# Module 1: The science of dietary fibre

**Objectives**

This module will help you understand:

- What dietary fibre is, including how it is defined, classified and measured.
- The properties of different fibre types.
- What functional fibres are.

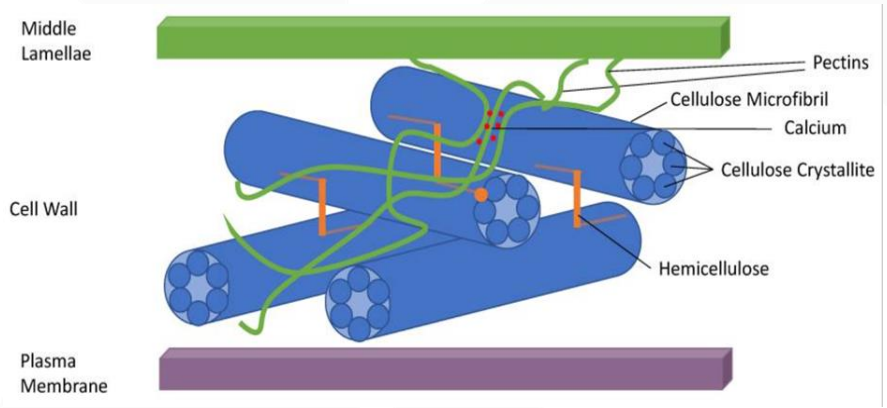
# Why should we be interested in dietary fibre?

- It is increasingly recognised that diets rich in fibre have important health benefits.
- Research has suggested an increased risk of chronic diseases such as cardiovascular disease, certain cancers and type 2 diabetes with dietary patterns that are low in fibre and high in saturated fat, sugars and salt.
- Dietary fibre is also important for gut health and in the prevention of constipation (the health benefits of fibre are covered in more detail in module 3).

# What is dietary fibre?

- Fibre is important for our health but what is it?
- Typically, dietary fibres are **carbohydrates** including **polysaccharides** such as cellulose and pectin. But some other substances, such as lignin and waxes are also considered as dietary fibres.
- Dietary fibre does not refer to one single chemical entity but rather to a complex range of substances in plant foods which cannot be completely broken down by human digestive enzymes and so doesn't get digested in the small intestine.

The majority of dietary fibres are structural polysaccharide components of plant-cell walls known as non starch polysaccharides (NSP).




Dietary fibre also encompasses resistant starches – starches that cannot be digested in the small intestine.

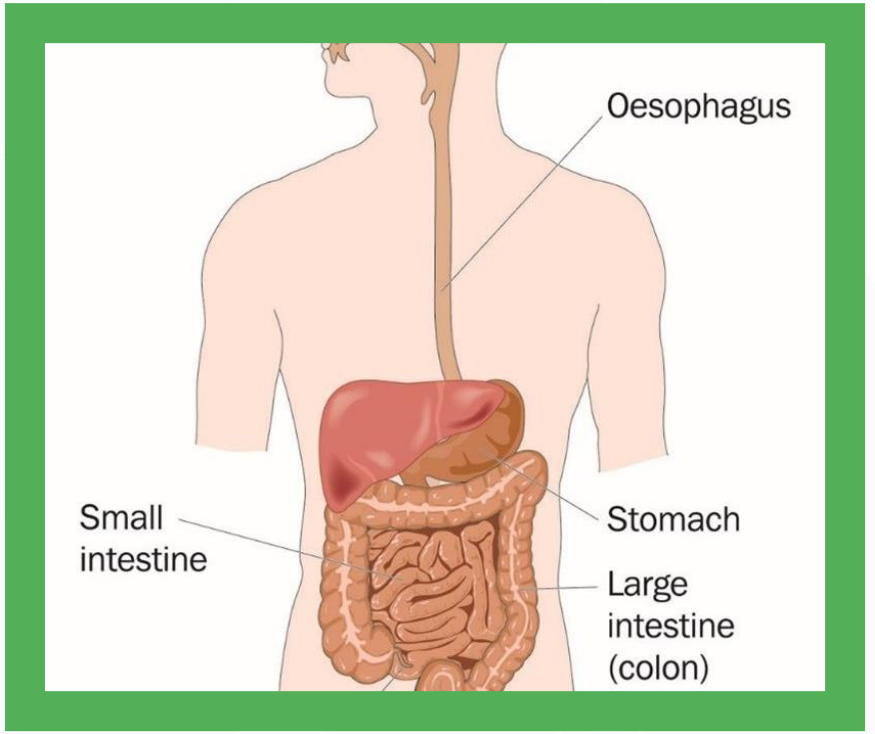
Most foods do not contain a single type of fibre but a range of different naturally occurring dietary fibres. Ingredients containing certain fibres can also be added to food products.

