Project title: Development of novel food ingredients that promote health via modulation of the gut microbiota

Supervisors: Petra Louis & Wendy Russell, University of Aberdeen, The Rowett Institute; Stephen Fry, University of Edinburgh); Helen Kettle (Biomathematics and Statistics Scotland, Edinburgh)

Background

The human large intestine is colonised by a diverse microbial community (microbiota) whose activities, such as providing different metabolites, interacting with the immune system and posing a barrier to disease-causing microorganisms, have a profound effect on the host. The microbiota thrives on dietary carbohydrates that cannot be digested by the host. These non-digestible carbohydrates (NDCs) originate from cereals, fruit and vegetables, and contain different types of sugars and sugar linkages. The physicochemical state of NDCs is crucial in determining fermentability, but the interplay between carbohydrate structure and the microbial community involved in its breakdown remains poorly understood.

The development of carbohydrate components originating from plant cell-wall-based materials that vary in their effect on the microbiota can lead to functional ingredients for the food industry which exert beneficial health effects. Carbohydrates that are poorly fermentable could be used as sugar replacers to create more healthy food products containing less readily digestible sugar. Fermentable compounds with a beneficial effect on the microbiota, by selectively stimulating beneficial bacteria and associated health-promoting bacterial products, could be developed into novel prebiotic compounds for a range of food products.

Aim and hypotheses

We hypothesize that different plant cell wall-derived components can be developed into novel functional food ingredients with health benefits. This project aims to investigate the fermentation of a range of materials by the human gut microbiota with a view towards developing health-promoting food ingredients. The source materials would ideally originate from renewable sources or waste products to reduce emissions and achieve sustainable production of the novel ingredients, which will therefore also be investigated here.

Technical approach

The project will entail the following objectives:

1. Production and chemical characterisation of different test materials from lignocellulosic feedstocks, including organic wastes. Fractionation of plant-based feedstocks and waste materials into different fractions (cellulosic, hemicellulosic, pectic and lignin-rich), and their structural characterisation by acid and enzyme-catalysed hydrolysis followed by chromatography.
2. Fermentability of different preparations of existing and new substrates becoming available through objective 1. In addition to pure materials (different fractions; different molecular weights), synergistic effects between different types of NDCs will also be investigated. After incubation with faecal microbiota in vitro, community changes (molecular methods) and product formation (analytical techniques) will be followed. Once the main bacterial species involved in the fermentation have been identified, defined microbial consortia will be examined to investigate bacterial interactions (such as cross-feeding) and inter-individual variation.
3. Radiolabelling of selected non-digestible carbohydrates. In the light of data from the above, we will select a small number of relatively non-digestible carbohydrates and prepare them in radiolabelled form, then test these substrates to quantify the metabolic fate of the different chemical constituents in the presence of faecal microbiota. This will include tests on the effect of chemical linkages and side-chains using variations of solubilised polysaccharides as well as the effect of the molecular surroundings on the digestibility.
4. Mathematical modelling. We have established an in silico model of carbohydrate breakdown by the human gut microbiota. The model will be adapted to microbial fermentation of plant cell wall-based materials and used to inform on a rational design of the defined microbiota studies carried out in objectives 2 and 3, the results of which will in turn be used to refine the model further. Specific questions addressed will include effect of carbohydrate chain length, synergistic effects between different substrates and the specific roles of individual microbes.