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Review Article

Classification and regulatory perspectives of dietary fiber

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ABSTRACT

This review discusses the history and evolution of the state of dietary fiber (DF) with account of refinements in extraction methods and legal definitions subsequent to the launch of DF hypothesis. For a long time, defining and regulating DFs relied heavily on their chemical compositions and analytical methods. Although chemical compositions and analytical methods still play an important role in the definition of DF, physiological activity has also been taken into consideration. The precise definition of DF is still evolving, particularly whether oligosaccharides degrees of polymerization (DP) 3–9 should be considered as DF or not. Decades of scientific research have initiated the expansion of the term DF to include indigestible oligosaccharides with their DP between 3 and 9; hence responding to the positive health benefits of DF as well as fulfilling the needs in food labeling regulations.

1. Introduction

From crude fiber to dietary fiber (DF), DF has been recognized as resistant polysaccharides having degree of polymerization (DP) > 10 in many countries for a long time. Analytical methods, physiological effects, food regulation at national level, and other interconnected factors have been considered as important criteria in the evolution of the DF's definition in the past few decades. Some debates regarding the definition of DF still exist. Facing the dilemma of whether or not saccharide with a lower DP could be named as DF, "oligosaccharide" has been categorized as DF in food labeling systems in some countries. In the present review, various classifications of DF, physiological efficacies of DF, and evolution of definitions and measurement methods are discussed.

2. From roughage to dietary fiber

Hippocrates once said that "wholemeal bread makes larger feces than refined bread." This enlightened the importance of fiber in terms of its physiological benefits such as alleviation of constipation. In the early days, the concept of fiber was an indigestible moiety which was quantified and named as "crude

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fiber". It was referred to as the residue of plant-based food left after extraction with solvent, dilute acid, and dilute alkali [1]. It was not until 1953, the new term "dietary fiber" was introduced by the British physician Eban Hipsley. Hipsley defined DF as a sum of indigestible constituents that made up the plant cell wall, encompassing the "unavailable carbohydrate" as described much earlier by McCance and Lawrence [2] in 1929.

As suggested by Trowell [3] in 1972, DF consists of the remnants of edible plant cells, polysaccharides, lignin, and associated substances resistant to digestion by the alimentary enzymes of humans. In more detail, the constituents of DF include cellulose, hemicelluloses, lignin, gums, mucilage, oligosaccharides, pectin, and other associated minor substances (e.g., waxes, cutin, suberin). From then on, the term crude fiber was replaced by DF gradually. The compositional profile of different indigestible carbohydrates including crude fiber, nonstarch polysaccharide (NSP), soluble dietary fiber (SDF), insoluble dietary fiber (IDF), indigestible fraction, and resistant starch (RS) are summarized in Table 1.

3. Classification

DF can be classified in many different ways such as structure and solubility. In terms of structure, polysaccharides are categorized into linear or nonlinear molecules. On the basis of solubility, they can be divided into soluble or insoluble DFs. IDF consists mainly of cell wall components (e.g., cellulose, lignin, hemicellulose), while SDF consists of noncellulosic polysaccharides (e.g., pectin, gums, mucilage) [4].

3.1. *Does starch count as dietary fiber?*

Unlike Trowell's definition of DF, NSPs are carbohydrate fractions excluding starch and free sugars [5]. According to the findings from Englyst et al [6] (1992), starch can be typically divided into three fractions based on its digestive rate, including rapidly digesting starch, slowly digesting starch, and RS. RS is an extremely broad and diverse term which covers a wide range of materials, and is divided into four types, i.e., physical inaccessible starch (RS1), ungelatinized starch granules (RS2), retrograded starch (RS3), and chemically modified starch (RS4) [7,8].

In the 1980s, RS was proposed and categorized as a kind of insoluble fiber as it could not be digested in the small intestine. According to Trowell or other definitions as mentioned above, RS has been regarded as a type of DF in terms of structure and digestibility in the intestine. RS is one of the good substrates for the growth of colonic microbiota and is able to increase bacterial mass in feces [9]. Consumption of RS may stimulate the growth of specific bacteria purported to provide beneficial health effects [10]. During its fermentation, some physiologically important metabolites including short-chain fatty acids (e.g., mainly acetic, propionic, and butyric acids) are formed. Butyric acid is the most important energy source for the colonocyte cell [11]. The beneficial effects of RS on the gastrointestinal tract have also helped it gain recognition as a member of DF in some studies as well as the international food standard setting bodies such as the Codex Alimentarius Commission (Codex), European Food Safety Authority (EFSA). Codex has given a more specific explanation regarding the classification of RS. If RS is naturally present in food, it could be classified as DF. However, if it is derived from an artificial synthesis, such as physical, enzymatic, or chemical synthesis, it should provide desirable physiological benefits to be considered as DF [12–14].

3.2. *Are short-chain carbohydrates regarded as dietary fiber?*

Indigestible carbohydrates with degrees of polymerization (DP) between 3 and 9 were in general regarded as

Table 1 – Compositional profile of selected indigestible carbohydrates among different analytical methods [46–53].

Indigestible carbohydrates	Polysaccharides (DP > 9)				Noncarbohydrate residues [a]		Oligosaccharides (DP 3–9)
	Starch	Cellulose	Hemicellulose	Pectin	Lignin	Others	
Crude fiber		•	•		•	•	
Nonstarch polysaccharide [b]		•	•	•			
Soluble dietary fiber [c]			•	•		•	• [d]
Insoluble dietary fiber [e]	•	•	•	• [f]	•	•	
Indigestible fraction [g]	•	•	•	•	•	•	
Resistant starch [h]	•						

AOAC = Association Official Analytical Chemists; DF = dietary fiber; DP = degree of polymerization; NSP = nonstarch polysaccharide.

[a] Noncarbohydrate residues such as polyphenols (e.g., condensed tannin), wax, saponin, cutin, phytate, crude protein, or ash.

[b] Referring to the Englyst NSP methods, in which the be determined by gas chromatography, or by high performance liquid chromatography to obtain values for the constituent monosaccharides to determine the residual NSP after the removal of starch.

[c] Referring to the analytical method of AOAC 991.43, with which small amounts of oligosaccharides (DP 3–9) are included.

[d] Small quantities of oligosaccharides such as inulin, polydextrose, resistant maltodextrin, and short chain polysaccharides may be included in the soluble fraction. Determination of total amount of individual oligosaccharides should refer to the methods of AOAC 997.08 and AOAC 2001.03 for inulin and resistant maltodextrin, respectively.

[e] Referring to the analytical method of AOAC 991.43.

[f] A portion of pectic substances is water insoluble and is therefore included in the total amount of insoluble dietary fiber.

[g] As described by Saura-Calixto et al [53] (2000), samples were successively incubated with pepsin and α-amylase at 37°C, centrifuged, and dialyzed. The indigestible fractions consists of DF, resistant starch, resistant protein, and other associated compounds.

[h] Referring to the analytical method AOAC 2002.02.