Corresponding Author:
Shirley Hinde
Registered Dietitian / Senior Lecturer in Nutrition
Cardiff Metropolitan University
School of Sport and Health Sciences
Centre for Nutrition and Dietetics
Western Avenue
Cardiff, CF5 2YB
Not Given
work: 02920417219
FAX: Not Given
shinde@cardiffmet.ac.uk

Understanding the role of carbohydrates in optimal nutrition

Why should you read this article?

- To ensure patients are provided with evidence-based advice on the multi-factorial roles of carbohydrate within the diet
- Identify appropriate signposting to dietary resources.

Abstract:

Eating for good health is a topic widely covered across social media and attracts much interest. In recent years, the focus has shifted to carbohydrates, with a plethora of health benefits being attributed to the low carbohydrate diet. Much of this coverage runs counter to Government-led dietary guidelines. As a result, patients needing help with weight management or blood glucose control may experience levels of confusion or be encouraged to experiment with fad diets promising quick results. As front-line healthcare practitioners, nurses are in a prime position to provide patients with support and signposting to evidence-based dietary resources. In turn, nurses themselves require support in order to build their knowledge on this complex nutrient and increase their understanding of the role carbohydrates play as part of a healthy balanced diet.

Keywords:

Glycaemic carbohydrates; non-glycaemic carbohydrates, health role, Eatwell Guide.

Introduction

Carbohydrates are a major source of dietary energy (Scientific Advisory Committee on Nutrition (SACN) 2015). Composed of carbon, hydrogen and oxygen, the term defines a large group of components from the smallest, highly soluble monosaccharide molecules, through to complex indigestible fibres (Food Agriculture Organisation/World Health Organisation (FAO/WHO) 1998). Although sourced largely from plants, milk sugars and honey are also a carbohydrate source in the UK diet (Bates et al 2014).

Classifications of carbohydrates include molecular size, digestibility and glycaemic response. As such, the physiological and health impacts vary, albeit with a degree of overlap (SACN 2015). In addition to energy provision, carbohydrate-dominant foods are a potential highly useful source of micronutrients, including iron, zinc and B vitamins (Bates et al 2014; Lean & Combet 2017). Diets high in unrefined fibre-rich carbohydrates have anti-carcinoma and cardio-protective potential (World Cancer Research Fund (WCRF) 2007; SACN 2015) and the relatively low calorie contribution has potential to aid weight management and improve glycaemic control (Ruxton 2016). On the contrary, consumption of simple sugars is strongly associated with dental caries (SACN 2015), while highly refined starches are associated with poor glycaemic control (Taplin et al 2018). The physiological and health situation is therefore as complex as the carbohydrate group itself.

This article aims to provide enabling support to the nurse practitioner by clarifying what constitutes dietary carbohydrates, considers the multi-factorial roles and impacts, and re-establishes their importance within a healthy balanced diet.

Media-messages and public confusion

In recent years, carbohydrates, as a general term, have been much maligned by a sector of health-conscious celebrities and wellness gurus. Typing *low carb, gluten-free* and *clean diets* into an internet search engine draws up a wide range of associated material on the supposed superior nutritional benefits of cutting out or cutting down dietary carbohydrate. The suggested benefits of these dietary restrictions include improving weight loss, body strength, gut problems, brain function and energy levels (Dennett 2016). This trend, with often highly prescriptive messages, questions Government-led evidence-based guidelines on healthy eating, as laid down in the Eatwell guide (Public Health England (PHE) 2016). Undertaking further rapid netnography will highlight a plethora of worldwide media coverage on the confusions around carbohydrates: from the Bournemouth Echo (2017) article *Confused about carbs?* , to the Korea Herald 2018 piece entitled *Carb Phobia: health diet or excessive frenzy?* A reciprocate number of evidence-based responses from reputable UK bodies is suggestive of the size of the problem and extent of the possible confusion. Dr Alison Tedstone (2017) is the National Director responsible for diet, nutrition and obesity in the Health and Wellbeing Directorate of Public Health England. She suggests a key challenge to effective public health is addressing the confusion among the target audience. It falls to the healthcare practitioner to reduce the misunderstandings that lead to poorer health (Tedstone 2017). However, the healthcare practitioner must fully understand the subject themselves before using their skills to draw out the simple, most effective messages for their patients.

