



# ENFiber

European Network for Valorising Food  
Processing Waste into Sustainable Fibers

## Dietary fibres

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# What do we mean by dietary fibre?

- Dietary fibre is a group of food components that escapes digestion and absorption in the human small intestine.
- The group includes several carbohydrate polymers with different structures and properties.
- Some fractions undergo microbial fermentation in the colon. Others contribute mainly through water retention and physical bulk.
- The everyday term “roughage” captures only part of this broader concept.



Regulation (EU) 1169/2011, Annex I

# Where does dietary fibre come from?

- Whole grains supply fibre in the bran and other grain tissues.
- Beans, lentils and chickpeas provide fibre within a protein- and starch-containing food matrix.
- Fruit and vegetables contribute cell-wall material in both skins and edible tissues.
- Nuts and seeds offer additional sources. Each food contains a mixture of fibre components.
- That mixture is why two foods with the same fibre amount may behave differently during processing and digestion.



U.S. Food and Drug Administration, Dietary Fiber fact sheet (2021).

# Basic structural language

- A monosaccharide is one sugar building block, such as glucose, xylose or fructose.
- A polysaccharide is a long chain of sugar units. An oligosaccharide contains a shorter chain.
- A glycosidic linkage is the bond connecting units. In  $\beta$ -(1 $\rightarrow$ 4), the numbers identify the linked carbon positions and  $\beta$  describes the bond configuration.
- Chain length, branching and charged groups influence hydration, packing and interactions. These features help explain why fibres behave differently.

Supplied FIBER101 notes v4; sources detailed in speaker notes.

# Cellulose, hemicelluloses and lignin

| Component and source             | Basic structure                              | Relevance                                                   |
|----------------------------------|----------------------------------------------|-------------------------------------------------------------|
| Cellulose: plant cell walls      | Linear glucose chains, $\beta$ -(1→4) bonds  | Chains associate into strong microfibrils                   |
| Hemicelluloses: plant cell walls | A family including xylans and mannans        | Backbones and branches vary with source                     |
| Arabinoxylan: cereal tissues     | Xylose backbone with arabinose substitutions | Branching affects accessibility and hydration               |
| Lignin: lignified tissues        | Complex aromatic polymer, not a carbohydrate | Associated lignin has a qualified role in fibre definitions |

Supplied FIBER101 notes v4; sources detailed in speaker notes.

# $\beta$ -Glucan, pectin and inulin: different structures

| Fibre and familiar source               | Basic structure                                                                                 | Property to remember                               |
|-----------------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------|
| Cereal $\beta$ -glucan: oats and barley | Linear glucose polymer with $\beta$ -(1 $\rightarrow$ 3) and $\beta$ -(1 $\rightarrow$ 4) links | Mixed linkages affect chain packing and viscosity  |
| Pectin: citrus peel and apple pomace    | Galacturonic-acid-rich regions with variable methyl esters                                      | Gelation depends on grade, sugar, acid and calcium |
| Inulin: chicory root                    | Mainly $\beta$ -(2 $\rightarrow$ 1)-linked fructose, often with terminal glucose                | Chain length influences solubility and texture     |

Purushotham et al. (2022); pectin specifications, FAO; supplied notes v4.

# Seed gums: guar, carob and psyllium

| Ingredient                  | Source                                           | Basic structure                                       |
|-----------------------------|--------------------------------------------------|-------------------------------------------------------|
| Guar gum                    | Seed endosperm of <i>Cyamopsis tetragonoloba</i> | Mannose backbone with galactose side groups           |
| Locust bean gum (carob gum) | Seed endosperm of <i>Ceratonia siliqua</i>       | Galactomannan with fewer galactose branches than guar |
| Psyllium husk (ispaghula)   | Outer seed coat of <i>Plantago ovata</i>         | Complex, highly branched arabinoxylan-rich material   |

FAO guar and locust bean gum specifications; Fischer et al. (2004).

