Understanding the role of carbohydrates in optimal nutrition

Shirley Hinde

Abstract

In recent years, the regulation of carbohydrate intake has become regarded as essential to achieve a balanced diet, with a range of health benefits attributed to low-carbohydrate diets. However, much of the advice on reduced carbohydrate intake does not reflect government-led dietary guidelines. As a result of this conflicting information, patients requiring assistance with weight management or glycaemic control may become confused about the appropriate carbohydrate intake, or be encouraged to experiment with ‘fad’ diets. As front-line healthcare professionals, nurses are in a prime position to advise patients on carbohydrate intake, as well as signposting them to evidence-based dietary resources. This article outlines the constituents of dietary carbohydrate, considers the health benefits of carbohydrates, and explains their importance as part of a healthy and balanced diet.

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Keywords
diet, health promotion, healthy eating, meals, nutrition, nutritional intake, nutritional requirements, nutritional support, public health

Carbohydrates comprise a significant food group that provide a major source of dietary energy and assist in the regulation of blood glucose levels (Scientific Advisory Committee on Nutrition (SACN) 2015). They are composed of carbon, hydrogen and oxygen atoms. There are various forms of carbohydrates, from soluble monosaccharide molecules, such as glucose, to complex indigestible fibres (World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO) 1998). Although carbohydrates are derived largely from plants, other common sources of carbohydrate include milk sugars and honey (Public Health England (PHE) and Food Standards Agency (FSA) 2014).

Carbohydrates can be classified by molecular size, digestibility and glycaemic response (SACN 2015). In addition to energy provision, foods with a significant carbohydrate content are a beneficial source of micronutrients, including iron, zinc and B vitamins (PHE and FSA 2014, Lean and Combet 2017).

Diets high in unrefined fibre-rich carbohydrates – such as plant-based foods – also have anti-carcinoma and cardio-protective benefits, while the relatively low calorie contribution of these carbohydrates has the potential to assist in weight management and improve glycaemic control (World Cancer Research Fund and American Institute for Cancer Research 2007, SACN 2015). Conversely, the consumption of carbohydrate in the form of simple sugars is associated with dental caries (SACN 2015), while highly refined starches are associated with suboptimal glycaemic control (The British Dietetic Association 2018).

This article aims to clarify the constituents of dietary carbohydrate, to consider the health benefits of carbohydrates, and to emphasise their importance as part of a healthy and balanced diet.

Carbohydrates and public health

In recent years, the important role of carbohydrates as part of a healthy diet has...
been dismissed by some sections of the health media, with multiple articles detailing the supposed nutritional benefits of removing or reducing dietary carbohydrate intake (Spritzler 2016). The suggested health benefits of a reduced carbohydrate intake include weight loss, reduced gastrointestinal conditions, and improved brain function and energy levels (Dennett 2016). However, the promotion of a reduced-carbohydrate diet often contradicts government-led evidence-based guidelines on healthy eating, such as the Eatwell Guide (Figure 1) (PHE 2018). The Eatwell Guide (PHE 2018) recommends that individuals include a proportion of carbohydrate-dominant foods in their diet, including fibre-rich foods such as wholegrain cereals. Carbohydrate containing fibre-rich foods such as pulses and fruits and vegetables are also represented within the Eatwell Guide. It also recommends that foods high in sugar, fat and salt should be consumed occasionally and not considered a necessary or regular part of a healthy diet (PHE 2018).

One important challenge in ensuring effective public health provision is to address any confusion around healthy eating among the general public (Tedstone 2017). Part of the role of healthcare professionals such as nurses is to reduce any misunderstandings around lifestyle factors that may lead to suboptimal health (Tedstone 2017). Therefore, nurses must fully understand the role of carbohydrates as part of a balanced diet, and use their communication skills to promote effective healthy eating messages.

When providing public health messages, another consideration is whether the message is too simplistic, resulting in scientific inaccuracy. For example, a public health message that might be effective for those with type 2 diabetes mellitus could be that ‘All types of carbohydrate will increase your blood glucose level’ (The British Dietetic Association 2018). This is an unambiguous message that may be appropriate in some clinical situations and with particular patient groups. However, it is not scientifically accurate to state that all types of carbohydrate increase blood glucose levels; therefore, promoting such a broad message does not support complete understanding of carbohydrates among the general public.

