Scientific Advisory Committee on Nutrition

Paper for information: Complex Carbohydrates. Report on a review of FSA Research

Agenda item: 5

Please see attached paper for information.

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Complex Carbohydrates. Report on a review of FSA Research

Research Programme N03: Complex Carbohydrate Programme

1. This programme has been completed and reviewed:

The role of complex carbohydrates in the diet programme review

2. Complex carbohydrates can be defined as all polysaccharides in food: starches and non-starch polysaccharides (NSP). The original rationale for the complex carbohydrates research programme came from the associated benefits of increased consumption of complex carbohydrates on insulin sensitivity, CVD risk, obesity and certain cancers.

3. The programme initially focussed on investigating mechanisms of action in the small intestine with respect to the absorption of carbohydrate, and to determine if there were any adverse effects of increased complex carbohydrate consumption, i.e. on absorption of micronutrients or due to subsequent colonic bacterial fermentation.

4. The programme developed over its lifetime – between 1990 and 2001 –latterly focussing on the effects of bacterial fermentation on the colonic mucosa and its relationship to health. This has led to the new FSA research programme – which started in 2001: Diet and Colonic Health (N12). The current priority, of which, is to develop valid diet-related intermediate biomarkers for colo-rectal cancer and, subsequently, investigate the impact of relevant dietary factors on colo-rectal cancer risk.

5. Professor David Southgate was commissioned to undertake an overview of the complex carbohydrates research programme, and Professor John Cummings, a member of the Scientific Advisory Committee on Nutrition, was asked to provide commentary on the way ahead.

Research project results

6. The projects can be considered as being concerned with two major themes:
   - the physiological effects of complex carbohydrates and
   - the consequences of the colonic fermentation of complex carbohydrates

The physiological effects of complex carbohydrates

7. The physiological effects of complex carbohydrates includes projects that addressed either the effects of absorption of carbohydrates or the effects of complex carbohydrate on the availability of micronutrients.

Effects of absorption of carbohydrates

8. The central hypothesis for this work was that the digestible components of complex carbohydrates (starches and their degradation products) are assimilated more slowly than sugars. The consequences of this – a delayed and prolonged rise in blood glucose and subsequent insulin release – were suggested to be beneficial to those with reduced insulin sensitivity: a risk factor for both diabetes and cardiovascular disease. In many ways this concept was an extension of the dietary fibre hypothesis of Burkitt and Trowell (1977), who suggested that foods that were more slowly absorbed may have metabolic benefits in relation to diabetes and to the reduction of coronary heart disease.

9. The main findings from projects investigating these issues were:
   - Studies comparing the rates of absorption of different starches and sugars from the small intestine, using isotopically labelled carbohydrates, confirmed that starches were digested more slowly, leading to lower, but longer, elevations of blood glucose levels. The rates varied between different foods confirming the basis of many studies of the glycaemic index of foods. There were profound differences between starch from different sources, the extent of disintegration of the plant cellular tissues and the type of heat processing that the food starch has received. It is, therefore, not possible to generalise about the ‘effects of starch’.

- Sucrose was absorbed and metabolised very rapidly probably because of the fructose component; however, in healthy subjects there were no significant differences between high-sugar or high-starch diets on insulin resistance, although sucrose did seem to raise the levels of non-esterified fatty acids in the blood. Substantial individual differences in responses were observed, there were profound effects of time of day, and the timing of meal times had effects on glucose clearance – a beneficial effect on insulin sensitivity was observed when subjects were constrained to eating regular meals.

- The differences in the metabolic effects (insulin sensitivity) of simple sugars were not different from some starches; however, it is important to remember that the results were obtained with healthy subjects. Studies that have compared the effects of sugars with starches on insulin sensitivity in subjects with impaired glucose tolerance have generally shown a beneficial metabolic effect (Jenkins et al. 2002). Overall, however, evidence demonstrating a beneficial effect of fibre consumption on insulin sensitivity appear to be stronger (Bessesen, 2001).

- One other observation of interest was that advice to increase the intake of complex carbohydrates could lead to an inadvertent increase in the intake of simple sugars.

10. In subsequent funding this area of the N03 programme was not followed-up and was criticised for this. The studies themselves were regarded to be of high calibre.

