lab that alginates have a similar ability to inhibit lipase as orlistat. We therefore aim to screen a bank of alginates (over 20), some of which are already used in the food industry at low levels and other naturally occurring biopolymers to determine the best lipase inhibitor profile using a lab based colorimetric assay. Using the best inhibitors we will demonstrate their ability to inhibit lipase activity in conditions as close as possible to those in the gut, i.e. with other food components etc.</p> | | |

The best candidate/s from the above studies will then be tested (delivered in bread in the first instance) in human volunteers. A group of healthy subjects will be used to determine acceptability of the biopolymer in the food vehicle and to determine the best balance between lipase inhibition and levels of biopolymer intake. Our preliminary studies showed no acceptability problems with alginate levels as high as 10% by weight in bread. Following the studies with the healthy subjects the biopolymer enriched foods will be tested to demonstrate calorific intake reduction in ileostomy patients.

This study has the potential to provide evidence that normal foods supplemented with fibre biopolymers can be used to treat obesity/overweight and allow this to be translated by the food industry into the development of a range of other tasty and affordable food products. Such a range would have the potential to reduce calorific intake, as well as include the health benefits of dietary fibre.

APPLICATIONS FUNDED THROUGH DRINC 2ND CALL AUGUST 2009

| Immunomodulatory effects of pre- and probiotics | | |
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| Parveen Yaqoob | University of Reading | £542,784.95 |
| Richard Aspinall | Cranfield University | £51,325.39 |
| Number of PhD studentships awarded: 1 | | |
| <p>The number of people aged 65 years and over is expected to rise by over 60% in the next 25 years, which presents an enormous challenge for the healthcare system. Elderly people suffer from more frequent and severe infections than younger people; influenza is particularly common in older individuals and is a major cause of death in the elderly population. Ageing dramatically affects immune function; as we age, the repertoire of cells potentially available to respond to a new pathogen shrinks and there is an accumulation of poorly functioning mature cells. This phenomenon is known as immunosenescence and partly explains the increased susceptibility for infection in older individual. Vaccination is recommended to protect the older people against influenza, but immunosenescence also reduces the efficacy of vaccination. It has been estimated that 30-50% of older adults fail to mount protective antibody responses after influenza vaccination, representing a considerable waste of resource and a false sense of security for those receiving the vaccinations.</p> <p>Probiotics are beneficial bacteria, which can be consumed and which have a long and safe record of use in humans. They have shown promise in the prevention or treatment of several disease states ranging from lactose intolerance, constipation and diarrhoea, alleviation of allergy and even to more chronic systemic diseases, such as cardiovascular disease and cancer. Often they are taken together with prebiotics, which are normally fermentable carbohydrates that provide a food source for the beneficial bacteria when they reach the lower gut. There is particular interest in the positive influences of pre- and probiotics in older people, who are subject to alteration in gut microflora composition as well as immunosenescence. Several studies have demonstrated beneficial effects of specific pre-</p> | | |

and probiotics on immune function in older subjects. However, none of these studies have taken into account the age-related shift in immune cell populations. Furthermore, there is little understanding of the mechanisms underlying these effects. Despite this, probiotics have recently been proposed as prime candidates for 'anti-immunosenesence' therapy. We propose to investigate the impact of a pre- and probiotic on immune function in young and older subjects, taking into account the age-related shifts in immunity due to immunosenescence. We aim to establish biomarkers and methodology which could be exploited to establish the underpinning science behind the immunomodulatory effects of commercial pre- and probiotics.

The project will involve 60 young (18-35y) and 60 older (65-85y) subjects, who will take a pre- and probiotic mixture or a placebo for a total of 8 weeks. The probiotic is not currently commercially produced, but has been demonstrated to have particular ecological fitness and anti-pathogenic effects in the gastrointestinal tract in old age. A suitable prebiotic will be selected on the basis of ability to promote optimal growth and survival of this probiotic. After 4 weeks on the treatment, the subjects will receive an influenza vaccination. Blood samples will be taken before treatment, and at 4, 6 and 8 weeks after commencement. The samples taken at 6 and 8 weeks will be used to assess the immune response to the vaccination. A wide range of immune parameters will be assessed, taking into account the age-related shifts in immune cell populations. In conjunction with the human study, a series of in vitro studies will investigate the mechanistic basis for the impact of the probiotic on immune function and will determine whether there are differential effects of the probiotic in young and older subjects at the cellular and molecular level. The overall aim of both components of the project is to determine whether older subjects derive specific additional benefit from pre- and probiotics by modulation of the impact of immunological ageing.

| Influence of prebiotics on human gut microbiota, LPS and markers of metabolic syndrome. | | |
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| Glenn Gibson | University of Reading | £586,984.97 |
| Number of PhD studentships awarded: 1 | | |
| <p>Obesity is fast becoming the greatest health challenge of the 21st century. Central to our ability to intervene in this situation is a clear understanding of the link between diet and obesity and the ability of industry to deliver food products capable of reducing risk. This project will lay down the scientific rationale linking the gut microbiota with obesity, and provide a rationale for using functional foods in the obese for improved health, targeted towards modulating the gut bacteria.</p> <p>Traditional risk factors for obesity and associated metabolic disorders are dietary, genetic and exercise linked. However, there is the contention that these cannot fully explain the explosive increase seen in recent years. This was given added significance in 2006 when the first reports appeared suggesting that gut bacterial profiles in obese and lean persons differed. It was hypothesised that the bacterial profiles variably affected calorie extraction rates from food</p> | | |

and that some of their metabolites could influence satiety. This is still an area of some debate (and it may be that the traditional risk factors themselves affect microflora profiles), however what is not in question is that the gut microbiota has a major role to play in human metabolism. This is because of the huge numbers that are present and their constant supply of nutrients (principally diet).

Should the gut microbiota differences be a factor in obese related conditions, then this opens up the possibility of altering the situation by using dietary ingredients that have a selective fermentation in situ. Prebiotics are functional foods ingredients that exert major composition and metabolic changes in the human gut microbiota. Together with probiotics, they are attracting much attention for their ability to improve gastrointestinal health. New products are constantly being developed, with the main remit being improved digestion and wellbeing. Research on modulating the gut flora has largely targeted gut infections including links into chronic disorders like IBS and ulcerative colitis. Given the recent link between gut microflora and obesity, it makes sense to research whether prebiotics can exert a modulatory role. In this project, these have been chosen over probiotics as they are more efficacious in exerting change in bacterial populations within the gut.

Our collaborative research in animal models has shown that LPS, a cell wall constituent of Gram -ve bacteria, can exert a metabolic endotoxaemia which is characteristic of diabetes in humans. Prebiotics target Gram+ve flora (principally bifidobacteria). Further studies in the murine showed that the toxic effects of LPS could be reversed by repressing Gram -ves at the expense of bifidobacteria.

Here, we aim to replicate these experiments in humans at risk of metabolic syndrome. We will use a proven prebiotic (BiMuno, a type of galactooligosaccharide GOS), that was originally developed in our laboratories and is now commercially available, to target bifidobacteria in a human feeding study. Prior to this, food quality expertise will be applied towards assessing the most appropriate dietary delivery vehicle that maintains functionality of the ingredient and has optimal sensory qualities. A placebo will also be trialled. The outcomes will be an in vivo assessment of the capacity to alter gut microbiota and concomitant effects upon validated markers of metabolic syndrome.