**Carbohydrate classification**

One seminal theory is that there are two types of carbohydrate: physiologically available carbohydrate (able to be metabolised) such as starches and sugars, and physiologically unavailable carbohydrate (unable to be metabolised) such as fibre (McCance and Lawrence 1929, WHO and FAO 1998). However, it is now recognised that this theory does not represent the complete story, because while so-called unavailable carbohydrates such as fibre may not provide energy...
The most basic form of carbohydrate are single monosaccharides monomer units (for example, glucose), which bind with other monomer units to form disaccharides (for example, lactose) or polysaccharides (for example, starch). Therefore, carbohydrates can be classified in terms of molecular size and complexity. Table 2 provides a simple representation of carbohydrate classification according to molecular composition, alongside dietary examples. The sweetness associated with the smaller carbohydrate molecule reduces with increased molecular size and solubility, for example from honey or syrup to rice and pulses (Geissler and Powers 2005).

In the author’s clinical experience, a simpler classification that could be useful for nurses is one based on digestibility and subsequent glycaemic response. Blood glucose levels rise in response to the consumption of digestible carbohydrate, allowing the body to use glucose to provide energy. In general, carbohydrates with smaller molecular structures – such as glucose, lactose and maltose – are efficiently digested and absorbed in the human gut. However, not all carbohydrates produce a glycaemic response, irrespective of their size and digestibility (Bender 2014, SACN 2015). Therefore, it is important for nurses to understand the physiological effects of carbohydrates of various sizes.

**Table 1. Comparison of theories on the physiological use of ingested carbohydrate**

<table>
<thead>
<tr>
<th>Theory</th>
<th>Types</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory based on availability of carbohydrate to provide energy</td>
<td>Physiologically available carbohydrate</td>
<td>Carbohydrate that is digested in the small intestine, absorbed, then available for energy metabolism</td>
<td>Starches and sugars</td>
</tr>
<tr>
<td></td>
<td>Physiologically unavailable carbohydrate</td>
<td>Carbohydrate that is not digested nor absorbed and remains unavailable for energy metabolism. This type of carbohydrate also increases faecal mass</td>
<td>Non-starch dietary fibre</td>
</tr>
<tr>
<td>Theory based on the glycaemic response of carbohydrate</td>
<td>Glycaemic carbohydrate</td>
<td>Carbohydrate that is digested and absorbed in the small intestine, consequently raising blood glucose and stimulating insulin secretion (producing a glycaemic response)</td>
<td>Starches and sugars</td>
</tr>
<tr>
<td></td>
<td>Non-glycaemic carbohydrate</td>
<td>Carbohydrate that is not digested in the small intestine and does not produce a glycaemic response, but is instead digested by bacteria in the colon. The products of the subsequent fermentation in the colon (short-chain fatty acids) are available for energy metabolism. This type of carbohydrate also increases faecal mass</td>
<td>Polyols, oligosaccharides, resistant starch and fibres</td>
</tr>
</tbody>
</table>

(Adapted from World Health Organization and Food and Agriculture Organization of the United Nations 1998, Scientific Advisory Committee on Nutrition 2015)
Glycaemic response and disaccharides
Disaccharides comprise two monomer units that are bound together. Disaccharides break down into their monomer components in the small intestine and can then be absorbed to produce a glycaemic response. The amount of glucose present in common disaccharides varies as demonstrated in Table 3.

UK food labelling legislation for back of product labels requires the inclusion: ‘of which sugars’. The figures used on the label are drawn from laboratory analysis of, in the case of sugars, all monosaccharides and disaccharides within any given product. The analysis does not differentiate between milk sugar (lactose), fruit sugar (fructose) or added sugars such as sucrose. This is a potential source of confusion for consumers who are seeking to avoid dietary sugars because it may lead to restricted choices.

Before the SACN (2015) review of carbohydrates and health, sugars were defined by the scientific community as milk sugars, intrinsic sugars (those found within plant cell walls), and non-milk extrinsic sugars (Department of Health (DH) 1991). The SACN (2015) adopted the term ‘free sugars’. The definition of free sugars remains the same as the previously termed non-milk extrinsic sugars, namely ‘all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices’ (SACN 2015).

