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Review
A new look at dietary carbohydrate: chemistry, physiology and health

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The current view of dietary carbohydrates as simply providing us with energy is outdated. Because of their varied chemistry and physical form the rate and extent to which the different types are digested in and absorbed from the small intestine varies. This in turn leads to affects on satiety, blood glucose and insulin, protein glycosylation, lipids and bile acids. Some carbohydrates reach the colon where they are fermented and affect many aspects of large bowel function, colonocyte and hepatic metabolism.

A new framework for classifying and measuring food carbohydrates is needed to allow a greater understanding of the role of individual species in health and to inform the public of their importance. A classification based primarily on molecular size (degree of polymerisation) into sugars, oligosaccharides and polysaccharides, is suggested, with sub-groups identified by the nature of the monosaccharides. Greater knowledge of the chemical and physical properties of carbohydrates allow a more precise relation with physiology and health to be drawn.

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Descriptors: carbohydrates; diet; health; sugars; starch; fibre

Introduction

Historically carbohydrate has been thought of as being digested in the small bowel, and the products, sugars, absorbed, oxidised in muscle and other tissues and excreted as water and carbon dioxide. The exception to this was 'fibre' which was thought to pass through the gut and be excreted in faeces. It is now clear however that dietary carbohydrates are a diverse group of substances with varied physiological properties of differing importance to health (Asp, 1992, 1994; British Nutrition Foundation, 1990; Clydesdale, 1995; Delzenne & Roberfroid, 1994; Forbes *et al*, 1993; Greenberg, 1995; Stephen, 1991). (See Table 1).

Carbohydrates are not simply absorbed and provide energy. Because of the physical structure of the cell wall carbohydrates they affect satiety (Blundell *et al*, 1994; Haber *et al*, 1977) and the rate and extent of starch digestion, which is a major factor controlling blood glucose and insulin (Crapo *et al*, 1976; Englyst *et al*, 1996; Hermansen, 1994; Jenkins *et al*, 1981; Wolever & Miller, 1995). The concentrations of glucose and fructose in blood are also important in determining protein glycosylation and possibly the process of ageing (Brownlee *et al*, 1988; Dills, 1993; McDonald, 1995). Some starches affect large bowl function (Cummings *et al*, 1996; Munster *et al*, 1994; Phillips *et al*, 1995) and the concept of resistant starch (RS) has been developed (Englyst *et al*, 1992). Recently the importance of a previously neglected group of carbohydrates, the oligosaccharides, has emerged with the demonstration that some are fermented in the colon and selectively stimulate the growth of specific intestinal bacteria thought to be beneficial to health (Gibson *et al*, 1995; Gibson & Roberfroid, 1995; Hidaka *et al*, 1986). This knowledge requires a new framework for classifying and measuring dietary carbohydrate and is necessary for food labelling and public health policy.

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Historical aspects of classifying dietary carbohydrate

At the turn of the century carbohydrate was calculated 'by difference'. The protein, fat, ash and moisture content of food were determined, subtracted from the total weight and the remainder, or 'difference' was considered to be carbohydrate (Southgate, 1991).

A major step forward both conceptually and analytically was made by McCance and Lawrence in 1929 with the division of dietary carbohydrate into available and unavailable (McCance & Lawrence, 1929). In an attempt to prepare food tables for diabetic diets they realised that not all carbohydrate could be 'utilised and metabolised' namely provide the body with 'carbohydrates for metabolism'. They defined available carbohydrate as 'starch and soluble sugars' and unavailable as 'mainly . . . hemicelluloses and fibre (cellulose)'.

The division of carbohydrates along these lines is appealingly simple and conveys an important message about their physiological properties. However it is a concept which needs to be clarified today. It is now known that not all McCance and Lawrence's available carbohydrates, although defined physiologically by them, provide the body with carbohydrate for metabolism by absorption of sugars. In many populations of the world lactose is not absorbed (Buller & Grand, 1990), neither are all starches digested in the small bowel (Asp, 1992; Englyst *et al*, 1992). Moreover

Table 1 Physiological properties of dietary carbohydrates

An energy source (potentially all carbohydrates)	
Increased satiety	
Control of blood glucose and insulin	
Protein glycosylation	
Cholesterol lowering	
Bile acid dehydroxylation	
Laxative	
Through fermentation:	Hydrogen/methane production
	Increase in microbial biomass
	Control of colonic epithelial cell function
Selective stimulation of microbial growth, for example bifidobacteria	

there is a need to consider the place of oligosaccharides such as raffinose and stachyose in beans, and fructooligosaccharides in onions, leeks and artichokes, the majority of which are not digested in the small intestine (Bach-Knudsen & Hessov, 1995; Rumessen *et al*, 1990; Tadesse *et al*, 1980).

