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Codex dietary fibre definition – Justification for inclusion of carbohydrates from 3 to 9 degrees of polymerisation

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ABSTRACT

The main controversy about the DF definition, adopted by the commission of Codex Alimentarius, refers to the inclusion of carbohydrates of 3–9 degrees of polymerisation (DP), decision which may be made individually by the authorities of each country. Due to the possibility of having two definitions and the negative impact it would cause over the harmonisation of nutritional information, a bibliographic review was carried, from 2009 to 2011, aiming to gather justifications for the inclusion of carbohydrates of 3–9 DP in the definition. The current review presents scientific bases that are directed to three topics: physiological aspects; repercussion over the analytical method; and impact on consumers and other users. The decision of including unavailable carbohydrates of 3–9 DP in the definition of DF may cause effective global harmonisation in the nutritional labelling, considering that the main goal is to help consumers choose healthy foods.

1. Introduction

The interest in knowing dietary fibre (DF) and its physiological effects has increased lately, and this fact reflects the increased number of scientific publications along the last decades. According to bibliographic research, using specific keywords (DF, definition, concept, analysis, methodology, claim and consumer) in PubMed, it was observed that, until 1979, only 820 articles were published; during the 1980's, this number increased to 3075 articles; in the decades of 1990 and 2000, it increased to 4443 and 5616 articles, respectively; and during the years of 2010 and 2011, 1642 articles were published. This evolution reflects the importance of DF in the world and its participation in human health, considering its composition, structure and physical–chemical properties, as well as physiological effects that contribute to decreasing the risk for non-transmissible chronic diseases (NTCD) and its use as a functional ingredient (Cho & Samuel, 2009; Grabitske & Slavin, 2009; Raninen, Lappi, Mykkänen, & Poutanen, 2011; Roberfroid et al., 2010).

DF is composed by a complex and heterogeneous group of components and can be defined by its physiological characteristics, as well as by its chemical ones. The analytical methods used for DF quantification as a whole, or by individual specific components, have been continuously modified (DeVries, 2010; McCleary, 2010). Due to advanced researches on physiological and nutritional properties of specific DF components (fructans, resistant starch, polydextrose and others), several agencies and countries proposed broader definitions, correlated to the physiological effects (AACC, 2001; Commission of European Communities, 2008). Aiming to create a harmonised concept having all country members' consent, the Codex Alimentarius provided wide discussions on definition and analytical methods of DF (Codex Alimentarius, 2009; McCleary, 2010; McCleary et al., 2010).

At the 30th (Codex Alimentarius, 2008) and 31st meetings (Codex Alimentarius, 2009) of the Codex Committee on Nutrition and Foods for Special Dietary Uses – CCNFSDU, the definition of DF and analytical methods for quantification of total DF and individual specific components (Table 1) were agreed. The Commission of the Codex Alimentarius complied with the recommendation of CCNFSDU and adopted this definition of DF for nutrition labelling. The adopted definition is presented below:

"Dietary fibre means carbohydrate polymers[1] with ten or more monomeric units[2], which are not hydrolyzed by the endogenous

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[1] When derived from a plant origin, dietary fibre may include fractions of lignin and/or other compounds associated with polysaccharides in the plant cell walls. These compounds also may be measured by certain analytical method(s) for dietary fibre. However, such compounds are not included in the definition of dietary fibre if extracted and re-introduced into a food.

[2] Decision on whether to include carbohydrates from 3 to 9 monomeric units should be left to national authorities".

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Table 1
Summary of dietary fibre methods recommended by Codex Committee on Nutrition and Foods for Special Dietary Uses.

Description	Methods
General methods that do not measure the lower molecular weight fraction (i.e., DP ⩽ 9)[a]	AOAC 985.29; AOAC 991.43; AOAC 992.16; AOAC 993.21; AOAC 994.13
General methods that measure both the higher (i.e., DP > 9) and the lower molecular weight fraction (i.e., DP ⩽ 9)	AOAC 2001.03[b]; AOAC 2009.01[c]
Methods that measure individual specific components (monomeric units: the whole range for each type of components is covered)	AOAC 991.42; AOAC 992.28; AOAC 993.19; AOAC 995.16; AOAC 997.08; AOAC 999.03; AOAC 2000.11; AOAC 2001.02; AOAC 2002.02

Source: Codex Alimentarius (2009). Obs: In ALINORM 10/33/26, there is indication of three available methods, other than AOAC's.