If the research is successful it will lead towards a dietary intervention product that positively affects the risks associated with obesity in a manner that changes the microflora influence. This would have much impact upon a major 21st century dietary problem and tally that with an extremely topical functional food approach. The outcome would also partly inform on the health attributes that can be expected from altering a person's gut microbiota and has relevance for both the probiotic and prebiotic industries.

The Role of Plant Cell Walls in Regulating Starch and Lipid Bioaccessibility from Plant Foods: In Silico, In Vitro and In Vivo Studies

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| Peter Ellis | King's College London | £394,663.44 |
| Keith Waldron | Institute of Food Research | £205,730.67 |

Number of PhD studentships awarded: 2

Most people commonly eat plant foods rich in starch, notably cereal products (e.g. bread, rice), and also some that are rich in fat (e.g. tree nuts). However, little is known about how such foods release starch and fat in the human gut and how, in turn, this may influence digestion and ultimately the absorption of nutrients into the body. Improving our understanding of these processes is important for basic scientists studying the behaviour of foods in the gut and their effects on metabolism. It is also important for health professionals and policy makers that are worried about excessive food consumption and the growing problem of obesity and associated problems of heart disease and diabetes. Moreover, the rate and extent of starch and fat digestion and absorption into the blood stream are important factors in altering the risk of heart disease.

The release of fat and starch from plant foods and the digestion and absorption of these nutrients by the body are highly complex processes. Our progress in understanding these processes is impeded by the hugely complex structure and properties of plant foods and individual nutrients. Our project proposal brings together a unique combination of world experts from different institutions and disciplines. These experts have formed a large team in order to improve our knowledge of how edible plants behave in the gut and how the gut reacts to the starch and fat available for digestion. For example, it is important to know about the rate at which nutrients are released from plant foods as they move along the gut, since this will affect the time course of digestion and absorption. This in turn will influence the way the nutrients are metabolised within the body.

We currently study almond nuts and cereals, e.g. wheat, to see how fat and starch are released from plant tissues. Starch, fat and other nutrients are found inside numerous cells that make up the plant tissue, e.g. an almond seed contains about 50 million cells. Such cells are very small in size, often with a diameter of less than about one tenth of a mm. One significant factor that seems to affect nutrient release from plant cells is the presence of cell walls, more commonly referred to in nutrition as 'dietary fibre'. How starch and fat are released from these cells is poorly understood. Initial studies will involve examining the role of cell walls as physical barriers in controlling the release and digestion of nutrients, using various methods to examine plant tissue at a cellular scale. One novel method will be the use of a recently established 'Dynamic Gastric Model', a computer-controlled simulation of digestion in the human stomach. We will also feed human volunteers with the same plant foods rich in fat and starch, to determine the effects of processing and mastication on nutrient release and digestion and the rate at which digested nutrients are transported into the blood stream.

Finally, we will also produce a mathematical description of how fat and starch are released from edible plant tissues during digestion. It is envisaged that in the future, the use of mathematics will allow research scientists to predict the behaviour of similar foods in the gut without having to do so many laboratory experiments.

This work will help the food industry to produce new food products or ingredients that have a controlled release of starch and fat in the gut, which could, for example, help to reduce the risk of heart disease. Indeed, Premier Foods, a large food manufacturer, has agreed to collaborate with us and provide scientific and technological expertise. Premier Foods has also agreed to provide cereals (e.g. wheat) and food products made with these cereals, all of which have been specially prepared to control starch release. These raw materials and food products will be used in our project to study how they behave in the gut and assess their potential benefits in reducing the risk of heart disease.

| Increased Propionate Production In The Colon Is Associated With Reduced Appetite, Body Weight And Improved Insulin Sensitivity | | |
|--|---|-------------|
| Gary Frost | Imperial College London | £550,840.25 |
| Douglas Morrison | Scottish Universities Environmental Research Centre | £133,871.61 |
| Catriona Tedford | University of West Scotland | £94,991.78 |
| Number of PhD studentships awarded: 2 | | |
| <p>Obesity is the greatest public health challenge facing most developed and many developing countries. Obesity is directly related to increased mortality, causing 600 premature deaths in the UK per week. In the current obesity epidemic, using therapeutic foodstuff to tackle obesity would be economically viable for industrial partners.</p> <p>Recent epidemiological and experimental studies link the decline in consumption of non digestible carbohydrates (NDC) to the rise in obesity. NDCs are not broken down in the small intestine, but can be fermented by bacteria in the colon, part of the large intestine. Previous studies and our own pilot data shows that increasing the NDC in the diet of animals and humans reduces appetite and body weight and increase insulin sensitivity. Unfortunately, the high doses required to produce these effects are unpalatable and result in side effects, limiting the use of NDC supplements as a treatment for obesity or diabetes. Short chain fatty acids (SCFA) are molecules produced by the fermentation of NDC in the colon and are responsible for the biological effects of NDC. Recently, a receptor has been found that binds SCFAs, and in particular the SCFA propionate. This receptor is found on cells in the large bowel where it stimulates the release of appetite-inhibiting hormones, and on fat cells where it acts to decrease the release of free fatty acids. Reducing free fatty acid levels within the body increases the sensitivity of the body to insulin and thus reduces the effect of insulin resistance which is present in type 2 diabetes.</p> | | |

Until now, controlling the production of propionate in the colon has been impossible. Both the type of NDC ingested and the gut microbiota of an individual dictate the levels and types of SCFA produced in the colon. Recently, we have developed a novel molecule in which propionate is bound to a carrier molecule. The chemical bond that links propionate to its carrier molecule cannot be broken down in most parts of the gut. However, in the colon, this chemical bond is broken by the bacteria present there, delivering specific amounts of propionate to the colon. We have shown that supplementing the diet of rats with this propionate carrier molecule reduces their body weight compared to controls, and that in humans it reduces hunger and food intake.

This study will determine the effect of 24 weeks diet supplementation with this propionate carrier molecule on appetite, body weight and insulin sensitivity in obese volunteers. We will test the hypothesis that supplementing the diet with propionate carrier molecule will reduce appetite through gut hormone release and improve insulin sensitivity by reducing the concentration of free fatty acids in circulation. Industry will have an important role in developing products which produce propionate in the colon to reduce appetite and improve insulin sensitivity. In collaboration with Leatherhead Food International we will design foods which can be used to supplement the diet of the general population with propionate carrier.

Demonstrating the link between colonic propionate production and appetite regulation has significant implications for public health given current trends in obesity rates. However, if colonic production of propionate increases satiety, then simply adding any NDC may not be sufficient to increase propionate production to a significant level to impact on satiety. This study will determine if colonic propionate leads to a reduction in appetite and body weight and cause beneficial metabolic change, and will demonstrate proof of principle for using NDC esters to deliver SCFAs to the large intestine. These data will therefore provide valuable information for future studies investigating the effects of SCFAs on appetite regulation and insulin sensitivity.

Industry will play an important role in developing products which produce propionate in the colon to reduce appetite and improve insulin sensitivity.

| Impact of non-digestible carbohydrates on biomarkers of GI health: a human intervention study | | |
|---|----------------------------|-------------|
| John Mathers | Newcastle University | £396,081.22 |
| Ian Johnson | Institute of Food Research | £147,950.71 |
| Number of PhD studentships awarded: 1 | | |
| <p>What we eat affects the health of all parts of the body including the gut. Symptoms, disorders and diseases of the large bowel are major causes of anxiety, visits to general practitioners and medical treatment. In particular, the large bowel is one of the commonest sites for cancer development. Large scale observational studies of dietary practices and associated incidence of cancer provide very strong evidence that dietary choices and nutritional status (e.g. obesity) influence risk of cancer in the large bowel (colorectal cancer; CRC). Such evidence is</p> | | |

very encouraging because it suggests that many cases of bowel cancer could be avoided by appropriate dietary choices and/or by the development of novel foods or dietary agents with anti-cancer properties.