# Psyllium: a seed husk that forms a hydrated gel

- Psyllium, also called ispaghula, is obtained from the outer seed coat of *Plantago ovata*.
- Its gel-forming fraction is rich in highly branched arabinoxylan, with a xylose backbone and arabinose-containing branches.
- The husk swells strongly in water and forms a cohesive hydrated mass.
- In food formulation, this water-binding material can improve cohesion in gluten-free doughs. Husk form, dose and water addition matter.



Fischer et al. (2004), Carbohydrate Research 339:2009–2017; FIBER101 notes v4.

# Where is fibre located in plant foods?

- Cell walls provide cellulose, hemicelluloses and pectic substances that support plant tissues.
- Cereal outer layers concentrate many cell-wall components. Refining changes which tissues remain in the food.
- Some plants also contain non-digestible storage carbohydrates, such as inulin-type fructans.
- Some starch escapes small-intestinal digestion. This fraction is called resistant starch and depends on food structure and processing.



Englyst et al. (1992); Slavin (2013); Elleuch et al. (2011).

# Whole foods and fibre ingredients

- Intrinsic fibre remains within the original food structure, as in oats, beans and fruit.
- Extraction produces ingredients such as citrus pectin, chicory inulin or cereal fibre concentrates.
- Ingredient specifications describe purity, particle size, hydration and processing history.
- Regulatory recognition of an isolated ingredient requires a separate check. Technological usefulness alone does not establish fibre status.



**Illustrative sources: citrus pectin, chicory inulin and cereal fibre.**

Codex CXG 2-1985, §2.6; Regulation (EU) 1169/2011, Annex I.

# The Codex Alimentarius definition

- Carbohydrate polymers resistant to endogenous enzymes in the human small intestine.
- Core threshold: 10 or more monomeric units.
- National authorities decide whether to include chains with 3–9 units.
- Extracted and synthetic categories require evidence of a physiological benefit.

**10+ units in the core definition; 3–9 at national discretion**

Codex CXG 2-1985, §2.6; Regulation (EU) 1169/2011, Annex I; FDA dietary-fibre guidance.

# Three routes into the definition

| Category            | Origin                                   | Key consideration                  |
|---------------------|------------------------------------------|------------------------------------|
| Naturally occurring | Present in the food as consumed          | Food context                       |
| Obtained from food  | Physical, enzymatic or chemical recovery | Demonstrated physiological benefit |
| Synthetic           | Manufactured carbohydrate polymer        | Demonstrated physiological benefit |

Codex CXG 2-1985, §2.6; Regulation (EU) 1169/2011, Annex I; FDA dietary-fibre guidance.

# EU and US implementation

## European Union

- Degree of polymerization (DP)  $\geq 3$  under Regulation 1169/2011
- Naturally occurring, extracted and synthetic categories
- Benefits required for extracted / synthetic categories

## United States

- DP  $\geq 3$  carbohydrates plus specified lignin scope
- Intrinsic and intact plant material
- Food and Drug Administration (FDA) assessment of isolated / synthetic ingredients

Codex CXG 2-1985, §2.6; Regulation (EU) 1169/2011, Annex I; FDA dietary-fibre guidance.

# Resistant starch as dietary fibre

## What makes starch resistant?

- Resistant starch (RS) escapes digestion in the small intestine.
- Its glucose units remain in structures that digestive enzymes cannot readily access or hydrolyse.
- Only the resistant fraction counts towards fibre, rather than all starch in the food.

## When does it count as fibre?

- Resistant starch can meet the dietary-fibre definition.
- For extracted or modified ingredients, the applicable definition and evidence requirements still apply.
- The analytical method must recover the resistant fraction appropriately.

Sources: EU Regulation 1169/2011, Annex I; FDA, Questions and Answers on Dietary Fiber.