A further consideration is whether public health messages may be too simplistic, resulting in them being scientifically inaccurate. For example, a simple, potentially effective public health message for those with Type II diabetes is "*All types of carbohydrates will increase your blood glucose level*" (Taplin et al, 2018). This is an unambiguous message for the public. In some clinical situations, when working with particular patient groups, the unambiguous message will be the most appropriate one. However, it is scientifically inaccurate to say all types of carbohydrate increase blood glucose. Using such a message as standard does not encourage full understanding among the populace of the breadth and wealth of the carbohydrate.

The concept of carbohydrates that are physiologically *available* (i.e. to be metabolised) and *unavailable* for metabolic reactions was first introduced in a 1929 publication (cited in FAO/WHO

1998). Today there is recognition that the *unavailable* concept has flaws. Unavailable carbohydrates may not provide energy via glucose metabolism but can provide some energy once fermented in the large intestine (explored in more depth below). Therefore, the concept of glycaemic and non-glycaemic is now preferable (FAO/WHO 1998) and potentially more helpful terminology in getting to grips with the physiological role of carbohydrate (see Table 1 below).

Table 1: Relationship and comparison of terms used for describing the utilisation of ingested carbohydrate (CHO)

Concept based on availability of the CHO to provide energy		Concept based on the glycaemic response of a CHO	
Available CHO	**Unavailable CHO**	**Glycaemic CHO**	**Non-glycaemic CHO**
CHO that is digested in the small intestine, absorbed and available for energy metabolism (e.g. starches, sugars)	CHO that is not digested, not absorbed and unavailable for energy metabolism. Increases faecal mass (e.g. non-starch dietary fibres)	CHO that is digested in the small intestine. Absorbed and consequently raises blood glucose and stimulates insulin secretion (i.e. exerting a *glycaemic response*) (e.g. starches, sugars)	CHO that is not digested in the small intestine. *Does not exert a glycaemic response*. Digested by bacteria in the colon. *The products of fermentation (short chain fatty acids) are available for energy metabolism.* Increases faecal mass. (e.g. polyols, oligosaccharides, resistant starch, fibres)

As front-line healthcare practitioners, nurses are in a prime position to reduce confusions and directly influence health and wellbeing of patients and the public (Winslade et al 2013). However, the breadth of knowledge required by healthcare practitioners to meet the UK Department of Health's concept of make *every contact count* (DH 2012), on the potential multiple issues raised in the clinical situation is challenging, especially when restricted by time and workload.

Classifications

Monomer units are the carbohydrate in its most basic form. They exist as monosaccharides (e.g. glucose) or bind with other monomer units to form larger units, such as disaccharides (e.g. lactose) or polysaccharides (e.g. starch).

Carbohydrates can be classified in terms of molecular size and complexity. Table 2 below, provides a simplistic representation of this along with the extent of the dietary components identified as carbohydrate. The sweetness associated with the smaller carbohydrate molecule disappears with increased molecular size and solubility (Geissler & Powers 2005).

A classification arguably more helpful for the healthcare practitioner is that based on digestibility and glycaemic response. In general, smaller molecular structures (glucose, lactose, maltose), corresponds with easier digestion and absorption in the human gut. However, as already mentioned, not all carbohydrates invoke a glycaemic response, irrespective of their size and digestibility (Bender 2008; SACN 2015). The proceeding paragraphs discuss the physiological impact of carbohydrates from the smallest to the largest molecules.

Glycaemic response and Monosaccharides

As the body's preferred energy substrate, glucose is readily absorbed from the intestine. The resulting rise in blood glucose levels and consequential insulin response is physiologically crucial as it enables rapid utilisation of glucose for energy metabolism. However, as is well documented elsewhere (Bender 2008; Gandy & British Dietetic Association (BDA) 2014), the mechanisms by which the body controls blood glucose can be put under strain. A major contributer is the prevalence of overweight or obesity. The resulting chronic high blood glucose levels and development of insulin resistance has major long-term consequences for health and quality of life. The bad press that starches as well as simple sugars receive is related to their role in raising blood glucose levels.