Identification of beneficial dietary agents requires intervention studies i.e. carefully controlled experiments in which volunteers are given known amounts of the test agent. For both practical and ethical reasons, it is seldom appropriate to use the development of cancer as the endpoint in such experiments and there is a need to use surrogate outcome measures. This is analogous to using blood pressure or blood cholesterol concentration as surrogate outcome measures (or biomarkers) in studies of diet and heart disease risk. Unfortunately, in the area of diet and gut health, progress is hampered by the lack of robust biomarkers of CRC risk for use as surrogate endpoints. To address this gap, we have developed a number of novel biomarkers of diet-related CRC risk which can be measured in small samples (biopsies) taken during clinical examination of the large bowel. We have shown that these biomarkers can be detected BEFORE the development of CRC and so may be a useful tool to identify those at higher risk of the disease. In our on-going work, we are investigating relationships between what people eat (and other aspects of lifestyle) and these biomarkers in a cross-sectional study. The next logical step is to test how the most promising biomarkers respond to dietary intervention to determine how useful they will be as biomarkers of gut health.

We will do this by carrying out a carefully controlled experiment in which volunteers will be given food supplements of resistant starch (RS) and polydextrose (PD) - both are carbohydrates with special properties. They are widely used food ingredients for which there is already evidence that they may help reduce CRC risk. Both food agents show bioactivity in the large bowel where they appear to have beneficial effects on gut physiology and immune function including anti-inflammatory effects.

In our human intervention study, 70 healthy volunteers will be given RS and/or PD or another carbohydrate with no effects on the large bowel (a placebo) for 7 weeks. We will collect tiny pinch samples of the lining of the gut (mucosal biopsies) before and after the intervention for biomarker measurement. These biomarker studies will include measurement of genes which are known to be involved in the early stages of the development of cancer and which may be modifiable by changing diet. Dietary components such as RS and PD may influence how genes are switched on and off by affecting regulatory marks on DNA known as DNA methylation so we will quantify DNA methylation for a panel of key cancer-related genes. We will also measure the rates at which cells are being produced (cell proliferation) in the gut lining because faster cell proliferation appears to indicate higher CRC risk. In addition we will collect blood and stool for measurements of markers of inflammation. There is growing evidence that poor diet and obesity can lead to the development of a chronic inflammatory state and that this may predispose to CRC. Through their fermentation by bacteria in the large bowel, RS and PD may help reduce inflammation and so protect gut health.

| Effects of Fruit Juice Processing and Human Metabolism on the Functionality of Anthocyanins for Cardiovascular Health | | |
|---|----------------------------|-------------|
| Colin Kay | University of East Anglia | £290,952.70 |
| Paul Kroon | Institute of Food Research | £74,849.19 |
| Nigel Botting | University of St Andrews | £163,798.39 |
| Number of PhD studentships awarded: 1 | | |
| <p>People who consume the highest quantities of fruits and vegetables appear to be more protected against heart disease than those who consume lower quantities. Evidence suggests that this protective effect is in part the result of substances in the fruits and vegetables called polyphenols. In recent years, berries and berry derived juices and wines have been promoted as especially healthy foods as they are high in a particular class of polyphenol called anthocyanins. These anthocyanins are reported to have activities that benefit the heart and blood vessels.</p> <p>Cardiovascular diseases (CVD) and specifically stiffness of the arteries results from accumulated damage to blood vessel walls. There is a single layer of cells that lines the blood vessels which is sensitive to agents/compounds within the blood. When this layer is damaged as a result of injury or chronic disease, it loses its ability to maintain normal blood vessel function and becomes prone to processes that lead to heart disease. Anthocyanins and anthocyanin containing foods have been shown to have direct protective effects on this cell layer, thus restoring proper function to the blood vessels. However, the anthocyanins in the foods we eat often become altered during standard food processing and storage conditions, an effect that is believed to negatively alter their function relative to those in raw fruits or vegetables. As well, when we eat anthocyanins they become modified by our bodies, resulting in drastic changes to their original form. Previous experiments have used unaltered or original forms of anthocyanins to explore how these compounds affect the cells in our bodies and blood vessels. However, no studies have explored the true activity of anthocyanins as they exist within our bodies, as altered products in our circulatory system resulting from changes during processing and digestion. The effects of these alterations on the disease fighting properties of anthocyanins are currently unknown and could be greater, different or impartial to what we currently perceive.</p> <p>The aim of the present program of research is to identify the actions of pure anthocyanins relative to their altered products of processing and digestion on CVD risk. In order to determine their functions, we must first identify their forms in the body after we eat them. We will identify changes that occur to anthocyanins (cyanidin-3-glucoside, the most abundant anthocyanin in nature) in common fruit juices on the UK market, during standard processing and storage conditions. We will also feed human participants a pure anthocyanin (cyanidin-3-glucoside) in order to trace its path and alteration through the body. We will then study the</p> | | |

effects of the identified compounds on CVD risk by exploring their activities on the cells (cultured-cells) lining our blood vessels.

With this study we hope to prove the usefulness of anthocyanins as a dietary treatment for the prevention of cardiovascular disease, using the relevant compounds found in the body; thus providing informed advice on the health benefits of anthocyanins. The results of this study are also relevant to agricultural industries as levels of anthocyanins in food crops can be easily increased using breeding strategies and pre and post harvest manipulation. This project is particularly relevant to the processed food and beverage industry, as although the alteration of anthocyanins during food processing has generally been considered of negative consequence, the proposed research could establish this as a neutral or potentially beneficial outcome; providing valuable evidence to support the use of fruit juices for the delivery of beneficial components for health. This proposal will also generate findings that may be useful for future studies aimed at investigating the relative activity of other dietary polyphenols, such as those found in coffee, tea, wine or chocolate.

| Maximising satiety through manipulating expectations, sensory quality and nutrient content | | |
|---|----------------------|-------------|
| Martin Yeomans | University of Sussex | £539,704.80 |
| Number of PhD studentships awarded: 1 | | |
| <p>Understanding the processes which promote satiety and so decrease the risk of overeating and a consequent positive energy balance are critical to our future ability to counteract the worldwide rise in the incidence of obesity. The traditional view of satiety is that suppression of appetite after eating arises from physiological effects of the ingested nutrients. However, while it is clear that nutrients do generate satiety signals, there are many aspects of satiety that cannot be explained simply as an effect of nutrient ingestion. For example, nutrients ingested as beverages generate weak satiety, whereas nutrients in a different liquid context (soup) generate strong satiety. This implies that something about the context in which nutrients are consumed is critical to the subsequent experience of fullness. Taking a more cognitive view, this research considers the extent to which consumer expectations about how filling a food will be may modify satiety. Thus a beverage may be consumed on the expectation of reduced thirst but not satiety, thereby leading to a failure to attribute physiological satiety cues generated by the drink nutrients to the actual drink product. Conversely, if the expectation is that a food will lead to strong feelings of fullness, this may lead to greater suppression of appetite than that generated by the same nutrients in the absence of expectations. Preliminary data in our laboratory are consistent with this view: protein was more effective in suppressing appetite when consumed in a context which was consistent with satiety than on its own. This research builds on this finding in a 3-phase programme designed to test the principle that expectations interact with physiological cues to modify satiety and so direct consumer behaviour. To achieve this, in Phase 1 we explore for the first time how expectations generated by label information and sensory quality modify the</p> | | |