The term 'unavailable' as defined by McCance and Lawrence is correctly used for those carbohydrates which reach the colon but it can be misinterpreted as meaning unavailable to the body in any way. Whilst carbohydrates which reach the large bowel do not provide the body with carbohydrate for absorption they are more or less extensively degraded by the anaerobic bacteria, with the production of short-chain fatty acids (SCFA) (acetic, propionic and butyric acids) which are then absorbed and provide the host with energy (Cummings, 1983). They also have a variety of important physiological effects (see below).

Current food tables vary in their approach to classifying and measuring carbohydrate. Some still use carbohydrate 'by difference' (Stewart & Tamaki, 1992). In the UK (Holland *et al*, 1991) total carbohydrate is obtained 'from the sum of analysed values of *available carbohydrate*', which is defined as the sum of free sugars and complex carbohydrate (dextrins, starches and glycogen). Two different sets of analyses for dietary fibre are given.

A new classification of dietary carbohydrate for nutrition

In deciding how to classify dietary carbohydrate the principal problem is to reconcile the various chemical groups with a division of carbohydrate which reflects physiology and health properties. A classification based purely on carbohydrate chemistry does not provide a ready guide to their importance to health. However, a classification based on physiological properties also creates a number of problems. It requires that a single effect be identified as overridingly important, and used as the basis for the classification, for example available/unavailable. This then groups together several chemical classes of carbohydrate which each individually may have other important properties, that would be difficult to identify. Under such a system an 'unavailable' carbohydrate such as dietary fibre would include components some of which contribute to the regulation of blood glucose and insulin. It is also difficult analytically because the analyst needs a chemical rather than physiological objective.

Since chemistry ultimately determines function we propose a classification based primarily on molecular size to provide the main classes, with subgroups defined by molecular size and the nature of the monosaccharides. The classification is analogous to that used for dietary fat, which is based on the chain-length of the fatty acids, on the number and position of the double bonds and their configuration as cis or trans and on the nature of the molecule into which they are esterified. As the primary basis for carbohydrate we propose using DP, Degree of Polymerisation, that is the number of individual monosaccharide units which make up the molecule. These main classes are then subdivided on the basis of the types of monosaccharide that are present, with a view to keeping broadly similar physiological types together within the subgroup. The classification of food carbohydrate based on its chemistry is already widely used (Cummings & Englyst,

Table 2 Classification of the principal dietary carbohydrates

Major classes (DP)	*Sub-groups (type of monosaccharide and α or β bonds)*	*Physiology*
Sugars (1–2)	(i) Monosaccharides	Absorbed from small intestine
	Glucose, fructose	Glucose and sucrose give rapid glycemic responses
	(ii) Disaccharides	
	Sucrose, maltose, trehalose	Absorbed
	Lactose	Lactose is fermented in many populations
	(iii) Sugar alcohols	
	Sorbitol, maltitol lactitol	Pooly absorbed and partly fermented
Oligosaccharides (3–10)	(i) Malto-oligosaccharides (α-glucan)	(a) Digestible—digested and absorbed from small intestine and give rapid glycemic response (b) Resistant—Pass into the large intestine and may be fermented.
	(ii) Other oligosaccharides (NDO)	
	Fructooligosaccharides Galactooligosaccharides	Fermented. Some selectively stimulate growth of bifidobacteria in large bowel
Polysaccharides (10)[a]	(i) Starch (α-glucans)	(a) Digestible—varying rates of digestion and glycemic responses (b) Resistant—not absorbed in small bowel. May be fermented, and affect large bowel function
	(ii) Non starch polysaccharides (NSP)	(a) Cell wall—Contribute to regulation of carbohydrate digestion in small bowel. Fermented mostly but dependent on cell wall structure; major determinant of large bowel function; provide physical structure to plant foods (b) Non cell wall—fermented to a variable degree. Varying effects on carbohydrate and lipid absorption and in the large bowel

DP = Degree of Polymerisation or the number of monosaccharide units which make up the molecule. For isolated (synthetic) oligosaccharides used as food ingredients DP refers to the *average* value.
NDO = Non-digestible oligosaccharides.
[a] In practice the division between oligosaccharides and polysaccharides is best made on the basis of solubility in 80%v/v ethanol. This group will thus contain carbohydrates of DP greater than 10. If IUB-IUPAC maintain the current definition of oligosaccharides then it will be necessary to find a new name for this group, such as 'short chain carbohydrates'.