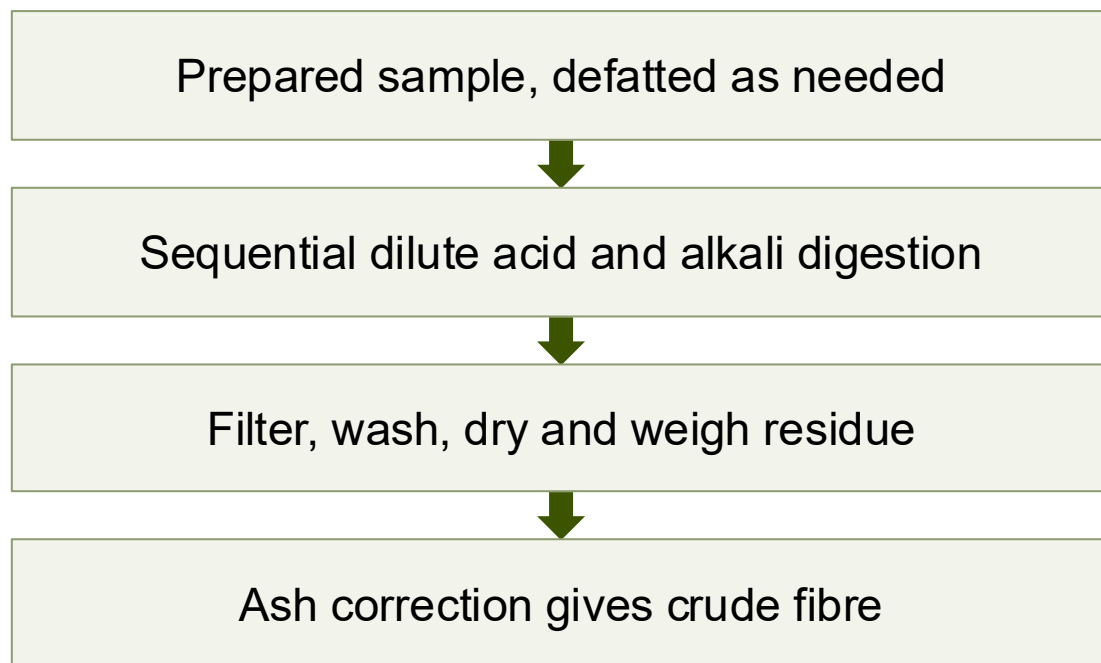
# Resistant starch (RS): five forms of resistance

| Type | Basis of resistance       | Teaching example                    |
|------|---------------------------|-------------------------------------|
| RS1  | Physical inaccessibility  | Intact structures in grains / seeds |
| RS2  | Native granular structure | Selected raw starches               |
| RS3  | Retrogradation            | Starch after cooking and cooling    |
| RS4  | Chemical modification     | Modified resistant starch           |
| RS5  | Amylose–lipid complexes   | Complexed starch fraction           |

Englyst et al. (1992); supplied FIBER101 notes v4.