satiating effects of protein both in a snack and breakfast context. These experiments will first identify effective expectation manipulations and then examine their impact on satiety both when a product is first encountered and after repeat consumption. To ensure the outcome is both consistent and relevant to real-life behaviour, separate studies will use more controlled laboratory tests of eating and more naturalistic studies in a quasi-restaurant setting. The outcome of this 2-year Phase will be a clear test of the concept that expectations may interact with post-ingestive cues to generate satiety. How these expectations may modify actual physiological satiety responses will be tested in Phase 2, which examines how expectation-nutrient interactions modify the release of satiety hormones. As with Phase 1, these effects will be tested both acutely, and as a function of learning about the product as a consequence of repeated consumption. Finally, Phase 3 explores the utility of these findings for food product development by examining the effects of extended home consumption of products designed to generate maximum satiety through combinations of expectation and nutrient content. Separate home consumer trials will be run with the snack and breakfast products developed in Phase 1 and 2, and outcome measures will include effects of consuming high-satiety products on overall energy intake, and consumer evaluations of the products in terms of acceptability and future purchase intentions. The overall outcome of the programme will be both a detailed evaluation of the interaction between consumer expectations and physiological controls of satiety for the first time, and the use of such interactions to formulate new design rules for the development of future food products that generate consumer-perceivable satiety benefits.

APPLICATIONS FUNDED THROUGH DRINC 3RD CALL SEPTEMBER 2010

| Mining diversity in cereal (wheat) fibre to improve the nutritional quality of bread | | |
|---|----------------------------|-------------|
| Peter Fryer | University of Birmingham | £312,621.06 |
| Clare Mills | Institute of Food Research | £213,435.78 |
| Peter Shewry | Rothamsted Research | £86,139.40 |
| <p>Wheat is the major food crop grown in the UK. A substantial proportion is used for human consumption, making it an important source of calories, protein, minerals, vitamins and dietary fibre in the human diet. Consumption of fibre is linked to decreased risk of cardiovascular diseases, certain types of cancer, (such as colon and breast) and type-2-diabetes. Cereal-based foods, in particular bread, are a staple in the UK diet and represent one of the major sources of carbohydrate. Whilst there have been drives to increase consumption of wholegrain and wholemeal products, many consumers still prefer the texture and appearance of white bread. Manufacturers are addressing this through processing, using novel fibre-derived ingredients and white wheats to give breads supplemented with bran the appearance of white loaves. However, the value of doing this nutritionally has yet to be demonstrated for each product.</p> <p>White bread is an important UK foodstuff, but being a starchy food which is rapidly broken down to glucose it has a high glycaemic index (GI). Wholemeal bread contains a higher level</p> | | |

of dietary fibre, which is considered to be healthier, but forms only a small fraction of the bread eaten in the UK. Dietary fibre contains two components; soluble and insoluble, with the major soluble component in wheat being a fraction known as arabinoxylans (AX), which make up ~70% of wheat endosperm cell wall polymers. The mechanism by which fibre acts is not clear - although there is evidence that its effect is to change the viscosity of the material in the stomach and gut, slowing absorption of nutrient into the body.

The aim of this grant is to identify the mechanism for the effect of fibre by studying the effect of changing AX structure and solubility. We will first grow (at Rothamsted) four wheat lines which have been shown in previous Rothamsted and IFR collaborative work to have very different AX contents. These will be milled into flour and made into loaves using standard methods at Campden BRI, the UK centre for baking. Grains, flour and breads will be studied to find out what happens to the AX during the breadmaking process, using novel methods developed at IFR and Rothamsted. In addition, we will develop and unify existing equipment at IFR and Birmingham; a model stomach at IFR and a model gut at Birmingham, into a form where it can be used to simulate gastric and duodenal digestion, and study how the cell wall components behave through simulated digestion processes. Using these methods we will be able to identify and explain the effects of AX, and then design breads which have a healthier human response.

Outcomes will thus be (i) understanding of some of the ways to make white bread more healthy, as well as (ii) a validated model for digestion, and (iii) understanding the role of AX in dietary fibre. This understanding can be used in the validation of health claims as well as in the developments of new grains, processes and products and the model digestion systems will help the food industry to explore new healthier food formulations in a more cost-effective manner.

| Can bioactive compounds from the diet prevent the onset or slow the progression of osteoarthritis? | | |
|--|---------------------------|-------------|
| Ian Clark | University of East Anglia | £525,124.91 |
| <p>Osteoarthritis is a disabling joint disease where the cartilage is destroyed leading to pain and immobility. There is a lack of medicines to treat osteoarthritis, and since the elderly population are more likely to have severe osteoarthritis, this will be an increasing problem.</p> <p>Despite many years of research, there are no drugs available which can slow or stop the progression of osteoarthritis. In part, this is due to the fact that drugs for use in any disease which is not life threatening must be very safe (i.e. have few side effects). Also, the costs of running clinical trials in osteoarthritis are prohibitive. There is a need to develop new strategies to combat this disease.</p> <p>The connection between diet and osteoarthritis has been explored to some extent. The high intake of some foodstuffs has been linked a slower progression of the disease. These</p> | | |

analyses are imperfect since diet is recorded via a retrospective questionnaire across a long time period. Nevertheless, they prove the concept that diet can influence joint health.

There are many compounds found in food which have biological activities. To date, we have focused on two compounds: sulforaphane which is found at high amounts in broccoli and other related vegetables; diallyl disulphide which is found at high amounts in garlic. Both of these compounds have been investigated for activity in other diseases e.g. heart disease and cancer, but have not been looked at in terms of arthritis.

We have added sulforaphane and diallyl disulphide to our laboratory models of the cartilage destruction that is a key facet of osteoarthritis. We have shown that they are effective in slowing or preventing cartilage destruction in these. We have also added these compounds to human cartilage taken from patients with osteoarthritis and maintained in the laboratory and shown that they slow destruction.

The objectives of this study are therefore: to refine and improve our work to identify which foods are associated with protection from osteoarthritis; to continue to identify the components of these foods which will prevent or slow cartilage destruction; to test these compounds in a variety of laboratory models using cells or tissues from patients with osteoarthritis; to undertake studies in man to find out whether these compounds get into the joint and/or cartilage tissue in appropriate amounts to slow cartilage destruction.

These studies are essential ahead of a full-scale clinical trial in human osteoarthritis and represent an exciting possibility in the prevention and treatment of this disabling disease.

| The collective bioactivity of dietary flavonoids: importance of specific structural characteristics for cardiovascular benefits | | |
|--|---------------------------|-------------|
| Colin Kay | University of East Anglia | £357,230.30 |
| Nigel Botting | University of St. Andrews | £95,558.80 |
| <p>A high intake of fruits and vegetables reduces heart disease risk, but the components of the fruits and vegetables that provide these protective effects remains unclear. Growing evidence supports a role of fruit and vegetable components called flavonoids and research shows that people who consume high intakes of flavonoid-rich foods have improved cardiovascular health. In particular, research shows that some flavonoids and flavonoid-rich foods exert direct protective effects on blood vessel walls, and since cardiovascular diseases (CVD) and specifically stiffness of the arteries results from accumulated damage to blood vessel walls, these data suggest that flavonoids can help restore and optimise vessel function; therefore reducing CVD risk.</p> <p>When researchers measure the amount of any one type of flavonoid in the blood after we eat flavonoid-rich foods, their levels are too low to explain the observed cardiovascular benefit. Therefore, it is likely that the health benefits of flavonoid consumption results from the</p> | | |

collective effects of consuming multiple types of flavonoids at the same time. We therefore believe that the health benefits resulting from flavonoid consumption must be the result of many different types of flavonoids working together, as happens when we eat them in our normal diet.