# Non-digestible carbohydrates

- Nutritionally, it is important to differentiate between two broad categories of carbohydrates:

**Digestible carbohydrates** (e.g. sugars) absorbed and digested in the small intestine

**Non-digestible carbohydrates** (e.g. fibres) reach the large intestine where they are at least partially fermented by the gut bacteria in the colon




The physiological effects associated with consumption of dietary fibre are distinct from digestible carbohydrates and include:

- decreased intestinal transit time and increased stool bulk
- reducing blood cholesterol levels
- reducing postprandial blood glucose

# Dietary fibre: Definition

- Definitions of dietary fibre have evolved over time as analytical methods and understanding has evolved, but there is still some disagreement about its exact definition and how it should be analysed.

Current definitions are typically based around descriptions provided by national and international bodies for food standards, such as CODEX Alimentarius, and have focused on fibre being the **non-digested and/or non-absorbed fraction** of carbohydrates in plant foods.

**Why do we need definitions?**

From a regulatory standpoint, definitions can bring clarity. They provide parameters for research and product development for industry and scientists, and they facilitate consistent application of labelling and health claims which gives consumers confidence in the declarations on the packaging of the food they eat.

Further Interest? See supplementary material for
**A historical look at different definitions of dietary fibre**

# The CODEX definition of dietary fibre

Carbohydrates can be classified based on the chemical character of the individual sugar or saccharide molecules (monomers) and the **degree of polymerisation** (DP) (i.e. the number of monomeric units in the polymer).

**In 2008, the CODEX Alimentarius (the FAO/WHO international food standards) agreed a definition for dietary fibre as:**

- *carbohydrates which are not digested or absorbed in the human small intestine with **ten or more monomeric units (i.e. DP ≥10).***