1995; Englyst & Hudson, 1996; Southgate, 1995). (See Table 2)

Sugars

Sugars may be divided into mono and disaccharides and sugar alcohols and can be measured accurately (Southgate, 1991). Mostly they are rapidly absorbed and provide a ready source of energy. The exception is lactose, a β-linked disaccharide and the principal sugar in milk, which is not absorbed by most of the adult population of the world (Buller & Grand, 1990). β-galactosidase activity is however retained in the small bowel mucosa of most Caucasians in Northern European countries, Australia and New Zealand and in North America. In other countries when lactose is ingested it passes into the large intestine where it is fermented.

Sugars in general add sweetness to food, make it pleasant to eat and are used by the food industry to aid in food preservation and to improve the flavour and texture of cakes, biscuits and confectionery and many other foods. It is an important contributor to the bulk of some foods and through its ability to reduce water activity acts as an inhibitor of microbial growth. Free glucose in foods, the glucose moiety of sucrose and the glucose released from malto-oligosaccharides and from some forms of starch all appear rapidly in the blood after a meal. The concentration of glucose in the blood has a number of implications for health including in diabetes, ageing and possibly cancer (Giovanucci, 1995). Sugars have been implicated in dental caries (Department of Health, 1989; Konig & Navia, 1995). Nevertheless caries incidence has declined in many Western countries in recent years, as a result of the increased use of fluoride and improved dental hygiene. Epidemiological evidence does not support a role for sugars at currently recommended intakes in the aetiology of obesity (Hill & Prentice, 1995), diabetes or cardiovascular disease (Clydesdale, 1995; Department of Health, 1989).

Advances in food technology in the past decade have led to the commercial availability of pure fructose which is now incorporated into many speciality food and beverage products. This has raised concerns about its physiological and health properties. Fructose is well absorbed in the amounts present in a normal diet, but at intakes exceeding twice the normal daily consumption of 10 g/d can lead to an increase in very low density lipoprotein (VLDL) secretion and produce hyperinsulinaemia and hyperuricaemia and gastrointestinal effects in susceptible individuals. It is also, along with glucose and other reducing sugars, an initial substrate in the Maillard reaction, which yields products that add to the aroma and flavour of food. Similar reactions occur in vivo and may contribute to protein cross-linking in human tissues such as the lens and ultimately to ageing (Forbes *et al*, 1993). Thus sugars, like all the other classes of carbohydrate, are physiologically diverse and are best classified by their molecular size (DP) and nature of individual monomers.

Oligosaccharides

Oligosaccharides have been variously defined as including anything from 2–19 monosaccharide units (British Nutrition Foundation, 1990; Food and Drug Administration, 1993; IUB-IUPAC *et al*, 1982). Fixing the lower limit at 2 has not however found favour with many nutritionists (Asp, 1995; Cummings & Englyst, 1995; Southgate, 1995) and by convention in human nutrition the disaccharides are included as sugars (Bach-Knudsen & Hessov, 1995; Roberfroid, 1993; Rumessen *et al*, 1990; Tadesse *et al*, 1980).

Most authorities recommend a DP of 10 as the dividing point between oligo and polysaccharides (Cummings & Englyst, 1995; IUB-IUPAC *et al*, 1982). Whilst this is the correct terminology (IUB-IUPAC *et al*, 1982) there is not a rational physiological or chemical reason for this division. Dietary carbohydrates form a continuum of molecular size from simple sugars up to complex polymers with a DP of 100 000 or more. In practise precipitation from aqueous solutions with 80%v/v ethanol is the step used in many carbohydrate analysis procedures to produce these two groups (Englyst *et al*, 1994; Prosky *et al*, 1992; Southgate, 1991). However some branched-chain carbohydrates of DP between 10–100 remain in solution in 80%v/v ethanol so there is no clear and absolute boundary. Furthermore carbohydrates, such as inulin and polydextrose contain mixtures of polymers of different chain lengths that cross the oligosaccharide/polysaccharide boundary. In categorising oligosaccharides found normally in the diet, we recommend using alcohol precipitation as a practical way of delineating them from polysaccharides. For novel oligosaccharides such as are now being developed by the food industry as ingredients we suggest the average DP for that particular substance, as determined by the manufacturer, as the basis on which to put it into the appropriate carbohydrate class. (See Table 3).