Complex combinations of flavonoids are found in our blood and vessels as a result of the consumption of a diversity of flavonoid-rich foods, such as fruits, vegetables, chocolate, juice, wine, and tea. However, although we know that flavonoids are consumed as mixtures of compounds, to date, researchers have studied their impacts in isolation and using levels of flavonoids that are well above that which could be obtained through eating a normal diet. These existing findings are therefore likely to be inaccurate, making it difficult to use these findings to provide dietary advice for the health benefits of flavonoid consumption.

We plan to study the cardiovascular benefits of consuming multiple flavonoids as would be consumed in the normal UK diet to provide more accurate data which could be used in the future to provide advice on the true health benefits of flavonoid consumption.

Aims and objectives:

We aim to use an advanced cell culture model involving both vascular and immune cells to establish if the beneficial effects of flavonoids on cardiovascular health are the result of many types of flavonoid working together. We will also apply flavonoids and their metabolites in both isolation and in combination to provide a more biologically realistic model.

These studies will explore the activities of the flavonoids found in the highest abundance in the present UK diet as established using survey data from the National Diet and Nutrition Survey. As this survey established the current UK consumption of fruits and vegetables to be around 3 portions per day on average (and 2 portions below recommended intake levels), we will test the effects of consuming doses relative to 3, 5 and 7 servings of fruits and vegetables per day.

Implications:

This proposal promotes a nutritional strategy to improve cardiovascular health using a 'natural' dietary approach, involving flavonoids from multiple food sources which hold strong industrial, agricultural and public relevance.

This project will provide evidence of the health impact of our current dietary consumption of flavonoid-rich foods, in relation to reaching optimal levels of 5-a-day and above; and will aid in the design of future feeding interventions directed at addressing dietary change in the UK for health benefit. This project will also provide 'proof of concept' for the design of future flavonoid intervention trials by establishing optimal cardiovascular endpoints, flavonoids and doses. Lastly, establishing a shared and cumulative bioactivity of a number of flavonoids will aid in establishing future functional health claims for many products high in flavonoids.

Enhancing the consumer perception of reduced fat foods through interfacial design and rheological behaviour

| | | |
|-------------|----------------------------|-------------|
| Peter Wilde | Institute of Food Research | £269,452.17 |
| Paul Clegg | University of Edinburgh | £209,971.06 |

We aim to develop a strategy to disguise the (low) fat content in certain food types by changing the way emulsified fats are perceived by the senses. By this route we hope to improve the consumer acceptability of healthier, reduced fat foods. Many foods contain small dispersed droplets of oil, known as emulsions to impart desirable tastes and textures. These foods, include milk, cream, yoghurts, mayonnaise, soups, sauces etc, and are estimated to form around 25% of our dietary fat intake. We aim to change the sensory perception of fat content in emulsions by controlling the outer stabilising layer of the oil droplets. We will make model foods that will be imaged in 3 dimensions whilst flowing, under conditions similar to those in the mouth, so that we can understand the fundamental processes involved. The results will be correlated with sensory perception and acceptability of these foods in human volunteers.

Obesity is a major challenge facing the health of the UK population and costs the NHS an estimated £2b each year which is forecast to rise. This is blamed on a combination of diet and lifestyle. We habitually consume slightly more energy than we require, building up reserves in case of times of food shortage. This leads to a steady increase in our body mass index (BMI) with age, so that the 55-65 age range has the highest obesity rates. Small reductions in energy intake over long periods could therefore significantly reduce obesity levels. The sensory perception of fat in food emulsions is complex; thus many low fat foods are less acceptable to consumers. Improving the acceptability of these foods could help to reduce the small energy excess responsible for long term weight gain.

Fat has to be emulsified into small droplets (emulsion) to keep it evenly distributed within the food. Ingredients such as proteins and other emulsifiers form a layer on the emulsion droplets to stabilise them and prevent separation. This layer affects the way the droplets interact with each other and the rest of the food, which in turn affects how we sense them in the mouth. We have shown previously that emulsions stabilised by proteins have an increased sensory perception of fat content, compared to other types of emulsifier. In more controlled experiments, we have also shown that the protein-coated droplets can increase the viscosity of the whole emulsion. We think this is because proteins form a stronger, solid layer on the emulsion droplets, whereas emulsifiers form a fluid-like layer.

Our aim is to determine how the layer on the emulsion droplets enhances the sensory perception of fat content in emulsified foods. Our key objectives are:-

- Develop emulsion systems that form surface layers with a wide range of strengths using proteins, emulsifiers, particles and processing methods.
- Understand the complex viscosity and flow behaviour using high speed confocal (3-D) imaging under shear flow.

- Design model food emulsions stabilised by these surface layers with enhanced viscosity.
- Measure the sensory perception of fat content of these model foods
- Determine consumer preference of new model foods compared to existing reduced fat foods.

The Institute of Food Research (IFR) will develop and design a range of well controlled emulsions with defined surface properties.

Leatherhead Food Research will determine the sensory and consumer response to these foods.

The University of Edinburgh will use state of the art confocal imaging techniques to visualise in 3-D how the emulsion droplets are behaving under flow conditions similar to those found in the mouth.

This will give more precise understanding of the mechanisms involved that will make it possible in the future to design reduced fat foods with better consumer preference. This should increase the uptake of healthier, reduced fat foods and thus help to address long term weight gain.

Dietary polyphenols as modulators of redox signalling pathways to reduce chronic inflammation in the elderly

| | | |
|-----------------|-------------------------|-------------|
| Malcolm Jackson | University of Liverpool | £441,015.10 |
|-----------------|-------------------------|-------------|

A great deal of evidence indicates that consumption of diets rich in fruit and vegetables helps maintain health by protecting against age-related disorders including some cancers and cardiovascular diseases. Numerous studies have been undertaken to try and understand the mechanisms by which these diets exert beneficial effects on health. Many previous studies identified the potentially protective components of fruit and vegetables as "antioxidants" that were thought to prevent a generalised unwanted oxidation of cells and tissues that increased with ageing. However, despite extensive studies, formal trials have shown no beneficial effect of "antioxidants" when they are given as supplements. In recent years it has also become recognised that oxidation processes, mediated by highly reactive free radicals, are not necessarily deleterious to cells, but may be very localised within sub-cellular compartments of cells and that they normally regulate intracellular signalling processes and mediate many key physiological effects. Thus the original idea that "antioxidants" in the diet act to scavenge all oxidants in cells and tissues and therefore produce benefit has been questioned.

During ageing there is a breakdown of highly regulated cell signalling pathways due to changes in oxidation in very specific parts of cells and this leads to the production of deleterious substances that promote inflammation and which increase the susceptibility of the elderly to many chronic disorders. It is clear from internationally-based studies of diets

consumed by healthier elderly populations that a group of compounds found in fruit and vegetables, called polyphenols are beneficial against many age-related disorders, but we currently do not understand how they act to produce these health benefits. Polyphenols were originally thought to have beneficial effects because they are "antioxidants" and our hypothesis is that they are protective against chronic age-related disorders by targeting specific parts of the cell to prevent oxidation of key components of the beneficial intracellular signalling pathways.