[a] These methods have quantitation loss for inulin, resistant starch, polydextrose and resistant maltodextrins.

[b] This method includes resistant insoluble and soluble polysaccharides, resistant maltodextrins, lignin, and plant cell wall and have quantitation loss for resistant starch.

[c] This method includes soluble and insoluble polysaccharides, lignin, resistant starch and oligosaccharides.

enzymes in the small intestine of humans and belong to the following categories:

- Edible carbohydrate polymers naturally occurring in the food as consumed
- Carbohydrate polymers, which have been obtained from food raw material by physical, enzymatic or chemical means and which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities
- Synthetic carbohydrate polymers which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities.

Although there is a global DF definition, some issues must be discussed in order to allow the implementation in different countries. The two main topics are the inclusion of carbohydrate polymers of 3–9 DP, decision which may be made individually by the authorities of each country, and the necessity of defining which beneficial physiological effects of DF must be considered by the national authorities. Unless all countries accept (or not) that carbohydrates of 3–9 DP are considered as DF, there will be two definitions instead of one (Howlett et al., 2010; Lupton, Betteridge, & Pijls, 2009).

Due to the possibility of two existing definitions and its negative impact over the harmonisation of the nutritional information, a bibliographic review was carried, from 2009 to 2011, aiming to gather justifications for the inclusion of carbohydrate polymers of 3–9 DP in the definition, considering that the main goal of nutritional labelling is to help consumers choose healthy foods. In this paper, the original statements are presented between " ".

2. Worldwide definitions of DF including carbohydrates of 3–9 DP

Unavailable carbohydrate polymers of 3–9 DP (oligosaccharides) are already part of the DF definition proposed and adopted by several institutions (from countries such as Canada, Australia, New Zealand and others from the European Union) and expert groups in the field. Table 2 presents a few examples of these definitions (only the part related to the components). It is possible to observe that the scope of these definitions is not always identical, but there is a large overlap. Although the American Association of Cereal Chemists and the Institute of Medicine include oligosaccharides in their definitions, the Food and Drug Administration (FDA) has not adopted a definition of DF nor declared if it will include carbohydrates of 3–9 DP or not (Turner & Lupton, 2011). Considering that several countries have already been adopting the inclusion of oligosaccharides (3–9 DP) in the definition of DF, keeping this criterion may facilitate the harmonisation of nutritional labelling.

3. Justifications for the inclusion of carbohydrates of 3–9 degrees of polymerisation in the DF definition

3.1. Physiological aspects for the inclusion of unavailable carbohydrates of DP ⩾ 3

Historically, a universal cutoff point at a DP of 10 and above had gained currency in the mistaken belief that it was consistently applicable to all carbohydrates in the frame for consideration as dietary fibres through precipitation in alcohol. However, in practise, this is not the reality and the methodology does not provide reliable basis for differentiating carbohydrates that present or not fibre properties or physiological effects, based only on the length of the chain (Quigley, Hudson, & Englyst, 1999). It is not possible to distinguish a clear cutoff point considering the solubility in ethanol 80%, once solubility is also determined by the chemical nature of the constituent monosaccharides, instead of the number of units *per se*, and therefore the relation between chain length and solubility in ethanol is imprecise (Howlett et al., 2010).

Similarly, there are no scientific evidences to distinguish the physiological effects of carbohydrates with a DP ⩾ 10 and those with DP ⩽ 9 because carbohydrates both above and below this cutoff point have already exhibited one or more beneficial physiological effect(s) generally associated with fibre. The unavailable carbohydrates that present beneficial physiological effects are distributed in a continuum chain length spectrum, without clear differentiation in any particular DP (Howlett et al., 2010).

A proposal for fructans to be classified as DF has existed for more than twenty years, once they are resistant to hydrolysis by the human enzymes due to their structural properties (beta 1–2 linkage), and have similar physiological action, presenting several beneficial effects such as improvement in intestinal health (Grabitske & Slavin, 2009; Raninen et al., 2011; Roberfroid et al., 2010). Raninen et al. (2011), in a review article, compared the physiological effects of three types of dietary fibre (grain fibres, inulin and polydextrose) with varying compositions, degrees of chemical and structural heterogeneity, origins, and physical properties. The authors clearly showed that inulin and polydextrose (both present oligomers above and below DP 10) provide similar beneficial gastrointestinal effects to the ones caused by grain fibres, which justifies their classification as dietary fibre.