Maltodextrins are industrially derived from starch and most are readily digested and absorbed in the small bowel. However food processing can alter the tertiary structure of some maltodextrins, for example pyrodextrins, and render them resistant to pancreatic amylase and brush border enzymes. The other oligosaccharides, and their industrial

Table 3 Oligosaccharides

Name (DP)	*Structure*	*Bond*	*Dietary sources*
Raffinose family (3) including Stachyose (4) and Verbascose (5)	$(Gal)_n$ 1–6 Glu 1–2 Fru	α and β	Beans, peas, soya
Fructooligosaccharides (2–60)[a]	Glu $(Fru)_n$ or $(Fru)_n$	β 1–2	From enzymatic synthesis, or partial enzymatic hydrolysis of inulin and also naturally occurring in onions, garlic, wheat, bananas, chicory roots and artichokes as inulin
Galactooligosaccharides (3–5)	$Glu(Gal)_n$ $(Gal)_n$	Mainly β 1–6	Enzymatic synthesis
Maltodextrins (3–20)	$(Glu)_n$	α 1–4	Glucose syrups
Polydextrose (3–100) Isomaltobiose and higher isomaltooligosaccharides	$(Glu)_n$ + citrate $(Gal)_n$ $(Glu)_n$	Mixture	Synthetic
		Mixture	Synthetic

[a] Naturally occurring fructans exist with a spectrum of DP from 2–60, with an average DP of 10. Partial hydrolysis or purification gives products with a DP < 10 and higher molecular weight inulins.

derivatives, are mainly polymers of fructose and galactose. They almost certainly pass into the large bowel and have become known as 'non-digestible' oligosaccharides (NDO) (Delzenne & Roberfroid, 1994). For most NDO evidence for their non-digestibility is incomplete and rests on the absence of pancreatic enzymes capable of hydrolysing the glycosidic bonds, and their effects on the colon. For fructooligosaccharides (FOS) and inulin, breath hydrogen studies (Gibson *et al*, 1995; Rumessen *et al*, 1990; Tadesse *et al*, 1980), quantitative recovery in human ileostomy effluent (Bach-Knudsen & Hessov, 1995) and prebiotic effects in the colon (Gibson *et al*, 1995) have been reported. Their non-digestibility in the small bowel and water solubility means that they provide a rapidly available substrate for bacterial fermentation in the colon, hence the known association of gas after eating meals containing beans, peas, artichokes etc.

There are currently no tables of oligosaccharide content of foods and few data giving oligosaccharide consumption in any populations in the world (Loo *et al*, 1995). The most important physiological property of NDO currently known, is to stimulate selectively the growth of bifidobacteria in the colon and possibly thereby increase colonisation resistance to pathogenic organisms (Gibson *et al*, 1995; Hidaka *et al*, 1986). In this context they are known as prebiotics (Gibson & Roberfroid, 1995). FOS in addition reduces serum triglycerides in rats and diabetic humans (Fiordaliso *et al*, 1995; Kok *et al*, 1996; Yamashita *et al*, 1984). They are used by the food industry as low-calorie substitutes for sugar and fat.

Polysaccharides

Starch (α glucans)

Starch is a mixture of two large polymers in varying proportions, the linear 1,4-α-linked amylose and 1,4;1,6-α-linked amylopectin. Starch is the major carbohydrate in the human diet and is 80–90% of all polysaccharides eaten. All starch can ultimately be degraded by human α-amylase. However the rate and extent to which it is digested in the small intestine determines its physiological properties. This in turn is dependent on three principal factors: (a) its physical state namely whole grains *vs* powdered or dispersed forms, (b) the nature of the crystalline form in the starch granule and the amylose/amylopectin ratio, for example cereal starches which are readily digestible but banana and potato are not unless cooked; legume starches lie somewhere in between, (c) any food processing which has led to retrogradation, for example cooked and cooled potato (Crapo *et al*, 1976; Englyst *et al*, 1992; Englyst *et al*, 1996; Hermansen *et al*, 1986; Hiele *et al*, 1990; Jenkins *et al*, 1981).

Slowing starch digestion, or modifying other factors such as lipid and protein content of the meal and thus slowing gastric emptying, reduces the glycaemic index and insulin responses. This is clearly important for diabetes and has led to major changes in dietary recommendations for diabetics. The importance of maintaining lower blood glucose profiles in healthy humans has been questioned, but recent studies suggest that this is a significant determinant of protein glycosylation (Brownlee *et al*, 1988; Dills, 1993; McDonald, 1995). Because of the physical nature of starch it has been assumed that it is hydrolysed and absorbed more slowly than sugars. This is not always the case. Some starches are rapidly digested and give rise to blood glucose responses (glycaemic index) similar to or even greater than sugars (Wolever & Miller, 1995). The rate at which glucose in a food, either as free glucose, or from sucrose or starch, becomes available for absorption in an in vitro system correlates well with the glycemic response to that food (Englyst *et al*, 1996).