CODEX ALIMENTARIUS
INTERNATIONAL FOOD STANDARDS

Food and Agriculture Organization of the United Nations

World Health Organization

The definition encompassed

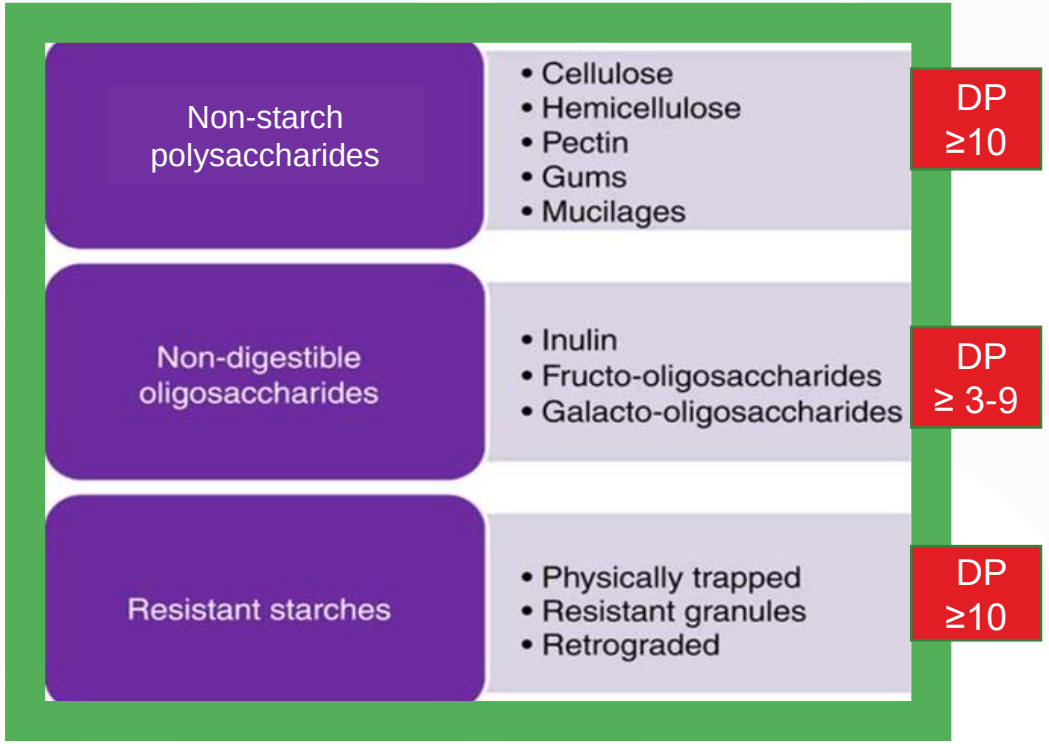
- edible carbohydrate polymers naturally occurring in foods such as wholegrains, legumes, fruit and vegetables, nuts and seeds.
- synthetic, isolated or extracted fibre (functional fibres).

**However these functional fibres can only be included in the definition of dietary fibre if they have a demonstrably physiological benefit to health**.

# Types of dietary fibre

- The CODEX definition also allows some flexibility, with authorities being able to decide whether compounds with **degree of polymerisation (**DP) of 3–9 could be included in the definition.

- The European Commission (EC), US Food and Drug Administration (FDA), Health Canada and the Food Standards Australia New Zealand (FSANZ) have adopted the definition to include three or more monomeric units which includes non-digestible oligosaccharides (DP 3-9) (e.g. inulin and fructo-oligosaccharides).




**US FDA definition for dietary fibre that can be declared on the Nutrition and Supplement Facts labels**: 'Non-digestible soluble and insoluble carbohydrates (with 3 or more monomeric units), and lignin that are intrinsic and intact in plants; isolated or synthetic non-digestible carbohydrates (with 3 or more monomeric units) determined by FDA to have physiological effects that are beneficial to human health'.

# What are functional fibres?

There is no internationally agreed definition of a functional fibre but generally they are considered to be **an ingredient that may be isolated or extracted using chemical, enzymatic, or aqueous steps added to a food that imparts a positive health effect.**

# How are functional fibres produced?

- Functional fibre ingredients can be produced from sources that might otherwise be considered waste products. For example, wheat straw, soy hulls, oat hulls, coffee grounds, peanut and almond skins, corn stalks and cobs, spent brewer's grain and waste portions of fruits and vegetables.

- Or they can be manufactured from grains like corn or wheat (e.g. polydextrose and soluble corn fibre) or from fruit, vegetables, legumes, nuts and seeds, or the fibres can be modified forms of traditional fibres.

# Functional fibres in foods

The emergence of novel sources of fibres as an ingredient has offered new opportunities to increase the fibre content of foods, with a potential physiological benefit.

Isolated dietary fibres have diverse functional properties which affect product quality and characteristics such as consistency, texture, and sensory characteristics.

Certain functional fibre ingredients can help to reduce fat and free sugars content in foods For example, inulin, polydextrose, soluble corn fibre and fructo-oligosaccharides are bulking agents that can be used in low/reduced sugar products.