Lupton et al. (2009) made similar comments, that included not only physiological but also methodological aspects: "There is also a concern regarding the perceived 'arbitrariness' of having a specific cutoff at a DP of 9 as there are no data showing a specific abrupt change in physiological effects between DP 9 and 10". The authors also added that: "There was a considerable debate at step 6 for DF definition as to whether three or more monomeric units was an average or a cutoff indicates that the CCNFSDU had previously decided on three as the lower limit, not 10; and there was no clear debate or rationale on which to base this substantial change to 10".

The International Life Sciences Institute (ILSI) Europe and ILSI North America's committees on dietary carbohydrates organised a forum in 2010, with 150 specialists to discuss critical aspects of the Codex dietary fibre definition that interfere in its global

Table 2
Examples of dietary fibre definitions that include carbohydrates of 3–9 degrees of polymerisation (DP).

Definitions/statements	Institution/reference
"Fibre means carbohydrate polymers **with three or more monomeric units**, which are neither digested nor absorbed in the human small intestine and belong to the following categories: - Edible carbohydrate polymers naturally occurring in the food as consumed; - Edible carbohydrate polymers which have been obtained from food raw material by physical, enzymatic or chemical means and which have a beneficial physiological effect demonstrated by generally accepted scientific evidence; - Edible synthetic carbohydrate polymers which have a beneficial physiological effect demonstrated by generally accepted scientific evidence"	**European Union (EU)** The current EU definition of DF (Commission of European Communities, 2008)
"Dietary fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre includes polysaccharides, **oligosaccharides**, lignin and associated plant substances, etc"	**American Association of Cereal Chemists (AACC)** The AACC International Technical Committee on Dietary Fibre and other Carbohydrates continues to support the definition adopted by the AACC (2001), once it is well aligned with the definition adopted by the CODEX (AACC, 2011)
"Dietary fibre means that fraction of the edible part of plants or their extracts, or synthetic analogues that are resistant to digestion and absorption in the small intestine, usually with complete or partial fermentation in the large intestine; and promotes one or more of these beneficial physiological effects: laxation, reduction in blood cholesterol, and/or modulation of blood glucose and includes polysaccharides, oligosaccharides (**DP > 2**), and lignins"	**Australia New Zealand Food Authority (ANZFA)** Standard 1.2.8 (FSANZ, 2011)
"Dietary fibre consists of: (1) carbohydrates with **a DP[1] of 3 or more** that naturally occur in foods of plant origin that are not digested and absorbed by the small intestine; and (2) accepted novel fibres. Novel dietary fibre is an ingredient manufactured to be a source of dietary fibre. It consists of carbohydrates (DP > 2) extracted from natural sources or synthetically produced, that are not digested and absorbed in the small intestine. It has demonstrated beneficial physiological effects in humans and it belongs to the following categories: it has not been traditionally used for human consumption to any significant extent; or it has been processed so as to modify the properties of the fibre; or it has been highly concentrated from a plant source" [1]DP: degree of polymerisation or number of saccharide units.	**Health Canada** Health Canada (2012)
"*Dietary Fibre* consists of **nondigestible carbohydrates** and lignin that are intrinsic and intact in plants *Functional Fibre* consists of isolated, nondigestible carbohydrates that have beneficial physiological effects in humans *Total Fibre* is the sum of *Dietary Fibre* and *Functional Fibre*"	**Institute of Medicine (IOM)** IOM (2005)
The committees on dietary carbohydrates of ILSI Europe and ILSI North America agree with the **inclusion of carbohydrates of 3–9 DP** in the DF definition	**International Life Sciences Institute (ILSI)** Howlett et al. (2010)