If starch or its hydrolysis products escape digestion they pass into the large intestine where they may be fermented. This fraction is known as resistant starch (Englyst *et al*, 1982; Englyst *et al*, 1992).

Non starch polysaccharides

Non starch polysaccharides (NSP), non α glucans, comprise 80–90% of the plant cell wall. Other NSP are found in plant foods in the form of gums (guar), mucilages (ispaghula) and storage carbohydrates (inulin). The amounts of gums and mucilages are quantitatively insignificant compared to the cell-wall NSP. Plant cell-wall NSP are a heterogeneous mixture of large straight-chain and branched polysaccharides which contain five-carbon sugars such as xylose and arabinose, and six-carbon sugars like galactose, mannose, glucose and uronic acids. Cell-wall NSP are present in all fruits, vegetables, cereals and nuts. They may readily be measured and characterised in the human diet (Englyst *et al*, 1994).

Many claims have been made for the benefits of plant cell wall containing foods. Arising out of research into dietary fibre two important effects have emerged. Firstly, by virtue of their physical properties in the plant cell wall, namely giving structure to plants, NSP exert a modifying effect on the absorption of nutrients such as starch and sugars which are enclosed within the plant cell. Thus plant cell wall NSP can influence the blood glucose response to foods. In addition, the gel properties of some plant cell wall polysaccharides, such as the β glucan of oats, modify lipid absorption and lower cholesterol, although this is by no means a general effect (Glore *et al*, 1994; Lairon & (Editor), 1994). Secondly, all plant cell wall NSP escape digestion in the upper gut of humans and reach the large intestine where they may be fermented by colonic bacteria.

Fermentation is the colonic phase of carbohydrate digestion, the major products of which are short-chain fatty acids (Cummings, 1995; Cummings *et al*, 1995). They are rapidly absorbed and metabolised by the body. In humans they are not known to stimulate insulin secretion in contrast to glucose. Acetate provides energy for the tissues. Propionate in ruminant animals, for example cows, sheep, goats and giraffe, is converted to glucose, but this is not an important pathway in humans where no clear role for it has yet been established. Butyrate is metabolised by colonocytes (Roediger, 1980) and has been shown to regulate cell growth, induce differentiation and affect apoptosis (Cummings, 1995; Cummings *et al*, 1995). These properties of butyrate may protect the colonocyte from transformation into a malignant cell.

One other effect of fermentation is to stimulate bacterial growth (biomasss) in the colon (Stephen & Cummings, 1980). Intestinal bacteria are eventually excreted in faeces, and thus contribute to the laxative properties of high NSP diets. In fact, all carbohydrates which reach the large intestine will have a laxative effect, although some are better laxatives than others (Cummings, 1993; Cummings *et al*, 1996; Gibson *et al*, 1995; Munster *et al*, 1994; Phillips *et al*, 1995).

Thus the colonic phase of carbohydrate digestion differs significantly from the small bowel phase. Some carbohy-

drates of each major class shown in column 1 of Table 2 reach the large bowel although in varying proportions.

Related issues

Energy value of dietary carbohydrate

Dietary carbohydrates which are absorbed as hexose (glucose, fructose, galactose etc), have a caloric value of 3.75 Kcal/g (15.7 KJ/g) (Southgate & Durin, 1970) and their cellular catabolism produces around 38 mol ATP/mol (Roberfroid *et al*, 1993). However, NDO, resistant starch and NSP, because they are only partly converted to short chain fatty acids through fermentation, are metabolically less efficient than hexose, have a lower caloric value, of between 0 (Southgate & Durin, 1970) and 2.4 (Goranzon & Forsam, 1987) Kcal/g (0–10 KJ/g) depending both on the degree of their colonic fermentation and the assumptions of the fermentation model used. Via the catabolism of the absorbed short chain fatty acids, they produce 10–17 mol ATP/mol of fermented -osyl moiety (glucose, fructose, etc) (Roberfroid *et al*, 1993).