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This table illustrates some of the functional fibres currently used in the food industry.

| Examples of functional properties of some dietary fibres | |
|---|---|
| **Fibre type** | **Potential functions** |
| Inulin | Fat/sugar replacer, texture modification |
| Konjac (flour) mannan carrageenan and gum for gelling | Binding agent |
| Pectin | Gelling agent, texture modification |
| Polydextrose | Bulking agent and texture modification |
| Psyllium seed husk | Thickener |
| Resistant starch | Swelling capacity, improves viscosity, gelling agent and water-binding |
| Soluble corn fibre | Bulking agent and improves viscosity |
| Xanthan gum | Thickener, texture modification |
| β-glucan | Binding agent |

# Functional fibres and health

There is evidence to show that particular isolated and extracted fibre have positive effects, for example, on blood lipids and gut function.

The nutrition and health evidence base would suggest a wide range of health benefits associated with including a mix of fibre rich foods in the diet, and therefore it is recommended that fibre intakes should be achieved through a variety of food sources.

Added and functional fibres could be one strategy to help bridge the gap between actual intake of fibre and global dietary recommendations.

# What is Resistant Starch?

- Resistant starch is a form of starch that cannot be digested in the small bowel, and as a result it is classified as a type of fibre.
- There are 5 types of resistant starch (RS1-RS5, see Table opposite).
- Resistant starch can be produced or modified commercially and incorporated into some food products as a functional ingredient.
- It is found naturally in some foods such as bananas, potatoes, grains, and legumes.
- US FDA have only approved RS2 and RS4 as dietary fibres, and the EU make reference to RS2 (high amylose maize) in their authorised health claim for resistant starch.

| Types of resistant starch (RS) | |
|---|---|
| **RS1** | Inaccessible to digestive enzymes due to the physical barriers formed by cell walls and protein matrices. Present in bread, seeds and legumes. |
| **RS2** | Starches protected from digestion due to their crystalline structure. Present in potatoes (higher amounts in raw versus cooked), bananas (higher amounts in unripe fruits). |
| **RS3** | Retrograded starch formed when starchy foods (e.g. potatoes, pasta) are cooked then cooled. |
| **RS4** | Chemically modified starch formed by crosslinking, etherisation or esterification. Present in foods containing modified starches such as some bread and cakes. |
| **RS5** | Two different components have been proposed as RS5 either amylose–lipid complexes, which either form during processing or are created artificially; or resistant maltodextrin which is processed to purposefully rearrange starch molecules. |

# The physicochemical properties of fibre: ‘soluble’ and ‘insoluble’

- The terms soluble and ‘insoluble fibre are frequently used to differentiate between soluble types of fibre (e.g. pectins) and insoluble components (e.g. cellulose).
- However, this differentiation is problematic for a number of reasons (see figure opposite).
- **Therefore, FAO/WHO proposed the distinction between soluble and insoluble fibre should be phased out.**

## Why should dietary fibre not be defined by its solubility?

Measuring / classifying fibre solubility is dependent on the method used; values for ‘soluble’ and ‘insoluble’ fractions can vary significantly.

Varying pH conditions within the gastrointestinal tract and between individuals may affect solubility.

Solubility alone does not predict the physiological effects and functional properties of fibre.

Fibre in foods is often a complex mix of soluble and insoluble fibres exerting different physiological effects in the gastrointestinal tract at the same time.