New developments in analytical techniques now permit analysis of the potential effects of dietary polyphenols on local oxidation and cell signalling processes at key sub-cellular sites and the proposed study will utilise these new techniques. As part of the study, we will develop a cell culture-based test to identify which specific dietary polyphenols can exert beneficial effects, and undertake studies with groups of elderly subjects to determine whether any polyphenols identified as beneficial in the cell culture test can reduce markers of inflammation.

Thus the project will potentially lead:

- 1) to identification of those dietary polyphenols that act to minimise the pro-inflammatory state in the elderly and therefore provide a basis for the food industry to make logical and justified cases to the public for consumption of specific foods.
- 2) to identification of polyphenols that act to minimise the pro-inflammatory state and which may provide the basis for novel formulations of polyphenol-enriched food products that could be targeted at maintenance and improvement of health in the elderly.
- 3) to provision, in the longer term, of the underpinning data that leads to a diet-based improvement in immune function and a delay in the onset of frailty in the elderly.

| Dendritic cell subsets in the maintenance of gut health and response to bioactives | | |
|--|----------------------|-------------|
| Fiona Powrie | University of Oxford | £385,838.68 |
| <p>In order to maintain human health, it is vital that harmful pathogens that enter the body (such as bacteria and viruses) are quickly eliminated by the immune system. However, immune responses must be carefully controlled so that they are only activated at an appropriate time. If this tight regulation is disrupted, the immune system can potentially attack and damage the organs and tissue of the body, resulting in so-called 'autoimmune disease'. Similarly, allergies can result if the immune system is activated in response to normally harmless substances, such as metal in jewellery or food substances.</p> <p>A particularly critical area of the body for immune regulation is the intestine. The intestine is lined with trillions of bacteria which are important in maintaining normal health, but could potentially trigger an immune response causing inflammatory bowel disease. Similarly, as food substances pass through the intestine, they could also potentially trigger immune</p> | | |

activation in the absence of tight control, resulting in food allergy. Therefore, understanding the cells and molecules that control activation of the immune system is paramount if we are going to understand how our immune system functions to maintain normal health.

In the food industry, there is great interest in the design of foodstuffs that can actively promote human health (so called 'bioactives'), especially in the gut. For example, many dairy products and drinks contain so-called 'probiotics', which are live bacteria intended to enhance gut health. However, the mechanisms by which bioactives enhance gut health are ill defined, and often there is mistrust from the public in manufacturer's claims that their products will improve health. Therefore, it is essential to understand how bioactives affect the biology of the gut to promote health, to provide important read-outs that can be used to scientifically assess existing and novel bioactives. The only way that enhancement of gut health will be achieved is by increasing our basic understanding of the cells and molecules that maintain and promote normal gut health. As immune regulation is critical in maintaining a healthy gut, understanding how immune responses in the intestine are regulated will be critical in identifying potentially beneficial effects of bioactives.

An important cell type involved in regulating all immune responses is the dendritic cell (DC). Our laboratories have recently shown, using mouse models, that important subsets of DC present in the intestine are critical in maintenance of gut health. These DC subsets are characterised by the expression of different proteins on their surface, called CD103 and integrin alpha v beta 8, and by their ability to produce important molecules called TGF-beta and retinoic acid. The DC promote immune regulation by inducing an immune cell type called 'regulatory T-cells', which are important cells in preventing harmful immune reactions.

To build on our mouse studies, it is now critical to identify the role of these specialised DCs in human gut health. Our proposal will characterise these specialised DCs, in terms of the protein markers and molecules they express and how they function in healthy humans. We will go on to identify how known bioactives affect the biology of these DC subsets. This work will therefore identify important cells and pathways that are central to the maintenance of gut health, provide novel data on the how known bioactives work, and identify read-outs by which novel bioactive food substances can be scientifically evaluated for potential beneficial effects on the gut.

| Reducing saturated fatty acids in the food chain through alteration of milk fat composition | | |
|--|-----------------------|-------------|
| Ian Givens | University of Reading | £292,718.67 |
| The UK considerably exceeds its target for saturated fats in the diet, and milk and milk products are the single largest source contributing about 30-40% of the total with cheese and butter contributing most. There is however evidence that there are likely to be benefits in terms of reduced vascular disease and some cancers from increased milk consumption although the evidence for cheese, butter and cream is lacking. Thus simply reducing consumption of milk to reduce saturated fat consumption is likely to be counterproductive. | | |

Studies with humans where blood cholesterol has been measured suggest that replacing a proportion of the saturated fat in milk/milk products with mono or polyunsaturated fats does improve their health value. Also there is now good evidence that changing the diet of the dairy cows can lead to milk being produced with reduced saturates and increased monounsaturates although a consequence is often a small increase in trans fats. These trans fats are different to those produced by industrial processes and are not likely to be as harmful to health. Such changes to the diet of the dairy cow may also have another positive effect as they are likely to reduce the amount of methane (a potent greenhouse gas) produced by the cow thus reducing the carbon footprint of the milk. This project will examine the potential of approaches to reduce saturated fats in milk in on-farm production, in research aimed at reducing saturates further whilst minimising trans fat and methane production and will also study the health benefits of such foods in humans using new methods of assessing risk of cardiovascular disease. The project will be organised into three workpackages (WP):

WP1 will study the changes in the various types of fat in milk when cows on a selection of commercial dairy farms are fed oilseeds in their diets scientifically proven to reduce saturates. Most work to date has been only in research centres and it is important to understand what happens in a commercial situation with many different factors (e.g. cow breed, background diet etc)

WP2 will examine new approaches to the production of milk with reduced saturated fat and whilst minimising the amount of trans fat in the milk and methane produced by the cow. Trans fats are produced by bacteria in the digestive tract of the cow by changing the make up of fats in the cow's diet. Methods to 'protect' these fats from bacterial action will be studied. Bacteria in the digestive tract are also responsible for the methane produced.

WP3 will compile all the results and findings and will prepare a structured plan to disseminate the findings.

The overall aim is to reduce the amount of saturated fat in the UK food chain. There is potential to reduce this by some 90,000 tonnes/year if the work led to widespread application. Also of note is the fact that the changes to the diet of the cow proposed are likely to have significant environmental benefits, mainly through a reduction in the amount of methane produced by the cow.

Unravelling the mechanisms of vascular protection by omega-3 PUFAs to optimise and support their use as bioactives by the food industry

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| Caroline Wheeler-Jones | Royal Veterinary College | £536,126.34 |
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We know that diet plays a significant part in the risk of developing atherosclerosis and other blood vessel diseases. There is evidence that a fat found in fish oil and some plant oils, omega-3 polyunsaturated fatty acids (PUFA), reduces deaths from cardiovascular disease (CVD), and omega-3 PUFA are widely advertised and marketed as bioactives in food and health supplements. The food industry can only make accurate health claims about a product

if they are based on good scientific understanding of its actions, but the reasons why omega-3 PUFA are beneficial are not defined. This project will address the urgent need for a better understanding of precisely how omega-3 PUFA protect arteries against the detrimental processes that damage vascular health. Many types of CVD begin when the layer of cells lining the arteries (endothelial cells; ECs) start to function abnormally. This causes white blood cells (monocytes) to enter the artery wall and turn into macrophages, which take up huge quantities of fat and eventually form fatty deposits in the artery wall. Thus, ECs and monocytes play crucial roles in determining the overall health of blood vessels and in CVD development. Fats from foods we consume are carried in the blood in microscopic particles known as chylomicron remnants (CMR). We have shown that fats from food can dramatically alter the functions of ECs, monocytes and macrophages during their transport in CMR and that this increases their ability to release factors which cause inflammation of the vessel wall, and their fat uptake, thus promoting the initiation of vascular damage. The overall aim of this project is to investigate the new idea that omega-3 PUFA protect against vascular dysfunction by modifying the interactions of CMR with these cell types, focusing particularly on ECs and monocytes since their impaired behaviour and interaction occurs earliest in the disease process. We hypothesise that omega-3 PUFA carried in CMR: reduce detrimental events inside the cells which promote the expression and release of molecules that cause inflammation and endothelial dysfunction; and activate protective intracellular events to increase the expression and release of molecules that limit these processes.