The daily intake of these dietary carbohydrates (NDO, resistant starch and NSP) is likely to remain relatively small, less than 10% and probably often not more than 5% of total daily calorie intake (Cummings & Frolich, 1993). Thus it is scientifically not justifiable to spend much effort in trying to give, for each such carbohydrate, a precise caloric value, the determination of which will often depend on the protocol used.

These dietary carbohydrates often interact with digestion of proteins and lipids, thus indirectly lowering the caloric value of the diet as a whole (Livesey & Elia, 1995). Such effects are however difficult to quantify precisely. They depend on the amount of resistant starch and/or NSP in diet and they are influenced by the composition of the meals. Depending on these conditions negative caloric values as low as -7.1 and -4.8 KJ/g have been reported for some of these dietary carbohydrates (Davies *et al*, 1987).

For the purpose of food labelling it is recommended that all carbohydrates, which are more or less completely fermented in human colon, be given a caloric value of 1.5Kcal/g (6.3 KJ/g) (Livesey & Elia, 1995; Roberfroid *et al*, 1993). If human data are available which demonstrate that a particular carbohydrate is largely (50% or more) resistant to colonic fermentation and is excreted as such in faeces, that average value should be reduced accordingly.

Complex carbohydrates

This term has no formal definition. It rose to prominence in human nutrition with the publication of 'Dietary goals for the United States' in 1977, the McGovern Report (Select Committee on Nutrition and Human Needs, 1977). The term was used largely to distinguish sugars from other carbohydrates, and in the report is synonymous with 'fruit, vegetables and whole grains'. The BNF Task Force report 'Complex carbohydrates in foods' defined it as polysaccharides containing 20 or more monosaccharide resides (British Nutrition Foundation, 1990). Complex carbohydrates could be a shorthand way of referring to starches and NSP together, but in this case the word polysaccharide would suffice. As a substitute for 'starch' it would seem to have no merit although is probably a more consumer friendly term than 'polysaccharides'.

Dietary fibre

There is no exact definition of dietary fibre. The original description of it by Trowell (Trowell, 1972), namely 'that portion of food which is derived from the cellular walls of plants, which is digested very poorly by human beings' is a physiological concept. Moreover, the epidemiological observations by Burkitt and others (Burkitt & Trowell, 1975), which led to the proposal that dietary fibre 'deficiency' results in a number of Western diseases, is an oversimplification and needs to be modified in the light of new knowledge of diet and disease. What Burkitt correctly observed was a type of diet, high in vegetables and cereals but low in fat and meat which was associated with a pattern of diseases very different from that seen in Western societies. Both Burkitt and Trowell identified fibre as the key although it is only one component of a healthy diet. However a diet rich in fruit, vegetables and wholegrain cereals, with their cell walls intact, is probably a healthy diet and for the purpose of food labelling NSP is the best surrogate for plant cell wall intake. The principal role physiologically of the plant cell wall in the human gut is to give physical structure to food and thus affect chewing, gastric emptying and modify the absorption of other nutrients in the small bowel. In the large intestine cell wall material is a substrate for fermentation.

The confusion of ideas about fibre has delayed progress in understanding the broader aspects of dietary carbohydrate, and led to the recommendation by the British Nutrition Foundation's Task Force on Complex Carbohydrates in Foods 'that the word *fibre* should become obsolete, at least in the scientific literature'. This suggestion can be put into practice in research, industry and medicine, but poses problems for food labelling because the consumer regards dietary fibre as a beneficial component of the diet. If the concept of the plant cell wall is retained then dietary fibre may be a useful term.

Labelling

For food labelling carbohydrate should be defined and measured as the sum of constituent sugars. The three main classes of carbohydrate, sugars, oligosaccharides and polysaccharides may then be subdivided as shown in Table 2, based principally on the nature of the monosaccharides present. For practical purposes the boundary between oligo- and polysaccharides is best made on solubility in 80%v/v ethanol, although the conditions for this (pH etc) will need to be clearly defined. Labelling legislation should allow carbohydrate subgroups identified in the table in columns 1 and 2 to be labelled separately, qualified only by the figure for total carbohydrate. Suitable methods are available for the specific measurement of all dietary carbohydrates.

Conclusions

The diversity of physiological and health effects of dietary carbohydrate means that we can no longer treat this part of the diet as simply providing us with energy. A new approach to dietary carbohydrate is needed based firstly on its chemical characterisation, as is used for other food analysis, and which will allow its accurate determination in the diet. It is only on this basis that the health importance of carbohydrate in food can be understood and appropriate food labelling and public health policy formulated. We recommend the classification detailed in Table 2 as a basis on which to proceed.

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