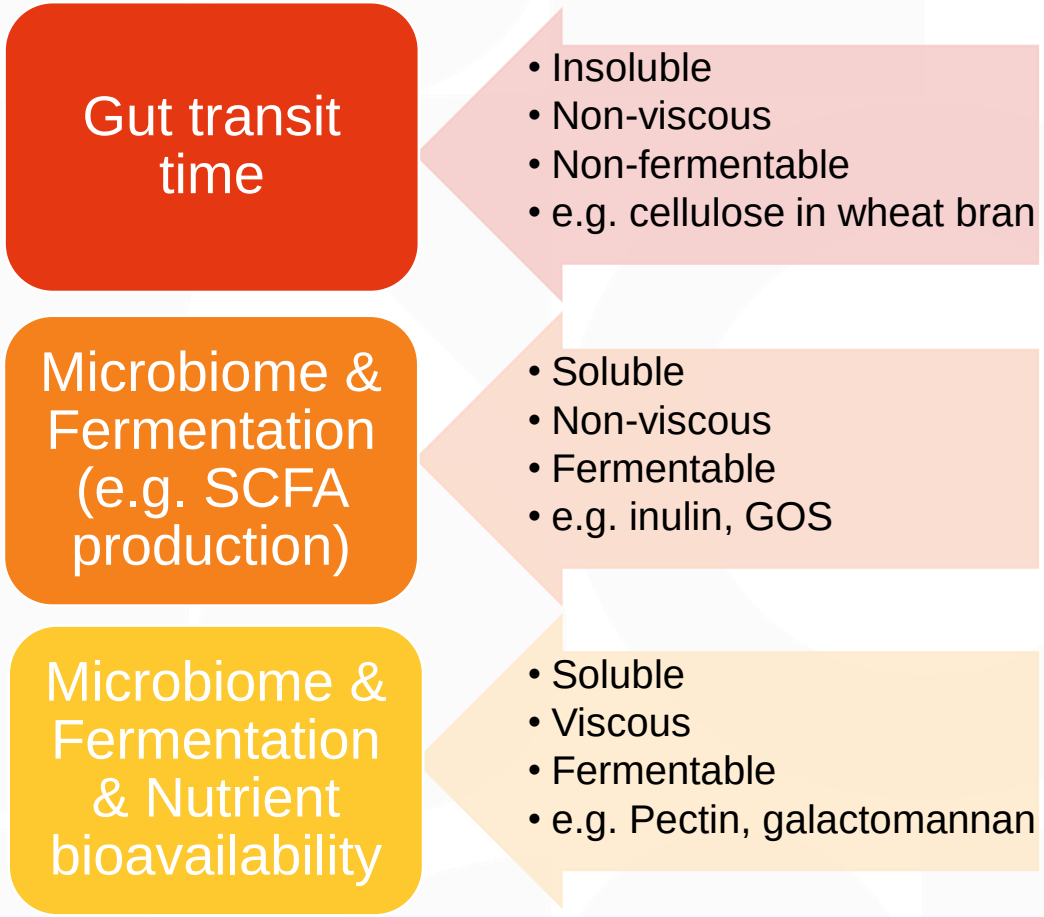
# Fermentability and viscosity of dietary fibres

Although ‘SOLUBILITY’ alone may be a poor indication of physiological function, it is important for its effect on VISCOSITY and FERMENTABILITY.

| Fermentability | Viscosity |
| --- | --- |
| • Fermentability may be considered a more appropriate way to categorise fibres in terms of their effect on health.<br>• Different fibres may be described as less or more fermentable or having a low or high fermentability.<br>• Higher fermentability will increase microbial biomass & fermentation end-products (e.g. short-chain fatty acids) | • Fibres can also be defined in terms of their viscosity.<br>• Some soluble fibres thicken when mixed with fluids. This includes gums, pectins, psyllium, and beta-glucans.<br>• They form a gel-like substance in the gut which can slow the rate of absorption of nutrients such as glucose. |
| **Fermentability** describes the capability of fermentation - the microbial conversion of complex molecules to end products like acids | **Viscosity** is a fluid’s resistance to flow. A fluid with a high viscosity, such as honey, flows at a slower rate than a less viscous fluid, such as water |

# Physicochemical characteristics and functionality

- The combination of the three physicochemical characteristics of fibre (solubility, viscosity and fermentability) work together to determine its functional properties in the gut.
- We will look at this in more detail in the next slide.




GOS, galacto-oligosaccharides;
SCFA, short-chain fatty acid.