The monosaccharide fructose is commonly referred to as fruit sugar but fructose is also found in sweet-tasting vegetables. The association between fructose, glycaemic response and energy metabolism is a complex one and is outside the scope of this article. Suffice to say large amounts of dietary fructose (which is a historically uncommon phenomenon), negatively impacts health (Bender 2008). This negative association is not seen with consumption of whole fruit and vegatables (WCRF 2007).

Table 2: Simplistic table of carbohydrate classification, in terms of molecular complexity and solubility

<table>
<tr><th colspan="6">CARBOHYDRATES</th></tr>
<tr><td>Monosaccharide
Single Monomer unit</td><td>Disaccharides
Double monomer units</td><td>Oligosaccharides
3-9 monomer unit chain</td><td colspan="3">Polysaccharides
Straight or branched chains of 10+ monomer units</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Starch</td><td>Dietary Fibre</td></tr>
<tr><td>Example:
Glucose in sweets, biscuits, fruit, honey.
Fructose in honey, fruit, vegetables.
Galactose in breast-milk & animal milks</td><td>Example:
Sucrose in sugar beet/cane
Lactose in milk
Maltose in fermented grains</td><td>Example:
Fructosyl-sucroses in onions, leeks,garlic

Galactosyl-sucroses in pulses
Resistant to digestion in the small intestine.</td><td>Digestible

Example: cooked pasta, potatoes, rice, oats, cassava, maize, etc.</td><td>*Resistant

Example: Resistant to digestion in the small intestine. Unavailable for enzymic digestion due to enclosure by fibrous cell walls, (e.g. sweet corn); raw starch granules (e.g. muesli flakes); cooked and cooled retrograded starch (e.g. potato salad)</td><td rowspan="3">A term that incorporates all carbohydrates that resists enzymic digestion in the small intestine and reaches the large intestine undigested. Colonic bacteria ferment the carbohydrate components producing short-chain fatty acids and gases.

By this definition, the term dietary fibre includes non-glycaemic polyols, oligosaccharides and the resistant element of starch.</td></tr>
<tr><td>Others (natural) Less common - mannose, xylose, arabinose, fucose</td><td></td><td>Maltodextrins added to processed foods (sweetener & texture modifier)</td><td></td><td></td></tr>
<tr><td>Others (synthetic) Polyols or Sugar Alcohols (mannitol, xylitol, sorbitol) Resistant to digestion in the small intestine.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>SIMPLE</td><td colspan="4">Increased molecular complexity
→
Reduced solubility</td><td>COMPLEX</td></tr>
</table>

*Resistant starch is defined as starch and starch degradation products not absorbed in the small intestine of healthy humans (FAO/WHO 1998)

Several other natural monosaccharides exist (see Table 2). These are present in small amounts in products such as beer, fruit and milk. They make up a small part of the UK diet (Bates et al 2014; Finglas et al 2014). The food industry has developed synthetic equivalents from these monosaccharides (collectively called polyols or sugar alcohols).

Polyols (also called Sugar Alcohols) are not digested in the small intestine and therefore incur no glycaemic response (SACN 2015). Nevertheless, they do come under the carbohydrate umbrella. The understanding and development of polyols by the food industry is key to the growth and availability of sugar-free products. Polyols are non-glycaemic. However, following the pattern of other non-glycaemic carbohydrates, they are fermentation by colonic bacteria. A by-product of the fermentation process is short-chain fatty acids (SCFA). These SCFA are a potential energy substrate and can be absorbed and metabolised for energy. The presence of SCFA in the gut lumen is directly proportional to a lowering of colon pH. The positive aspect associated with a more acidic colon environment is expanded upon below.

Glycaemic response and Disaccharides

Disaccharides are two monomer units bound together. They break down into their monomer components in the small intestine. The amount of glucose present varies with the disaccharide (see Table 3 below).