implementation. After the forum, the participants answered a survey about the consensus on the theme (Howlett et al., 2010). Regarding the inclusion or exclusion of carbohydrate polymers of 3–9 DP in the DF definition, the discussion and level of support presented by the survey indicated, together, a convincing consensus among experts in the field towards the inclusion, providing an explanation for science-based decision made by national authorities in the implementation of the Codex definition. Among the 75 participants interviewed in the survey, 86% agreed to include unavailable carbohydrates of 3–9 DP in the definition, while 3% were against this decision (for unknown reasons) and 11% of the participants did not answer the survey. One of the indications of the forum was that the scientific community agrees on maintaining a worldwide consensus regarding the inclusion of unavailable carbohydrates of DP $\geqslant$ 3 as dietary fibre. In 2011, the Functional Foods Task Force of ILSI Brazil widely discussed scientific evidence in the area of carbohydrates, microbiome and health, emphasising the need of a global harmonisation of fibre definition and recommending the inclusion of carbohydrates of DP 3–9 (Latulippe et al., 2013).

Therefore, it seems that there is no scientific evidence for assuming that unavailable carbohydrates provide different physiological effects when the number of degrees of polymerisation is <10 or $\geqslant$10, and the cutoff point of DP $\geqslant$ 10 to differ carbohydrates is arbitrary, once the relation between chain length and solubility in ethanol is imprecise; existing a consensus in the scientific community towards the inclusion of unavailable carbohydrates with DP $\geqslant$ 3 in the dietary fibre definition.

3.2. Repercussion of DF definition on DF analysis

The main methods for DF quantification, recommended by the CCNFSDU, are shown in Table 1. The enzymatic–gravimetric high pressure liquid chromatography method (AOAC 2009.01 or AACC 32-45.01) (McCleary et al., 2010) was created especially to quantify dietary fibre as a whole (including soluble and insoluble polysaccharides, lignin, resistant starch (RS) and oligosaccharides) and to solve existing problems in the classical used methods (AOAC 985.29 and AOAC 991.43), which do not quantify oligosaccharides, and partially quantify RS. Aiming to solve the problems mentioned above, DF methods that measure individual specific components were created; however, the practise of using both classical and specific methods to quantify DF results in the super estimation of values due to the considerable overlap between them (McCleary, 2010).

The AOAC 2009.01 method (which includes carbohydrates of low and high molecular weight) eliminates potential issues of double accounting when a carbohydrate fraction is partially or completely measured by a combination of specific methods. However, Lupton et al. (2009) alert that this method should not be used by national authorities that exclude the carbohydrate of DP of 3–9 from the DF definition, due to the loss that occurs in the quantification of high molecular weight soluble fibre. Following these thoughts, McCleary et al. (2010) consider that a new method should be developed for a demarcation of DP between 9 and 10 (instead of DP $\geqslant$ 3, for which the method 2009.01 was idealised). The authors also emphasise that this is a difficult goal to

accomplish once the DP may not be so efficiently delimited by solubility in ethanol, which is the basic principle for most DF general methods, because some carbohydrates of DP < 10 remain in the alcoholic precipitate while others >10 might not precipitate at all (Ku, Jansen, Oles, Lazar, & Rader, 2003; McCleary et al., 2010).

Several researchers are validating or improving this method for DF worldwide. Part of these results was presented during the 9th International Food Data Conference, Norwich, UK, September, 2011, Session 8: Update on dietary fibre methodology. The comparison of results between AOAC 2009.01 and AOAC 985.29 methods showed, for wheat grain based food products, similarities in high molecular weight DF and total DF and also a significant content of low molar weight DF (resulting in a higher content of total DF than the one obtained by the classical method). The authors suggest the introduction of an extra AMG hydrolysis step in the AOAC 2009.01 protocol in order to guarantee a complete hydrolysis of available starch (in high starch containing samples) and to avoid an overestimate of the low molecular weight DF content (Brunt & Sanders, 2013). The comparison of results obtained with AOAC 2009.01 and individual specific carbohydrate analysis also showed general agreement, with few exceptions for resistant starch and fructans in some products (Englyst, Quigley, Lawrance, & Elahi, 2011). McCleary et al. (2012) described the AOAC 2011.25 method to separately quantify insoluble and soluble DF, which is the main difference from the AOAC 2009.01.