Effects on the availability of micronutritients

11. Studies on the effects of complex carbohydrate on the absorption of micronutrients showed that only an effect on diffusion of nutrients might alter absorption, whereas, the ion binding effects deduced from the physico-chemical properties of complex carbohydrate were masked by the matrix of food materials in the intestine. Population studies showed that high intakes of NSP did not adversely affect micronutrient status and, in fact, the converse was true in that higher intakes of NSP were associated with an improved status of some vitamins.

12. The concerns about micronutrient absorption were criticised as being unjustified at the time the work was commissioned.

The consequences of fermentation in the large bowel

13. Carbohydrate entering the large intestine stimulates bacterial fermentation and increases biomass. The next group of projects were designed to study the effects of the products of fermentation of complex carbohydrates in the large intestine – short chain fatty acids – on the colonic mucosa.

14. Projects were concerned with establishing how the structures of the carbohydrates influenced the rate and extent of fermentation, and studies of the specific bacteria in the production of different proportions of short chain fatty acids. The projects evolved to studies of the short chain fatty acids, especially butyric acid, on cell proliferation and the specific mechanisms involved crypt cell proliferation and apoptosis. These studies included studies of cancers produced by specific chemical carcinogens on the role of spontaneous tumour production in models of human cancers.

15. The main findings from projects investigating these issues were:
    - The energy value of NSP and resistant starch was shown to be closely related to their fermentability.
    - Characterisation of different polysaccharides showed that the rate and extent of SCFA production was more influenced by food microstructure than chemical structure alone. Studies with ileostomists fed meals made from isotopically labelled starch confirmed there were substantial amounts of NSP of non-dietary origin, probably mucins, in the effluents. This would form an important contributor to butyrate production in the large intestine, and was enhanced by the presence of dietary carbohydrates.
    - Animal studies showed no consistent relationships between chain fatty acid profiles and proliferation rates and aberrant crypt foci number, or cancer risks. This would suggest that complex carbohydrates have no effects on the mucosal cell kinetics in the colon.

- A procedure was developed for the culture of normal colonic epithelia which should permit more detailed studies of the effects of dietary constituents on epithelial growth and development.
- Tissue culture work demonstrated that bile acids and butyrate, as would be provided by a balanced diet containing fermentable complex carbohydrates, seemed necessary to control the balance between cell proliferation and apoptosis; however, no direct effects on the genes that regulate the two processes were observed. Bile acids were trophic for precancerous stages in the human colon, whereas, butyrate counteracted this effect.
- An assay for defective DNA replication (a modified Comet assay) was developed on a range of cell culture and colonic mucosa preparations including small biopsies. The assay showed that defects were present in histologically normal tissues adjacent to adenomatous tissues and, subsequently forms the basis of an N12 project investigating the effects of folate status on the colo-rectal cancer risk.

16. This area of work was criticised for its reliance on animal work, as it is difficult to extrapolate to humans.

General comments

17. The programme was criticised for what seemed a lack a coherent overall strategy.

    Future work should be set in the context of carbohydrates as a whole, so that people are aware of both the individual components and their overlapping chemical and physiological properties.

    The currently accepted public health strategy, of the protective role of carbohydrates against colorectal cancer, needs to be studied in long term human studies using dietary change rather than food supplements.

Future research

18. The FSA research programme N12 – Diet and Colonic Health, focuses on the role of nutrition in preventing colorectal cancer using human subjects or human tissue culture. The initial priority for this programme is to develop reliable diet-related intermediate biomarkers for colorectal cancer. Once these techniques have been

established the programme priority will be to investigate the impact of dietary constituents on colorectal cancer risk.

19. The review highlighted the need to assess the effects of the amount and composition of dietary carbohydrate on insulin sensitivity and CVD risk. The reciprocal of this – the effect of the amount and composition of dietary fat on insulin sensitivity and CVD risk – was highlighted as an important area for future research at a FSA monounsaturated fatty acid workshop. It would be sensible, therefore, to commission a large multi-centre study to examine concomitantly the effects of modifications to the amount and composition of both carbohydrate and fat on insulin sensitivity and CVD risk.

References

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