



Dietary fibre: Challenges in production and use of food composition data

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ABSTRACT

Dietary fibre is a heterogeneous group of components for which several definitions and analytical methods were developed over the past decades, causing confusion among users and producers of dietary fibre data in food composition databases. An overview is given of current definitions and analytical methods. Some of the issues related to maintaining dietary fibre values in food composition databases are discussed.

Newly developed AOAC methods (2009.01 or modifications) yield higher dietary fibre values, due to the inclusion of low molecular weight dietary fibre and resistant starch. For food composition databases procedures need to be developed to combine 'classic' and 'new' dietary fibre values since re-analysing all foods on short notice is impossible due to financial restrictions. Standardised value documentation procedures are important to evaluate dietary fibre values from several sources before exchanging and using the data, e.g. for dietary intake research.

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1. Introduction

Over the last decades knowledge on dietary fibre has increased considerably, both in the physiological and analytical area. Health benefits of dietary fibre are associated with bowel function, reduced risk of coronary heart diseases, type 2 diabetes and improved weight maintenance (EFSA, 2010; Hauner et al., 2012). Analytical methods and definitions have evolved over the years. As a result more or less comparable dietary fibre values were produced and presented in food composition databases for use in food research, food industry and for nutritional counselling and education. Still dietary fibre is one of the components in foods that cause a lot of confusion among users and producers of food composition data.

We aim to give an overview of current definitions and analytical methods for dietary fibre and to discuss some of the issues related to the production and use of dietary fibre values in food composition databases.

2. Definition of dietary fibre

Dietary fibre is a heterogeneous complex of components, which complicates direct analytical measurements. Several classifications of dietary fibre fractions can be found, based on the analytical

methodology used, such as soluble and insoluble dietary fibre and high molecular weight dietary fibre (HMWDF) and low molecular weight dietary fibre (LMWDF). In Fig. 1 an overview is given of carbohydrates including available carbohydrates and dietary fibre fractions showing the interrelation and complexity.

As recently summarised by DeVries and EFSA dietary fibre was originally defined in 1972 by Trowell as 'that portion of food which is derived from cellular walls of plants which are digested very poorly by human beings' (DeVries, 2010; EFSA, 2010). The recognition that polysaccharides added to foods could have effects similar to those originating from plant cell walls led to a redefinition of dietary fibre by Trowell et al. in 1976 to include 'polysaccharides and lignin that are not digested in the human small intestine'. This definition was used for over 30 years and led to the development of analytical methods for dietary fibre that complied with this definition. The Prosky method was the basis for the AOAC official method 985.29 which was adopted in 1985 (DeVries, 2010; Greenfield & Southgate, 2003). In a wide range of countries this method was incorporated in national regulations and/or the amount of dietary fibre was defined as the amount measured with AOAC method 985.29.

However, the inclusion of polysaccharides added to foods in the definition of dietary fibre was not accepted universally, since epidemiological support for the health benefits of dietary fibre is for the major part based on diets that contain fruits, vegetables and wholegrain cereals which have the characteristic of containing plant cell walls. This view was expressed in a series of papers in a special issue of the European Journal of Clinical Nutrition