Until now, an adequate and validated analytical method, inside the general method category, is not available for a precise DF quantification when carbohydrates of 3–9 DP are not part of the definition, which implicates the need of developing a method that is compatible to this definition. Knowing that general methods are the most used ones for nutritional labelling and database, this exclusion may threaten the quality of the nutritional information and make the control by the regulatory agencies more difficult.

Once the AOAC 2009.01 method or updated versions present coherent results for the different components of the DF and have been tested for reevaluation of DF content of foods, the most adequate decision seems to keep only one definition, with the inclusion of carbohydrates of 3–9 DP.

3.3. Impact of DF definition that includes unavailable carbohydrates of DP ⩾ 3 on users

Dietary fibre has been proven to be an important driver of healthy food consumption (Hoefkens, Verbeke, & Van Camp, 2011; Martınez-Gonzales, Holgado, Gibney, Kearney, & Martınez, 2000). Health professionals and several consumers are aware of this importance and seek information about DF content in food composition tables and nutritional labels.

A study with 14,331 people in the European Union showed that the understanding of the relation between healthy eating and increase in DF intake varied from 8.2% to 22.7%, being greater in the Nordic countries (Martınez-Gonzales et al., 2000). Another study with 4828 people from six European countries verified that the attributes considered as positives (DF, vitamins and minerals) receive more attention at the moment of purchase than the negative ones (energy, total and saturated fats, sugar and salt), mainly among consumers that are more conscious about health issues (Hoefkens et al., 2011). Once consumers understand that DF is a group of compounds (including oligo as well as polysaccharides), any alteration in the concept may cause confusion and interfere in the adequate selection of foods, and hence affect the daily intake (Giuntini & Menezes, 2011). If each country adopts a different definition, a problem will be created, affecting consumers and food industries in a global market, once nutritional information on the label will be different for the same product (Howlett et al., 2010). Also, it is possible that it may create barriers for the international market (Giuntini & Menezes, 2011).

Food composition data is the work field of compilers, who aim to collect information to implement databases in a harmonised way. This task will be even more difficult during the steps of evaluation and publication, if different definitions and analytical methods are adopted. In the case of DF, this difficulty is higher due to the complexity of its components. A change in one component definition implies the necessity of new analysis in order to update the food composition tables, which demands high cost and much time; therefore, an international consensus on DF definition is essential to optimise these resources. Due to the utilisation of different methods for DF analyses and the existence of problems for quantification in certain food matrices, there is a discrepancy of DF data among tables from different countries, which may forbid data comparison (Westenbrink, Brunt, & van der Kamp, 2013). Facing this situation, the interpretation of results found in studies about DF physiological benefits may also be compromised (Howlett et al., 2010).

In the case of foods that are rich in oligosaccharides, the energy value has been overestimated in food composition tables and labels (using AOAC 985.29 or AOAC 991.43). Westenbrink et al. (2013) compared fibre and energy data in 6 foods, which were analysed by AOAC 985.29 and AOAC 2009.01 methods, and they observed that the energy of currant bread was 10% lower, in muesli fortified with dietary fibre and apple sauce it was 12%, and in orange juice, 20%. Therefore, depending on the frequency, combination and quantities that are consumed, this difference may become considerable for evaluation of consumption; reinforcing the need of including carbohydrates of 3–9 DP in the DF definition and the use of adequate methodology.

A single harmonised DF definition (including carbohydrates of 3–9 DP) involves benefits to consumers, science, compilers, industry and others, such as unequivocal identification on the label; possibility of comparison of DF contents in different databases; easier compilation process; fomentation to the commercialization of the product with similar labelling in different countries and the investments for research, aiming to improve the content of fibre in foods.

4. Conclusions

There is no scientific, methodological or physiologic justification for considering that unavailable carbohydrates have different behaviour when the number of degrees of polymerisation (DP) is <10 or ⩾10.

The decision of including unavailable carbohydrates of 3–9 DP in the DF definition may cause effective global nutritional labelling harmonisation and, at the same time, presents several advantages: it allows the comparison of DF intakes across different geographic regions and the interpretation of the studies assessing possible beneficial physiologic effects; it does not affect consumers' understanding of what DF is; it simplifies food composition compilers' and regulatory agencies' work; moreover, an adequate analytical method already exists. Several countries and entities already include carbohydrates of 3–9 DP in the DF definition. This decision may cause promotion of a healthier food supply, and hence healthier people.

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