To test these hypotheses we will use omega-3 PUFA from fish and vegetarian sources and human ECs and monocytes. We have established a method for making artificial CMRs that mimic exactly the effects of those that circulate in the blood stream. This enables us to incorporate omega-3 PUFA into the particles at different concentrations and to examine their specific effects on cultured human cells in comparison to other fats. To link these studies in our model systems with what happens in humans, we will also use CMR obtained from the blood of healthy volunteers given meals containing omega-3 PUFA or other fats. Alongside these studies we will use new techniques that allow us to examine in precise detail an enormous number of genes so that we can discover exactly which genes are altered by omega-3 PUFA, and how these differ from those changed by damaging fats. Current advice from the Scientific Advisory Committee on Nutrition to the general public is to increase the consumption of omega-3 PUFA, and as a result there is now considerable and growing interest from the food industry, and they are already being incorporated into common foodstuffs (eg. infant foods and margarines), and are promoted as health food supplements in capsule form. It is therefore essential for health professionals and the food industry, that the reasons why omega-3 PUFA help to preserve vascular health are properly understood. Our studies will provide comprehensive scientific information about how omega-3 PUFA protect against impaired vascular health when they are carried in CMR. Our mechanistic study will provide further support for, and underpin the endeavours of the food industry to develop healthy foods and accurately promote their health benefits.

Ergocalciferol (D2) vs. Cholecalciferol (D3) Food Fortification: Comparative Efficiency in Raising 25OHD Status & Mechanisms of Action (D2-D3 Study)

Susan Lanham-New

University of Surrey

£516,823.20

Vitamin D is the term used to describe two molecules, ergocalciferol (vitamin D2) and cholecalciferol (vitamin D3). The first of these is derived by ultra-violet irradiation of the ergosterol that is widely distributed in plants and other fungi whereas cholecalciferol is formed from the action of ultra-violet irradiation on the skin. Poor vitamin D status is a very common problem in the UK. This has important health consequences (such as muscle/bone function, increasing the risk of diabetes). We urgently need to find ways of improving vitamin D intake that are acceptable as a public health strategy.

Research that has just been completed by our group at the University of Surrey (Food Standards Agency funding; Project No. NO5064; £0.5M) has shown that (1) dietary intake of vitamin D is too low to have any effect on vitamin D status as there are too few foods providing a valuable natural source; (2) South Asian women are extremely vitamin D deficient; (3) Caucasians have extensive vitamin D insufficiency. There is evidence in the literature of differences in key polymorphisms of important genes that are critical to vitamin D metabolism in Asian Indian vs. Caucasians as well as differences in key vitamin D metabolism enzymes. This requires a fuller investigation since there are differences in the availability of vitamin D2 and vitamin D3 and hence public health advice on increasing vitamin D intake (particularly with respect to the development of vitamin D rich food products) needs to confirm that either form of vitamin D is effective. Furthermore, the South Asian community are vegan/strict vegetarians (~26%) and hence the source of vitamin D3 is a problem in this group due to being derived from animals (vitamin D3 supplements come from Lanolin, which is extracted from sheep's wool.) There is currently controversy as to the effectiveness of vitamin D2 vs. D3 in raising 25OHD levels in humans. It has been assumed, largely on the strength of evidence from studies in the 1930s, that D2 and D3 were equally effective in humans but some studies show that D3 is superior to D2 in raising 25OHD levels whereas the most recently published data suggests that D2 and D3 are equally effective. This requires urgent attention.

The proposed study will enable a better understanding of how comparable the two forms of vitamin D (ergocalciferol [D2] vs. cholecalciferol [D3]) are at raising vitamin D status in Caucasians and Asians and investigate the mechanisms of action with respect to any differences observed between the two vitamin D forms or between ethnic groups. Mechanisms of action will focus on genetic differences as well as differences in vitamin D metabolizing enzymes.

Using a team of scientists with different expertise, our principal objectives are to: (i) compare the efficiency of 10mcg/d [400IU/d] of ergocalciferol (Vitamin D2) vs. cholecalciferol (Vitamin D3) fortification of food products in raising 25OHD levels in Asian/Caucasian women; (ii) determine which vehicle for fortification (i.e. a SOLID vs. FLUID food) with ergocalciferol (Vitamin D2) vs. cholecalciferol (Vitamin D3) is more effective in raising 25OHD levels,

independent of ethnicity; (iii) investigate if 10mcg/d [400IU/d] is effective in raising wintertime 25OHD levels above 'deficiency/insufficiency' thresholds (25nmol/l and 40nmol/l respectively) in Caucasian and Asian women and whether there are any differences in ergocalciferol v. cholecalciferol fortification, independent of ethnicity; iv) investigate the mechanisms (genetic/enzymatic) for the differences observed in (i), (ii) & (iii).

ANNEX 3: WORKING GROUP MEMBERSHIP

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| 1. Chair | David Gregory , BBSRC Council |
| 2. Industry member of DRINC Steering Group | Mark Fowler , Nestl |
| 3. Industry member of DRINC Steering Group | Steven Walker , Campden BRI |
| 4. Industry member of DRINC Steering Group | Henglong Hu , GSK |
| 5. Industry member not on DRINC Steering Group | Yvonne Finnegan , Kraft |
| 6. Industry not involved in DRINC | Paul Molyneux , Premier Foods |
| 7. Industry not involved in DRINC | Stephen Parry , Findus Group |
| 8. Academic member of DRINC Steering Group | Clare Mills , Institute of Food Research |
| 9. Academic, DRINC Grantholder | Jeffrey Brunstrom , University of Bristol |
| 10. Academic, DRINC Grantholder | Colin Kay , University of East Anglia |
| 11. Academic, BBSRC/EPSRC/MRC research scientist not receiving DRINC funds | Susan Jebb , The MRC Human Nutrition Research (HNR) |

Funder representatives

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| Andy Cureton | BBSRC |
| Sharon Fortune | BBSRC |
| Karen Finney | MRC |
| Martin Sweet | EPSRC |
| Helen Kuhlman | Technology Strategy Board |

ANNEX 4: PAPERS PUBLISHED OR IN PRESS IN JOURNALS:

1st round projects:

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| <p>Prof. John Blundell</p> <p>Drivers of eating behaviour during chronic overconsumption: Role of food hedonics (liking and wanting) and peptide biomarkers on satiation and satiety</p> | <p>Publications or in press in:</p> <p>Appetite British Journal of Nutrition British Journal of Sports Medicine Current Opinion in Clinical Nutrition Handbook of Diet and Behaviour Handbook of Food Addiction International Journal of Behavioural Nutrition and Physical Activity Journal of Addiction Journal of Obesity Proceedings of the Nutrition Society Sports medicine</p> |
| <p>Dr Jeff Brunstrom, University of Bristol</p> <p>Understanding decisions about portion size: The key to acceptable foods that reduce energy intake?</p> | <ol style="list-style-type: none"> 1. Fay et al. (2011) What determines real-world meal size? Evidence for pre-meal planning. <i>Appetite</i>, 56, 284-289 2. Brunstrom et al. (2011) 'Expected satiety' changes hunger and fullness in the inter-meal interval. <i>Appetite</i>, 56, 310-315 3. Brunstrom JM. (2011) The control of meal size in human subjects: a role for expected satiety, expected satiation and pre-meal planning. <i>Proc Nutr Soc.</i>, 28, 1-7 4. Brunstrom, J.M., Collingwood, J., & Rogers, P.J. (2010). Perceived volume, expected satiation, and the energy content of self-selected meals. <i>Appetite</i>, 55, 25-29. 5. Wilkinson et al. Sensory specific satiety is anticipated during meal planning. (submitted) |
| <p>Prof. Ian Norton, University of Birmingham</p> <p>Self structuring foods with slow burn for control of satiety</p> | <ol style="list-style-type: none"> 1. A.B Norton, P.W Cox and F. Spyropoulos. Acid gelation of low acyl gellan gum relevant to self-structuring in the human stomach, <i>Food Hydrocolloids</i> (submitted). 2. J.F. Bradbeer, E.A.K. Heuer, A.B. Norton, F. Spyropoulos, P.W. Cox, I.T. Norton. A microstructure engineering approach to control the acid gelation kinetics of acid-sensitive hydrocolloid systems, (in preparation). |
| <p>Dr Roger Parker, Institute of Food Research</p> <p>Enhancing delivery of minerals using multifunctional carriers</p> | <p>Publication in preparation</p> |
| <p>Prof. Jeffrey Pearson, Newcastle University</p> <p>Bioactive Alginates and Obesity</p> | <ol style="list-style-type: none"> 1. Brownlee <i>et al.</i>, (2009) "Applications of Alginates in Food," in <i>Alginates: Biology and applications</i> 2. Brownlee (2011) <i>The physiological roles of dietary fibres</i>". <i>Food Hydrocolloids</i>; 25(2): 238-250 3. Brownlee <i>et al.</i>, (2010) <i>The physiological parameters</i> |

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| | <p><i>governing the action of pancreatic lipase”, Nutr. Res. Rev; 23: 146-154</i></p> <p>4. Seal CJ and Brownlee IA. (2010) <i>Whole grains and health, evidence from observational and intervention studies. Cereal Chemistry 87(2) 167-174</i></p> |
| <p>Prof. Lesley Rhodes, University of Manchester</p> <p>The effect of dietary bioactive compounds on skin health in humans in vivo</p> | <p>Publication in preparation</p> |
| <p>Dr Jeremy Spencer, University of Reading</p> <p>The Impact of Cocoa Processing on Flavanol Content, Absorption and Health Effects</p> | <ol style="list-style-type: none"> 1. Monitoring the formation of flavanol-Maillard adducts in model systems relating to cocoa roasting , Oruna-Concha <i>et al.</i>; Submitted to J Agri Food Chem. 2. Absorption, metabolism and vascular effects of alkalized cocoa , Oruna-Concha <i>et al.</i>; Submitted to Amer J Clin Nutrition. 3. Impact of cocoa processing on its potential to impact on the growth of the gut microbiota , Oruna-Concha <i>et al.</i>; Submitted to Brit J Nutrition. |
| <p>Prof. John McLaughlin, University of Manchester</p> <p>Defining the gut-to- brain signalling mechanisms underlying responses to nutrients</p> | <ol style="list-style-type: none"> 1. Little TJ, Gupta N, Case RM, Thompson DG, McLaughlin JT. (2009). Sweetness and bitterness taste of meals per se does not mediate gastric emptying in humans. <i>Am J Physiol Regul Integr Comp Physiol</i>, 297(3), R632-R639. 2. Little, TJ, Gopinath, A, Patel, E, McGlone, A, Lassman, DJ, D’Amato, M, McLaughlin, JT, Thompson. DG. Gastric emptying of hexose sugars: role of osmolality, molecular structure and the CCK1 receptor. <i>Neurogastroenterology and Motility</i> 2010 22: 1183-90 |
| <p>Prof. Paul Thornalley, University of Warwick</p> <p>Dietary activators of antioxidant response element-linked gene expression for good vascular health</p> | <ol style="list-style-type: none"> 1. Thornalley, P., Xue, M., Rabbani, N. (2009) Involvement of transcription factor nrf2 and antioxidant response element linked gene expression in countering oxidative stress in diabetes. <i>Eur J Biochem</i> 276, 79–80. 2. Thornalley, P.J and Rabbani, N. (2010) Oxidation modification of proteins: an overview. In: <i>Biomarkers For Antioxidant Defense And Oxidative Damage Principles And Practical Applications</i> (Aldini, G., Yeum, K.-J., Niki, E., and Russell, R.M. eds.), Wiley-Blackwell, New York, 137–156. 3. Rabbani, N. and Thornalley, P.J. (2011) Protein damage in diabetes and uremia – identifying hotspots of proteome damage where minimal modification is amplified to marked pathophysiological effect. <i>Free Radical Research</i> 45, 89–100. 4. Thornalley, P.J. and Rabbani, N. (2011) Thiamine in diabetic renal disease – dietary insufficiency, renal washout, anti-stress gene response, therapeutic supplements, risk predictor and link to genetic susceptibility. In: <i>Oxidative Stress in Applied Basic Research and Clinical Practice: Renal</i> |

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| | <p>Disorders (Miyata, T., Eckardt, K.-U. and Nangaku, M. eds), Human Press, 93-104.</p> <p>5. Murphy, M.P., Holmgren, Nils-Göran Larsson, A., Halliwell, B., Chang, C.J., Kalyanaraman, B., Rhee, S.G., Thornalley, P.J., Partridge, L., Gems, D., Nyström, T., Belousov, V., Schumacker, P.T. and Winterbourn, C.C. (2011) Unravelling the Biological Roles of Reactive Oxygen Species. <i>Cell Metabolism</i> 13, 361-366.</p> <p>6. Thornalley, P.J, Xue, M. and Rabbani, N. (2011) Methodologies for assessing in-vitro and in vivo activity of bioactive compounds. In: <i>Health-Promoting Properties of Fruits and Vegetables</i> (Terry, L. ed.), CABI, Oxford, UK, in press.</p> |
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2nd round projects:

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| Dr Ellis, Peter, Kings College London | Butterworth, P.J., Warren, F.J. & Ellis, P.R. (2011) Human α -amylase and starch digestion: an interesting marriage. <i>Starch/Stärke</i> . DOI 10.1002/star.201000150. |
| Prof. Martin Yeomans, University of Sussex | Yeomans, M. R. (2010). Psychological approaches to understanding satiation and satiety. <i>Agro Food Industry Hi-Tech</i> , 21(4), 16-19. Experiment 1 is under review with <i>American Journal of Clinical Nutrition</i> . Two further papers to be submitted in 2011. |

Fewer publications have been produced from the projects funded through the 2nd and 3rd funding calls due to the early stage of the projects and the double blind nature of some of the studies. All of the projects plan to produce publications from their research.

Further information:

<http://www.bbsrc.ac.uk/business/collaborative-research/industry-clubs/drinc/drinc-index.aspx>