# Crude fibre and total dietary fibre: method flow

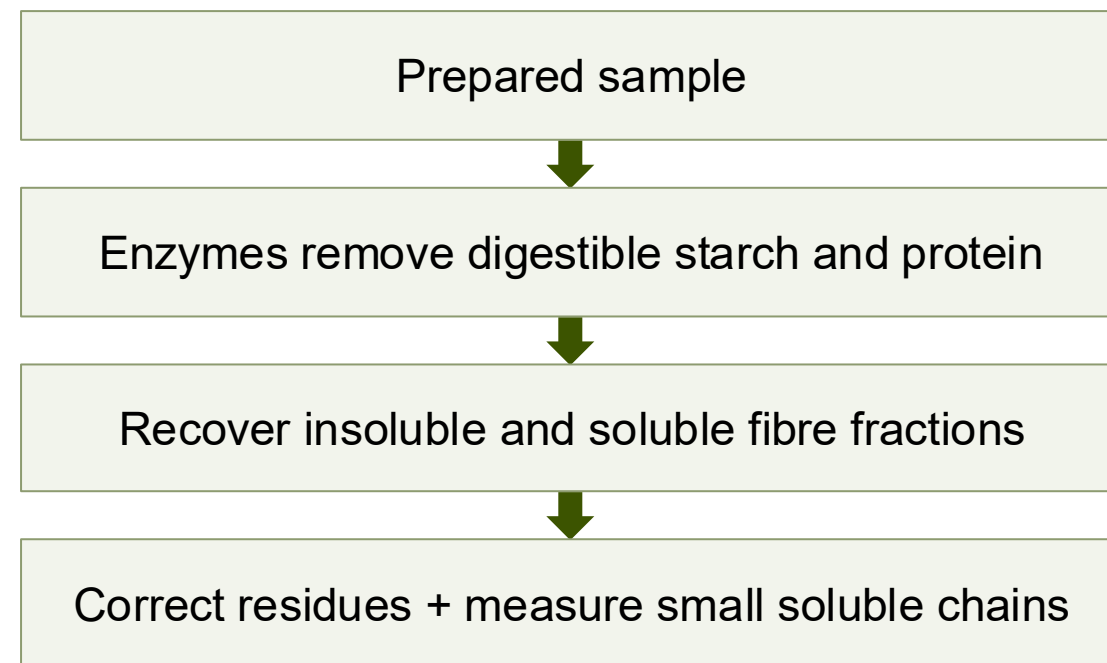
## Crude fibre



Limited residue. Loses soluble fibre and some insoluble components.

Sources: FAO, Methods of Feed Analysis; McCleary et al., AOAC Official Method 2022.01.

## Integrated total dietary fibre



Broader sum. Appropriate methods include resistant starch and soluble oligosaccharides.

# Reading fibre on a European food label

| Teaching cereal    | Per 100 g           | Per 40 g          |
|--------------------|---------------------|-------------------|
| Energy             | 1,520 kJ / 360 kcal | 608 kJ / 144 kcal |
| Fat                | 5.0 g               | 2.0 g             |
| of which saturates | 1.0 g               | 0.4 g             |
| Carbohydrate       | 60.0 g              | 24.0 g            |
| of which sugars    | 12.0 g              | 4.8 g             |
| <b>Fibre</b>       | <b>8.0 g</b>        | <b>3.2 g</b>      |
| Protein            | 15.0 g              | 6.0 g             |
| Salt               | 0.50 g              | 0.20 g            |

- Nutrition values normally use a 100 g or 100 mL basis. A stated portion may appear alongside it.
- Fibre is additional to the core mandatory declaration. Relevant claims bring further declaration obligations.
- This teaching cereal contains 8.0 g/100 g, but a 40 g portion supplies 3.2 g.

Fictitious values for teaching

Regulation (EU) 1169/2011, Articles 30–33 and Annex XV; 1924/2006, Article 7.

# The ingredient list and fibre value have different roles

- Ingredient names identify possible sources. The nutrition declaration reports the combined qualifying fibre amount.
- Wholegrain oats, wheat bran and inulin can all contribute, but their proportions and fibre contents differ.
- “Multigrain”, a brown colour or a picture of grain does not quantify fibre per serving.
- Compare products on the same basis, then check the amount you would actually eat.



**Illustrative ingredients: wholegrain oats, wheat bran, raisins, inulin, sunflower oil.**

Regulation (EU) 1169/2011, Articles 18 and 30–33.

# EU fibre claims: two alternative calculation bases

| Claim           | Per 100 g food | OR per 100 kcal |
|-----------------|----------------|-----------------|
| Source of fibre | ≥3 g           | ≥1.5 g          |
| High fibre      | ≥6 g           | ≥3 g            |

**Example: 2.5 g fibre / 150 kcal × 100 = 1.67 g per 100 kcal**

Regulations (EC) 1924/2006 and (EU) 432/2012, Annexes.

# A fibre amount and a health claim answer different questions

## Nutrition claim

- Amount in the food
- Example: source of fibre
- Check composition and the permitted threshold

## Health claim

- Specified fibre and effect
- Check dose and conditions of use
- Evidence cannot transfer automatically between fibres

Regulations (EC) 1924/2006 and (EU) 432/2012, Annexes.

# A U.S. label adds a Daily Value comparison

**5 g  $\approx$  18%**

of the 28 g Daily Value  
Illustrative amount per serving

- Dietary fiber appears within Total Carbohydrate on the U.S. Nutrition Facts label.
- The Daily Value (DV) is 28 g for the standard 2,000-calorie reference diet.
- A serving with 5 g fibre contributes about 18% of this Daily Value.
- General label guidance calls 5% DV or less low and 20% DV or more high. Use the stated serving size.