UK guidance on the intake of free sugars has changed over time. In 1991, the DH recommended that non-milk extrinsic sugars should constitute less than 11% of an individual’s dietary energy; since 2015, the SACN has recommended that free sugars should not exceed 5% of an individual’s total dietary energy after the age of two years. In particular, the SACN (2015) details the need to minimise the consumption of sugar-sweetened beverages for both children and adults. These recommendations have been incorporated into the Eatwell Guide (PHE 2018).

The negative effects associated with sugars result from them being generally easy to consume in high volumes, especially when present in drinks, and there is clear association between higher consumption of free sugars and higher energy intakes (SACN 2015). In addition to the increased calorie consumption, the lack of fibre in sugary drinks increases the glycaemic response, although this depends on the type of sugar involved (SACN 2015). For example, drinks containing sucrose (a disaccharide) result in a higher glycaemic response than drinks containing fructose (a monosaccharide). However, crucially, an individual who avoids sugars completely could potentially miss the multiple nutritional benefits of milk products, fruits and sweeter vegetables.

Glycaemic response and oligosaccharides
Oligosaccharides are present in a variety of glycaemic response and legumes such as onions and beans, and in smaller quantities in carbohydrates with a larger molecular weight such as wheat and rye (SACN 2015). Oligosaccharides are composed of 3-9 monomer units and are typically considered non-digestible, and therefore non-glycaemic in their natural form (SACN 2015). One exception is synthetic maltodextrin, which is widely used as an additive in the food industry and is easily digestible. Synthetic maltodextrin aside, oligosaccharides avoid normal enzymic digestion in the small intestine and travel to the colon where fermentation by specific-strains of bacteria takes place. Oligosaccharides are one of the carbohydrates identified as having prebiotic properties, which is important because prebiotics support the proliferation of strains of bacteria associated with gut health. The fermentation of oligosaccharides in the colon results in the production of short-chain fatty acids, which reduces the pH of the gut lumen. As a result, the increasingly acidic environment supports 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 affect blood cholesterol levels (Lean and Combet 2017).

Key points
• Carbohydrates are a major source of dietary energy and assist in the regulation of blood glucose levels (Scientific Advisory Committee on Nutrition 2015). Although carbohydrates are derived largely from plants, other common sources of carbohydrate include milk sugars and honey
• The most basic form of carbohydrate are single monosaccharides monomer units (for example, glucose), which bind with other monomer units to form disaccharides (for example, lactose) or polysaccharides (for example, starch)
• The Eatwell Guide (Public Health England 2018) recommends that individuals include a proportion of carbohydrate-dominant foods in their diet, including fibre-rich foods such as wholegrain cereals. Carbohydrate containing fibre-rich foods such as pulses and fruits and vegetables are also represented within the Eatwell Guide
• The evidence strongly suggests that consuming foods with a high percentage of added sugars can negatively affect health; however, it does not support the exclusion of other forms of carbohydrate from the diet

Although the role of gut microbiota is yet to be fully defined, colon microbiota, the pH of the gut lumen and the presence of short-chain fatty acids are significantly associated with colorectal health and effective gut function in general (SACN 2015).

Box 1 details the carbohydrates known to have prebiotic properties.

Glycaemic response and polysaccharides
Polysaccharides including starch are characterised by extended chains of monomer units. Starch is comprised of glucose monomer units, which means that it has glycaemic potential. However, research suggests that the digestibility of starch can vary substantially because the monomer units exist naturally in either straight or branched chains, which are associated with various digestive properties and levels of resistance
to enzymic activity (WHO and FAO 1998, SACN 2015, Lean and Combet 2017). This resistance to enzymic activity broadly depends on aspects such as:

- **Processing**, for example grinding (including through mastication) or fermentation which physically breaks down the plant cell walls.
- **Cooking**, which results in gelatinisation of the plant cell.

Consuming freshly cooked starches optimises enzymic access to the bonds between the monomer units and hence improves digestability.

Cooling the starch before consumption, which can reduce enzymic activity as a result of post-cooling structure changes at the site of monomer unit bonds. Higher fibre polysaccharides such as wholegrains, seeds and outer skins contain a range of components such as cellulose, insulin and pectins, which are not digestible but have prebiotic properties (SACN 2015).