# The physicochemical characteristics of common dietary fibres

| Fibre type | Common sources | Physicochemical characteristics | | | Functionality |
|---|---|---|---|---|---|
| | | Solubility | Viscosity | Fermentability | |
| **Cellulose** | All green plant cell walls | Insoluble | Non-viscous | Low | • Faster transit<br>• Stool bulking |
| **Arabinoxylans** | Wheat, psyllium | Low-medium | Medium | High | • Nutrient bioavailability<br>• Faster transit<br>• Water holding |
| **Beta-glucans** | Oats, barley, fungi | Low-medium | Medium-high | High | |
| **Pectins** | Fruit, vegetables, legumes | High | Medium-high | High | • Nutrient bioavailability<br>• SCFA production |
| **Inulin** | Cereals, fruits, vegetables | Medium-high | Low-high | High | • SCFA production<br>• Prebiotic |
| **Galacto-oligo saccharides** | Pulses | High | Low | High | |
| **Resistant starch 2** | Cereals, raw legumes, raw fruits, vegetables | Low | Non-viscous | High | • SCFA production<br>• Prebiotic potential |
| **Resistant starch 4** | Synthesized (e.g. acylated starches) | Low to high | Low to medium | High | • SCFA production<br>• Prebiotic potential |
| **Resistant maltodextrins** | Starch (e.g. from rice, corn, wheat, potato) | High | Non- viscous to low | High | • SCFA production |

*adapted from Gill et al. 2021*

SCFA : Short chain fatty acid

# Fibre Analytics:
# Why is it important to accurately quantify dietary fibre?

To define fibre intakes in nutrition studies looking at association of dietary fibre and health

To set dietary recommendations and inform public

For nutrition claims and labelling purposes

# How is dietary fibre analysed?

- The concept of dietary fibre as a food component resistant to digestion in the small and large intestine has proved difficult to translate into straightforward analytical chemistry.
- The complex and variable components that constitute dietary fibre require complex analytical chemistry.
- Different analytical approaches have evolved, and efforts have been made towards analytically meaningful interpretations and methods.

**Examples of different methods for measuring fibre**

| **Empirical** (AOAC Methods) | **Rational** (Englyst) |
| --- | --- |
| • AOAC methods measure dietary fibre gravimetrically (e.g. methods 985.29 etc) and by HPLC (methods 2009.01 and 2017.16) | • Englyst methods measure fibre chemically |

HPLC, High-performance liquid chromatography.
AOAC: Association of Official Analytical Collaboration

# More on the Englyst method…

- The Englyst method generally gives lower values than AOAC methods since lignin and resistant starch are not included.
- European Member States and the US use AOAC methods.
- Englyst was traditionally used as the official analysis method in the UK. However in 2015 the Scientific Advisory Committee on Nutrition recommended the use of AOAC and this is now used.

# More on AOAC methods....

**AOAC Method 2017.16:**

accurately measures all components of dietary fibre as defined by Codex Alimentarius, including resistant starch and non-digestible oligosaccharides.

**Analysis Name:** Rapid Total Dietary Fiber (CODEX Definition)

**Method Number:** AOAC 2017.16

**Scope of Application:** Applicable to plant materials, foods, food ingredients and raw materials consistent with the CODEX Fiber Definition including naturally occurring, isolated, modified, and synthetic polymers meeting the fiber definition. Plant materials include grains, cereals, fruits and vegetables.

**Description:** Enzymatic-gravimetric-liquid chromatographic method for the quantitative determination of Dietary Fibers. This method is similar in principle and procedure to AOAC 2009.01. The AOAC 2017.16 method differs in that it has a shortened digestion time and increased concentration for enzymes amylase/amg. This new process in digestion more closely resembles the human digestion process.