U.S. Food and Drug Administration, How to Understand and Use the Nutrition Facts Label (2024).

# Fibre intake and the food-science opportunity

## 25 g/day

European Food Safety Authority:  
adequate intake for adult bowel  
function

- The European Food Safety Authority (EFSA) considers 25 g/day adequate for normal bowel function in adults.
- Intake varies across countries and population groups; many adults fall below recommendations.
- Whole foods and carefully designed ingredients can both contribute to intake.

European Food Safety Authority (2010), EFSA Journal 8(3):1462.

# Classification needs more than one axis

| Property       | Question                                               | Why it matters                      |
|----------------|--------------------------------------------------------|-------------------------------------|
| Solubility     | Does it disperse / dissolve under the test conditions? | Analytical fraction and formulation |
| Viscosity      | How strongly does it resist flow at a given dose?      | Texture and upper-gut behaviour     |
| Fermentability | How do microbes use it, and how quickly?               | Colonic metabolism and tolerance    |

McRorie (2015); Slavin (2013); Ríos-Covián et al. (2016).

# Viscosity links formulation and physiology

- $\beta$ -Glucan, psyllium and suitable guar preparations can thicken aqueous systems when adequately hydrated.
- Concentration and molecular-weight distribution determine how much viscosity develops at the intended dose.
- Shear or enzymatic depolymerization may reduce viscosity while leaving the measured fibre mass similar.
- Assess the processed food under relevant conditions before transferring an ingredient-level conclusion.



McRorie (2015); Slavin (2013); Ríos-Covián et al. (2016).

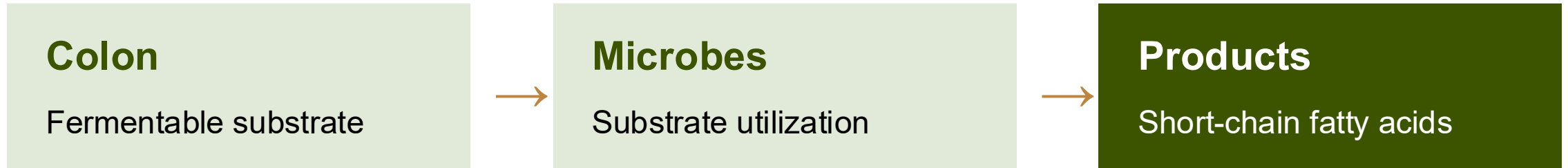
# Insoluble fibre: hydration, bulk and particle size

- Wheat bran and cellulose illustrate insoluble fibres that retain water and contribute physical residue.
- Particle size and tissue architecture influence hydration, mouthfeel and bowel-function responses.
- Fine milling changes surface area and interactions with other food components, even when chemical composition changes little.
- Specify both the amount of fibre and the physical form of the tested ingredient.



McRorie (2015); Slavin (2013); Ríos-Covián et al. (2016).

# Fermentation and short-chain fatty acids



- Short-chain fatty acids (SCFAs) include acetate, propionate and butyrate. Their proportions depend on substrate and microbial community.
- Butyrate provides an important energy source for colonocytes. Different substrates ferment at different rates and locations.
- Dose and tolerance matter. A demonstrated host benefit is required before describing an ingredient as a prebiotic.

McRorie (2015); Slavin (2013); Ríos-Covián et al. (2016).

# Fermentability varies between fibres

## Microbial access depends on structure

- Colonic microbes ferment the accessible fraction of a fibre. The rate and extent vary with structure, processing and the microbial community.
- Inulin and fructooligosaccharides can supply fermentation substrates. Chain length can alter their fermentation pattern.
- Psyllium can undergo partial fermentation while retaining a substantial physical effect through hydration and gel formation.
- Solubility, viscosity and fermentability are separate properties. Hydrocolloids cannot all be classified as fully fermentable fibres.

Sources: Kaur et al. (2011), J Food Sci 76, H137–H142; Boets et al. (2015), Nutrients 7, 8916–8929.