Table 3: Glucose content of common disaccharides

Disaccharide	**Monomer Units**
Maltose	Glucose + glucose
Sucrose	Glucose + fructose
Lactose	Glucose + galactose

The laboratory analysis of mono and disaccharides reflect the term: *of which sugars,* on food product labels (SACN 2015). Therefore, nutritional labelling information includes lactose found in milk and sugars naturally found within plants cells, in addition to added sugars. This is a potential source of confusion to consumers.

Prior to the 2015 SACN review of Carbohydrates and Health, sugars were defined by the scientific community as i) milk sugars, ii) intrinsic sugars (those found within plant cell walls), and iii) non-milk extrinsic sugars (Panel on Dietary Reference Values & DH 1991). In their 2015 publication, SACN adopted the term *Free Sugars*. The definition of free sugars remains the same as the previously termed non-milk extrinsic sugars, namely *"…all monosacchardes and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices"* (SACN 2015, p184). Table 4 below shows how the emerging evidence explored by SACN has influenced UK guidelines on free sugars intake.

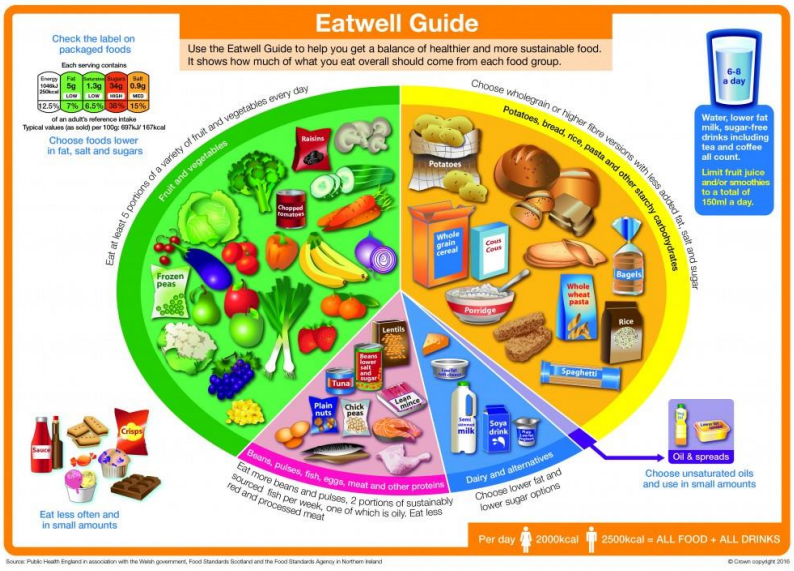
Table 4: Changes to population-based UK guidelines on intake of free sugars

Current guidelines: SACN 2015	**Previous guidelines: Panel on Dietary Reference Values & DH 1991**
Free sugars: Not to exceed 5% of total dietary energy from the age of 2 years upwards.	Non-milk extrinsic sugars: Less than 11% of total dietary energy

The new recommendation is incorporated into the pictorial Eatwell Guide (PHE 2016), which depicts the recommended diet for good health (see figure 1). In particular, SACN (2015) highlights the need to minimise the consumption of sugar-sweetened beverages for both children and adults (SACN 2015).

The negative aspect of sugars results from sugars being generally easy to consume in higher volumes, especially when present in drinks, and there is clear association with free sugars consumption and higher energy intakes (SACN 2015). In addition to the increased calorie consumption, the lack of fibre in sugary drinks increases any likely glycaemic response, although this depends on the type of sugar involved (SACN 2015), for example, sucrose containing drinks exerts a higher glycaemic response compared to fructose, which does not. However, on a positive and crucial note, individuals avoiding sugars *per se* can potentially miss the multiple nutritional benefits of milk products, fruits and the sweeter vegetables.

Figure 1: The Eatwell Guide (PHE 2015), updated in 2016 to reflect the evidence base. Health practitioners use the guide as the starting point for dietary advice of an individual. As can be seen, the guide includes a good proportion of carbohydrate-dominant foods, including fibre-rich types. The high sugar, fat and salty foods are positioned outside the guide as these should be occasional foods and not considered a necessary or regular part of a healthy diet.