Previous definitions of fibrous polysaccharides included the terms ‘soluble’ and ‘non-soluble’, which refer to different types of fibres (SACN 2015). For example, non-soluble fibrous polysaccharides include cellulose, while soluble fibrous polysaccharides include gums, mucilages and glucans. However, the physiological properties of soluble and non-soluble polysaccharides are less clearly defined than previously thought. For example, both types absorb water; both slow down gut transit time and reduce absorption of glycaemic carbohydrates; both are fermentable; and both are found

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### Table 2. Carbohydrate classification according to molecular composition, alongside dietary examples

<table>
<thead>
<tr>
<th>Form of carbohydrate</th>
<th>Dietary examples</th>
</tr>
</thead>
</table>
| **Monosaccharides** (Single monomer unit) | » Glucose in sweets, biscuits, fruit and honey  
» Fructose in honey, fruit and vegetables  
» Galactose in breast milk and animal milks  
» Less common natural monosaccharides include:  
  — Mannose  
  — Xylose  
  — Arabinose  
  — Fucose  
» Other types of monosaccharide include synthetic polyols (sugar alcohols) that are resistant to digestion in the small intestine, such as:  
  — Mannitol  
  — Xylitol  
  — Sorbitol |
| **Disaccharides** (Double monomer units) | » Sucrose in sugar beet or canes  
» Lactose in milk  
» Maltose in fermented grains |
| **Oligosaccharides** (3-9 monomer unit chain) | » Oligosaccharides are resistant to digestion in the small intestine and include:  
  — Fructosyl-sucroses in onions, leeks and garlic  
  — Galactosyl-sucroses in pulses  
  — Maltodextrins added to processed foods as a sweetener and texture modifier |
| **Polysaccharides** (Straight or branched chains of ten or more monomer units) | » Digestible starch, for example cooked pasta, potatoes, rice and oats  
» Resistant starch, which is not absorbed in the small intestine of healthy humans, for example:  
  — Starch unavailable for enzymic digestion because of enclosure by fibrous cell walls such as sweetcorn  
  — Raw starch granules such as muesli flakes  
  — Cooked and cooled retrograded starch such as potato salad |
| **Dietary fibre** | » The term ‘dietary fibre’ incorporates all carbohydrates that resist enzymic digestion in the small intestine and reach the large intestine undigested. Colonic bacteria ferment the carbohydrate components producing short-chain fatty acids and gases. Examples of dietary fibre include:  
  — Non-glycaemic polyols  
  — Oligosaccharides  
  — Resistant starch |

(Adapted from World Health Organization and Food and Agriculture Organization of the United Nations 1998, Scientific Advisory Committee on Nutrition 2015)

### Table 3. Glucose content of common disaccharides

<table>
<thead>
<tr>
<th>Disaccharide</th>
<th>Monomer units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maltose</td>
<td>Glucose plus glucose</td>
</tr>
<tr>
<td>Sucrose</td>
<td>Glucose plus fructose</td>
</tr>
<tr>
<td>Lactose</td>
<td>Glucose plus galactose (Bender 2014)</td>
</tr>
</tbody>
</table>

### Box 1. Carbohydrates associated with prebiotic properties

<table>
<thead>
<tr>
<th>Carbohydrates</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyls (sugar alcohols)</td>
<td></td>
</tr>
</tbody>
</table>
Oligosaccharides |  
Resistance starch |  
Traditionally recognised dietary fibre such as wholegrain bread, bran and potato skins |  
(Scientific Advisory Committee on Nutrition 2015) |
Table 4. Examples of the carbohydrate content of various common foods

<table>
<thead>
<tr>
<th>Food (per 100g)</th>
<th>Total carbohydrate (g)</th>
<th>Total dietary fibre (g)</th>
<th>Total sugars (g)</th>
<th>Glucose (g)</th>
<th>Lactose (g)</th>
<th>Fructose (g)</th>
<th>Sucrose (g)</th>
<th>Maltose (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White bread</td>
<td>49.9</td>
<td>2.9</td>
<td>2.9</td>
<td>Trace</td>
<td>0</td>
<td>0.2</td>
<td>Trace</td>
<td>2.7</td>
</tr>
<tr>
<td>Wholegrain rice (boiled)</td>
<td>29.2</td>
<td>1.5</td>
<td>0.1</td>
<td>Trace</td>
<td>Trace</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Peas</td>
<td>11.2</td>
<td>5.5</td>
<td>5.9</td>
<td>Trace</td>
<td>Trace</td>
<td>5.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pear</td>
<td>10.9</td>
<td>2.7</td>
<td>10.9</td>
<td>3.1</td>
<td>0</td>
<td>6.6</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>Low-fat fruit yoghurt</td>
<td>13.7</td>
<td>0.3</td>
<td>12.7</td>
<td>Trace</td>
<td>4.4</td>
<td>1.0</td>
<td>6.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Semi-skimmed milk</td>
<td>4.7</td>
<td>0</td>
<td>4.7</td>
<td>0</td>
<td>4.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(Public Health England 2014)