# Energy from fibre fermentation

## Microbial fermentation supplies usable energy

- Fermentation produces short-chain fatty acids (SCFAs), including acetate, propionate and butyrate.
- The intestine absorbs these products. Host tissues metabolize them, so fibre can contribute energy without small-intestinal digestion.
- Actual energy recovery depends on the substrate and how much undergoes fermentation.

## EU label convention: 2 kcal/g (8 kJ/g) of fibre

Example: 5 g fibre contributes 10 kcal under this convention. This is a labelling factor, not an identical biological yield for every fibre.

Sources: Boets et al. (2017), J Physiol 595, 541–555; EU Regulation 1169/2011, Annex XIV.

# Post-meal glucose: fibre type and meal dose

**4 g / 30 g**

$\beta$ -Glucan / available carbohydrate in the meal

- Viscous fibres can modify mixing and nutrient transport during digestion.
- The EU oat / barley  $\beta$ -glucan claim has a meal-specific condition.
- The specified amount is 4 g  $\beta$ -glucan per 30 g available carbohydrate.
- A general “high fibre” statement does not establish this effect.

Regulation (EU) 432/2012, Annex; McRorie (2015).

# Cholesterol: a daily intake condition

## 3 g/day

$\beta$ -Glucan intake stated for the cholesterol benefit

- Oat and barley  $\beta$ -glucans have a permitted EU cholesterol-maintenance claim.
- Consumer information specifies a daily intake of 3 g  $\beta$ -glucans.
- The food must also meet the specified amount per quantified portion.
- The claim applies to the defined constituent and conditions of use.

Regulation (EU) 432/2012, Annex; McRorie (2015).

# Bowel function and satiety need separate evidence

## Bowel function

- Bulking and transit are related but distinct
- Wheat-bran transit claim:  $\geq 10$  g/day
- Ingredient form and hydration matter

## Satiety / weight

- Swelling may influence gastrointestinal behaviour
- Effects vary with ingredient and context
- Use only evidence for the specified outcome

Regulation (EU) 432/2012, Annex; McRorie (2015).

# Prebiotic claims require a host benefit

- The International Scientific Association for Probiotics and Prebiotics (ISAPP) requires selective utilization by host microorganisms and a health benefit.
- Fermentation alone does not establish a prebiotic effect. Evidence must connect the defined substrate to a beneficial host outcome.
- A change in microbial composition is an intermediate observation, rather than sufficient evidence by itself.
- Scientific terminology and permission to make a claim must both be checked for the intended market.

Gibson et al. (2017), Nature Reviews Gastroenterology & Hepatology 14:491–502.

# Dietary fibre in the food matrix

- Fibre can thicken, gel, stabilize or provide bulk.
- A low technological dose may contribute little to dietary intake.
- A nutritional dose can change flavour, texture and processability.
- Formulation must address both roles together.



Elleuch et al. (2011); Saha & Bhattacharya (2010); FIBER101 lecture notes v4.

# Hydrocolloids and dietary fibre

## Hydrocolloid describes food function

- Hydrocolloids bind water and may thicken, gel or stabilize foods.
- The group includes polysaccharides and proteins.
- Gelatin is a protein hydrocolloid and does not qualify as dietary fibre.

## Dietary fibre describes a qualifying fraction

- Some hydrocolloids qualify as fibre, including pectin, guar gum and locust bean gum.
- A thickening effect alone does not establish fibre status or a health benefit.
- Assess the ingredient, digestion resistance and regulatory conditions separately.

Sources: FDA, Questions and Answers on Dietary Fiber; EU Regulation 1169/2011, Annex I.

# Other hydrocolloids: sources and structures

| Ingredient              | Source                 | Structural description                                             |
|-------------------------|------------------------|--------------------------------------------------------------------|
| Gum arabic (acacia gum) | Acacia tree exudate    | Branched polysaccharide mixture containing arabinose and galactose |
| Alginate                | Brown seaweeds         | Blocks of mannuronic and guluronic acid units                      |
| Carrageenan             | Red seaweeds           | Sulfated galactose-based polysaccharides                           |
| Gellan gum              | Microbial fermentation | Four-sugar repeat: glucose, glucuronic acid and rhamnose           |

**Hydrocolloids are polymers used to thicken, gel or stabilize water-based food systems.**

FAO additive specifications and alginate manual; Saha & Bhattacharya (2010).