**Older AOAC methods…**

TABLE I

**Codex/AOAC/AACCI Methods for the Analysis of Dietary Fiber (DF)**

| AOAC Method | AACCI Method | Codex Type[a] | What Is Measured[b] |
|---|---|---|---|
| 985.29 | 32-05.01 | I | Total HMWDF (IDF + HMWSDF) |
| 991.42 | 32-20.01 | I | IDF in foods |
| 993.19 | … | I | HMWSDF in foods |
| 991.43 | 32-07.01 | I | IDF and HMWSDF separately |
| 994.13 | 32-25.01 | I | Total HMWDF; provides sugar composition and Klason lignin |
| 2001.03 | 32-41.01 | I | HMWDF and LMWSDF in foods devoid of resistant starch |
| 993.21 | … | I | Total HMWDF in samples with >10% fiber and <2% starch |
| 2009.01 | 32-45.01 | I | HMWDF and LMWSDF in all foods |
| 2011.25 | 32-50.01 | * | IDF, HMWSDF, and LMWSDF in all foods |
| 995.16 | 32-23.01 | II | (1→3)(1→4)-β-Glucan in cereals, feeds, and foods |
| 997.08 | 32-31.01 | II | Fructans and FOS |
| 999.03 | 32-32.01 | III | Fructans and FOS (underestimates highly depolymerized FOS) |
| 2000.11 | 32-28.01 | II | Polydextrose |
| 2001.02 | 32-33.01 | II | Trans galacto-oligosaccharides |
| 2002.02 | 32-40.01 | II | Resistant starch ($RS_2$ and $RS_3$) |

[a] Asterisk (*) indicates that no decision has yet been made by Codex concerning this method. Method types are defined in Box 2.

[b] HMWDF = higher-molecular-weight DF; IDF = insoluble DF; HMWSDF = higher-molecular-weight soluble DF; LMWSDF = lower-molecular-weight soluble DF; and FOS = fructooligosaccharides.

**Some food databases still include values derived from outdated AOAC methods that do not reflect current CODEX fibre definitions. As such, the fibre content in foods can vary depending on the definition and/or the measuring methods used.**

# Key learning points (1)

**Benefits of fibre**

- A high fibre diet containing plenty of wholegrains, fruit and vegetables and plant-based proteins such as legumes, nuts and seeds is associated with health benefits and is recommended in food based dietary guidelines globally.

**Definition**

- The definition of dietary fibre typically focuses on fibre being the non-digested and/or non-absorbed fraction of carbohydrates that have a beneficial physiological effect. Most foods do not contain a single type of fibre but a range of different naturally occurring dietary fibres, and ingredients containing certain fibres can be added to food products.

**Functional Fibre**

- Functional fibres are considered to be an ingredient added to a food that imparts a positive health effect.

# Key learning points (2)

**Physiological function**

- The physiological effects that are associated with consumption of dietary fibre (non-digestible carbohydrates) are distinct from those of digestible carbohydrates.
- The terms ‘soluble’ and ‘insoluble’ fibre is frequently used but ‘solubility’ alone may be a poor indication of physiological function.
- The combination of solubility, viscosity and fermentability are important in determining the functional effects of fibres in the gut.

**Analytical methods**

- We need to quantify (measure) dietary fibre for research purposes, informing the public, and assessing nutrition claims.
- The Englyst method generally gives lower data than AOAC methods since lignin and resistant starch are not included. AOAC methods are largely recommended as the method for fibre analysis. The AOAC Method 2017.16 measures all components of dietary fibre as defined by Codex Alimentarius, including resistant starch and non-digestible oligosaccharides.

# Key references

**Definition of fibre**


- Augustin LSA et al. Dietary Fibre Consensus from the International Carbohydrate Quality Consortium (ICQC). Nutrients. 2020 Aug 24;12(9):2553.
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- Joint FAO/WHO Food Standards Programme, Secretariat of the CODEX Alimentarius Commission. CODEX Alimentarius (CODEX) Guidelines on Nutrition Labeling CAC/GL 2–1985 as Last Amended 2010. Rome: FAO; 2010.
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# Key references


**Physicochemical functions of fibre**

- Gill, S.K., Rossi, M., Bajka, B. et al. Dietary fibre in gastrointestinal health and disease. Nat Rev Gastroenterol Hepatol 18, 101–116 (2021).

**Methods of analysing dietary fibre (1)**

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- Englyst, H. N., Cummings, J. H. An improved method for the measurement of dietary fiber as non-starch polysaccharides in plant foods. J. AOAC International 1988, 71, 808-814.
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**Methods of analysing dietary fibre (2)**

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**Functional Fibres**

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