within intact plant cell walls (SACN 2015). Therefore, the SACN (2015) suggests that the terms soluble and non-soluble fibrous polysaccharides should be replaced with the collective term ‘dietary fibre’, which includes all fermentable polymeric carbohydrates of three or more monomer units – including oligosaccharides – that increase faecal mass, as shown in Table 2.

Table 4 provides examples of the carbohydrate content of various common foods, to demonstrate the range of carbohydrates typically ingested in the diet of a UK individual.

**Patient education**

As front-line healthcare professionals, nurses are in a prime position to reduce confusion about carbohydrates and directly influence the health of patients and the general public (Winslade et al 2013). Nurses can use the Eatwell Guide (Figure 1) (PHE 2018) as a starting point when providing patients with dietary advice.

Fibrous carbohydrates are refined to make them more attractive for human consumption, for example white bread is processed to remove wheat germ and bran. Various physiological, social and psychological factors will influence dietary choice; for example, an individual may choose to consume certain foods because of their health benefits, for social occasions such as religious holidays, or based on personal flavour preferences (Gandy 2014, Lean and Combet 2017). Therefore, it would be unrealistic for nurses to suggest that patients avoid all refined carbohydrate.

Furthermore, even after refinement, the total fibre content of refined carbohydrates may be significant. For example, Table 4 shows that the fibre content of 100g of white bread (approximately two thick slices), is higher than that found in the same weight (approximately two to three tablespoons) of wholegrain rice. In addition to enabling effective micronutrient fortification, a positive result of the fibre reduction involved in the process of producing refined flour is that it directly correlates with a reduction in the presence of phytic acid, which reduces the absorption of minerals such as iron and calcium (Lean and Combet 2017). In addition, the colonic fermentation of carbohydrates with prebiotic properties (Box 1) may stimulate mineral absorption and approximately 5% of calcium absorption has been shown to occur in the colon (SACN 2015). These points demonstrate the complexity of this food group and that even refined fibre polysaccharide carbohydrates have nutritional value. However, portion control remains important for the maintenance of a healthy weight.

While food types such as pasta or bread are often regarded as predominantly comprising a single nutrient such as carbohydrate, in reality this is rarely the case; for example, pasta can contain proteins and some fats (PHE 2014). When providing dietary advice to patients, nurses should recommend variety, balance and moderation to support them to achieve targets set by dietary guidelines (Lawrence and Worsley 2007, PHE 2018).

UK legislation on refined flour fortification, alongside voluntary action on cereal fortification by the food industry, has considerably improved the micronutrient intake for vulnerable groups such as those who are pregnant and adolescents, or in people with reduced food intake such as older adults (PHE and FSA 2014, Lean and Combet 2017).

As part of its responsibility to consider and respond to the evidence base, PHE (2018) supports the consumption of foods containing starchy carbohydrates such as cooked pasta, potatoes, rice and oats as a substantial part of a healthy diet, while encouraging consumption of higher-fibre options such as potatoes with the skins intact and pulses. When discussing healthy eating with patients, nurses should consider that milk sugars, carbohydrates naturally present in fruit and vegetables, including pulses, and fibre-containing starches, are recommended as part of a healthy and balanced diet.

**Conclusion**

Carbohydrates are a large and complex food group, which includes various commonly consumed foods. The evidence strongly suggests that consuming foods with a high percentage of added sugars can negatively affect health; however, the evidence does not support the exclusion of other forms of carbohydrate from the diet. Nurses are ideally placed to provide dietary advice to patients and the general public to promote healthy eating, which includes a variety of carbohydrates as part of a balanced diet.
References