# Bakery: hydration and structure must be rebalanced

- Bran and added fibres compete with flour components for water.
- Particle size can affect dough handling and crumb texture.
- Psyllium can contribute cohesion in gluten-free systems.
- Evaluate the baked product, not only the ingredient dispersion.



Elleuch et al. (2011); Saha & Bhattacharya (2010); FIBER101 lecture notes v4.

# Cooking and cooling can alter resistant starch

- Gelatinization can increase starch accessibility to digestion.
- Cooling can promote retrogradation and formation of RS3.
- The net effect depends on the food and processing history.
- Reheating does not imply a fixed or universal glycaemic response.



Englyst et al. (1992); supplied FIBER101 notes v4.

# Milling, extrusion and shear

| Process       | Potential change                            | What to measure                                     |
|---------------|---------------------------------------------|-----------------------------------------------------|
| Milling       | Smaller particles and altered accessibility | Particle size, hydration, texture                   |
| Extrusion     | Cell-wall disruption and solubilization     | Soluble / insoluble dietary fibre and digestibility |
| Intense shear | Depolymerization in susceptible systems     | Molecular weight and viscosity                      |

Elleuch et al. (2011); Saha & Bhattacharya (2010); FIBER101 lecture notes v4.

# Fermentation and storage change the ingredient

- Fermentation may change cell-wall accessibility and the distribution of soluble and insoluble fractions.
- Acid, temperature and storage time can shorten inulin-type fructan chains in susceptible formulations.
- These changes may affect sweetness, viscosity, analytical recovery and the intended physiological role.
- Test the final food across shelf life, rather than relying only on the initial ingredient specification.



Elleuch et al. (2011); Saha & Bhattacharya (2010); FIBER101 lecture notes v4.

# Four principles to take into practice

- Definition: check the jurisdiction and ingredient category.
- Function: specify viscosity, hydration and fermentability.
- Formulation: measure performance after processing and storage.
- Analysis: interpret a fibre value with its method and sample history.

# Abbreviations used in this lecture

| Abbreviation    | Full name                                                              |
|-----------------|------------------------------------------------------------------------|
| DP / NSP        | Degree of polymerization / non-starch polysaccharides                  |
| RS / SCFAs      | Resistant starch / short-chain fatty acids                             |
| FOS / GOS       | Fructo-oligosaccharides / galacto-oligosaccharides                     |
| NDF / ADF / ADL | Neutral detergent fibre / acid detergent fibre / acid detergent lignin |
| HM / LM         | High-methoxyl / low-methoxyl pectin                                    |
| DV              | Daily Value                                                            |

Terminology used in the cited definitions and methods.

# Organisations and regulatory abbreviations

- EU: European Union. EC: European Community, retained in the names of older regulations.
- EFSA: European Food Safety Authority. FDA: U.S. Food and Drug Administration.
- ISAPP: International Scientific Association for Probiotics and Prebiotics.
- AOAC INTERNATIONAL: analytical-methods organization, historically Association of Official Analytical Chemists.
- COST: European Cooperation in Science and Technology. METU: Middle East Technical University.

Organisation names.

# Definitions and regulatory references

- Codex Alimentarius. Guidelines on Nutrition Labelling, CXG 2-1985, section 2.6 and footnotes.
- EU Regulations 1169/2011 (Annex I), 1924/2006 (Annex) and 432/2012 (permitted claims).
- U.S. Food and Drug Administration. Dietary Fiber fact sheet (2021); Questions and Answers on Dietary Fiber; Nutrition Facts label guidance (2024).
- EFSA. Dietary Reference Values for carbohydrates and dietary fibre (2010), 8(3), 1462.
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# Methods, functionality and microbiome references

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# Sources for structure and method introductions

- Fischer et al. (2004). The gel-forming polysaccharide of psyllium husk. Carbohydrate Research 339:2009–2017. doi:10.1016/j.carres.2004.05.023.
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- Food and Agriculture Organization: Methods of Feed Analysis; pectin, guar, gum arabic and gellan specifications; alginate production manual.

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