Glycaemic response and Oligosaccharides

Oligosaccharides are composed of three to nine monomer units. Typically considered non-digestible, and therefore non-glycaemic in their natural form, the term includes synthetic maltodextrin; widely used in the food industry. Unlike other oligosaccharides, maltodextrins are digestible (SACN 2015). With the exception of maltodextrins, oligosaccharides avoid normal enzymic digestion in the small intestine and travel to the colon where fermentation by specific-strains of bacteria takes place. Oligosaccharides, therefore, are one of the carbohydrates identified as having prebiotic properties.

(See Table 5 for the carbohydrates known to have prebiotic properties). Being the preferred substrate for colonic bacteria, prebiotics support the proliferation of strains of bacteria associated with gut health. The resulting creation of SCFA reduces the pH of the gut lumen. The increased acidic environment affects the expulsion (as opposed to re-absorption) of cholesterol-containing metabolites such as those found in bile salts. This is one mechanism whereby prebiotics positively affects blood cholesterol levels (Lean & Combet 2017). Although not defined with any certainty, colon microbiota, pH and SCFA content are strongly associated with colo-rectal health and gut function in general (SACN 2015)

Oligosaccharides are present in a variety of vegetables and legumes. Common varieties include onions and beans. Furthermore, smaller amounts are in some larger molecular weight carbohydrates, namely wheat and rye (SACN 2015).

Table 5: Carbohydrates with prebiotic properties

Carbohydrate-based colon microbiota substrates
• Polyols / sugar alcohols • Oligosaccharides • Resistance Starch • Traditionally recognised dietary Fibre

Glycaemic response and polysaccharides

Polysaccharides, including starch, are characterised by long chains of monomer units. The monomer in starch is glucose, and hence starch has glycaemic potential. However, this is not a straight correlation. Research suggests digestibility of starch can vary substantially (Lean & Combet 2017; FAO/WHO 1998). The monomer units exist naturally in straight or branched chains and these are associated with different digestive properties and levels of resistance to enzymic activity (Lean & Combet 2017; SACN 2015). This resistance depends on aspects such as processing (e.g. grinding, fermentations); cooking (softening, gelatinisation of the plant cell, allowing enzyme access) and cooling prior to ingestion (enzymic activity reduces on cooling). Starch can also be contained within a fibrous cell wall (such as sweet corn and wholegrain rice), and effective mastication of the food will affect digestibility and availability and hence glycaemic response. Ingestion of resistant starch as a proportion of total carbohydrate is hard to quantify. Estimates suggest amounts between 3.2 and 5.7g/d (SACN 2015). An indigestible oligosaccharide component may also be present in the molecule. Furthermore, the higher fibre polysaccharides contain a range of components (cellulose, inulin, pectins), which are not digestible but have prebiotic properties (SACN 2015).

Previous definitions of fibrous polysaccharides included ***soluble*** and ***non-soluble.*** The terms refer to different types of fibres: non-soluble include the celluloses; soluble include the gums, mucilage's and glucans. These terms may be still helpful from an advisory point of view (due to the populace recognising the terms and food manufacturers utilising these terms on their products), and when conducting a literature review of the evidence on health and fibres. However, SACN (2015) suggest these terms should be phased out. Physiologically, the roles of the two forms are less clearly defined than previously thought. Both forms absorb water. Both slow down gut transit time and reduce absorption of glycaemic carbohydrates. Both are fermentable and both forms tend are found

together within intact plant cell walls (SACN 2015). Furthermore, dietary fibres previously came under the collective term of 'non-starch polysaccharides' (Panel on Dietary Reference Values and DH, 1991). Due to increased understanding of non-glycaemic carbohydrates, SACN (2015) adopted the new collective term 'dietary fibre', which includes all fermentable polymeric carbohydrates of three or more units (i.e. includes oligosaccharides), that increase faecal mass.

To highlight the variety of carbohydrates commonly ingested in typical UK diets, Table 5 provides examples of the range of carbohydrates found within common carbohydrate-dominant food.

Table 6: Type of carbohydrate found in common foods (g per 100g) (Finglas et al 2014)

Food	Total CHO	Total Dietary Fibre	Total Sugars	Glucose	Lactose	Fructose	Sucrose	Maltose
White bread	49.9	2.9	2.9	Tr	0	0.2	Tr	2.7
Wholegrain rice (boiled)	29.2	1.5	0.1	Tr	0	Tr	0.1	0
Peas	11.2	5.5	5.9	Tr	0	Tr	5.9	0
Pear	10.9	2.7	10.9	3.1	0	6.6	1.2	0
Low-fat fruit yoghurt	13.7	0.3	12.7	Tr	4.4	1.0	6.1	0.3
Semi-skimmed milk	4.7	0	4.7	0	4.7	0	0	0

Polysaccharides and the patient/ public health message

Fibrous carbohydrates are refined to make them more attractive for human consumption. Dietary choice is important on a physiological, social and psychological level (Gandy 2014; Lean & Combet 2017); therefore, it would be unrealistic or inappropriate to suggest avoidance of all refined polysaccharides. Variety, balance and moderation are concepts that support the achievement of dietary guidelines (Lawrence & Worsley 2007). Furthermore, while it is relevant to refer to foods as being predominantly-carbohydrate, foods rarely contain only one nutrient (Finglas et al 2014). UK legislation on refined flour fortification, alongside voluntary action on cereal fortification by the food industry, has considerably improved the micronutrient intake of vulnerable groups such as those with increased needs (e.g. during adolescence or pregnancy) or reduced intakes (e.g. the elderly) (Bates et al 2014; Lean & Combet 2017).

Even following refinement, the total fibre content of refined carbohydrates may be significant. For example, Table 6 shows the fibre content in 100g of a farmhouse white loaf (approximately two thick slices), is higher than that found in the same weight (two-three tablespoons) of wholegrain rice. Furthermore, the reduction in fibre in refined flour directly correlates to a reduction in the presence of phytic acid. Phytates have a propensity to bind to minerals such as iron and calcium in the small intestine and reduce their absorption (Lean & Combet 2017). On the other hand, the colonic fermentation of carbohydrates may stimulate mineral absorption and approximately 5% of calcium absorption has been shown to occur in the colon (SACN 2015); highlighting once more the complexity of this food group.

After consideration of these aspects, it is clear that even the more refined, less fibrous polysaccharides have nutritional value. However, portion control is key. As seen in Table 2, the higher fibre carbohydrates have the higher molecular weight. These correlate to greater satiety and aid weight management. Lower molecular weight carbohydrates generally correlate to less gastric satiety, thereby increasing the calorie potential (weight-for-weight) while potentially reducing the individual's ability to regulate blood glucose. As part of their responsibility to consider and respond to the evidence base, Public Health England (2015) continues to support starchy carbohydrates in general as a substantial part of a healthy diet, while encouraging consumption of higher fibre options. (PHE 2015).

Conclusion

Carbohydrates are a large and complex group, which includes many commonly consumed foods. Whereas the evidence strongly suggests drinks and foods containing a high percentage of added sugars can negatively impact health, the exclusion of other carbohydrates from the diet is not supported by the evidence.

Key Points:

Carbohydrates are a large food group, ranging from single-unit soluble molecules to complex insoluble molecules and include indigestible molecules of varying size. Predominatly of plant origin while including milk sugars.

Nutrition labelling information reflects complexity. *Carbohydrates: of which sugars*, includes lactose found in milk, sugars naturally found within plants cells and sugars added during manufacture. This is a potential source of confusion to consumers.

Not all carbohydrates raise blood glucose levels. A useful skill for the nurse practitioner is to understand the glycaemic potential of different carbohydrate groups.

Sugar-sweetened beverages are dominant glycaemic carbohydrates. In addition, these nutritionally poor drinks contribute to total energy intakes and weight gain.

Milk sugars, carbohydrates naturally present in fruit and vegetables and fibre-containing starches are relatively low-glycaemic carbohydrates. They can be encouraged as part of a healthy balanced diet.

Refined starchy carbohydrates:

- Portion control is prudent. A range of types is recommended, as depicted by the Eatwell Guide.
- The fibre content of refined carbohydrates such as white bread, can still be a significant contributor to total fibre intakes.
- Micronutrient content, naturally present or due to fortification, has been shown to make a considerable contribution to total micronutrient intakes.

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