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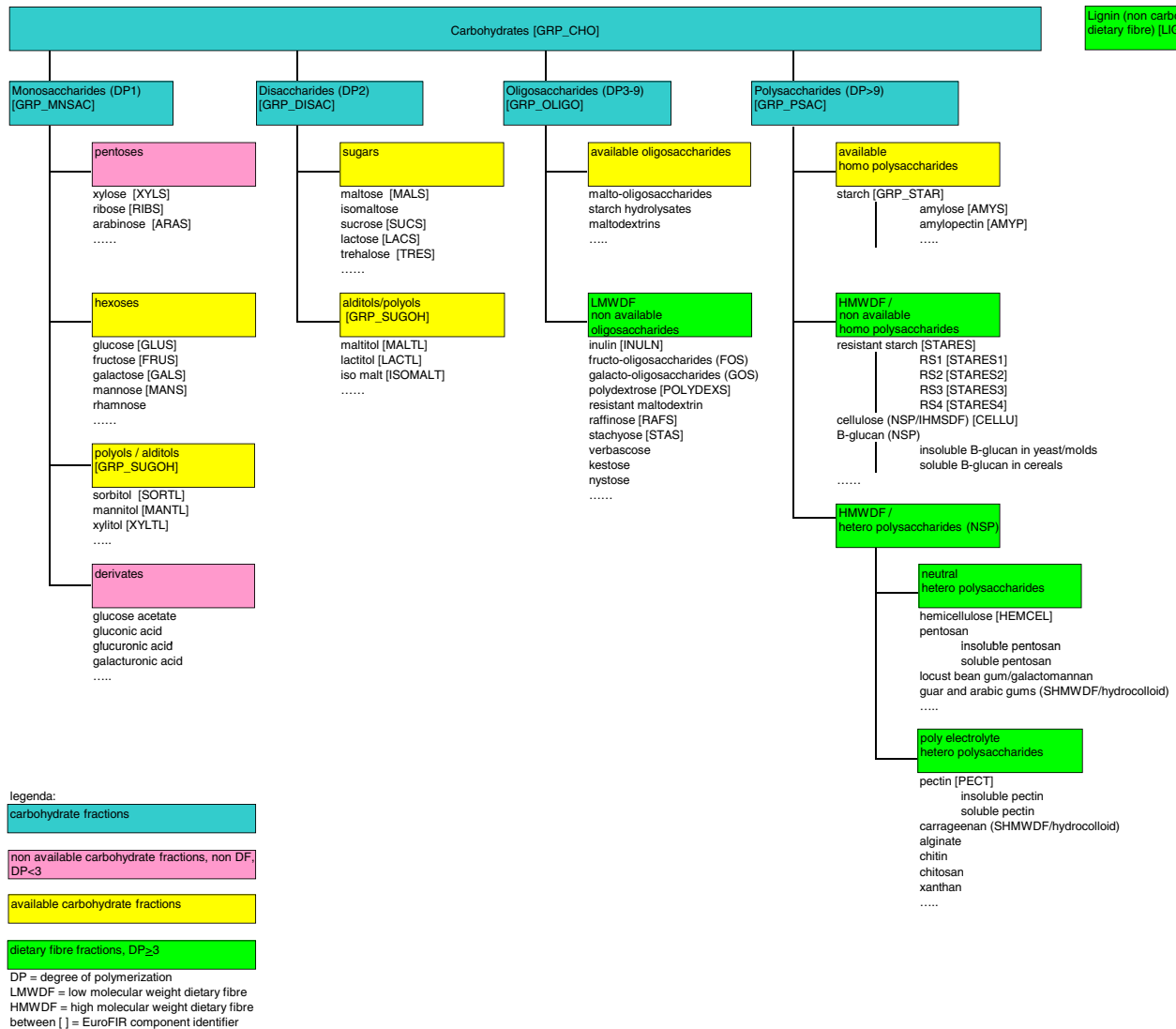


Fig. 1. Schematic overview of carbohydrates including dietary fibre fractions with EuroFIR component identifier.

(Nishida, Martinez Nocito, & Mann, 2007). The Englyst method (Englyst & Hudson, 1996) was recommended as a method for measuring these plant cell wall related fibres. Dietary fibre levels measured with the Englyst method are lower than those measured with AOAC method 985.29, since lignin and resistant starch are not included. Although the Englyst method has not been accepted as standard method by AOAC or other authoritative bodies, dietary fibre levels according to Englyst were included in the food composition databases of the UK and some other countries.

The debate on the definition of dietary fibre was finalised in 2008/2009 by the Codex Alimentarius Commission defining dietary fibre as follows (Codex, 2009):

Dietary fibre means carbohydrate polymers with ten or more monomeric units, which are not hydrolysed by the endogenous 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.

The decision on whether to include carbohydrates from 3 to 9 monomeric units should be left to national authorities.

The European Commission adopted this definition and includes all polymers with 3 or more monomeric units (European Commission, 2008). In addition to the EU also non-EU countries, Canada and China have chosen for including these polymers, whereas in other countries no decision has yet been made.

The definition as adopted by Codex, EU and others includes on the one hand non-digestible carbohydrates added to food, but requires on the other hand generally accepted scientific evidence for a beneficial health effect for those added fibres.

3. Analytical methods

For years the AOAC985.29 and AOAC991.43 have been the main methods of analysis for the determination of the dietary fibre in foods (DeVries, 2010). The AOAC991.43 method distinguishes between insoluble and soluble high molecular weight dietary fibre (HMWDF) and in the AOAC985.29 method total HMWDF, being

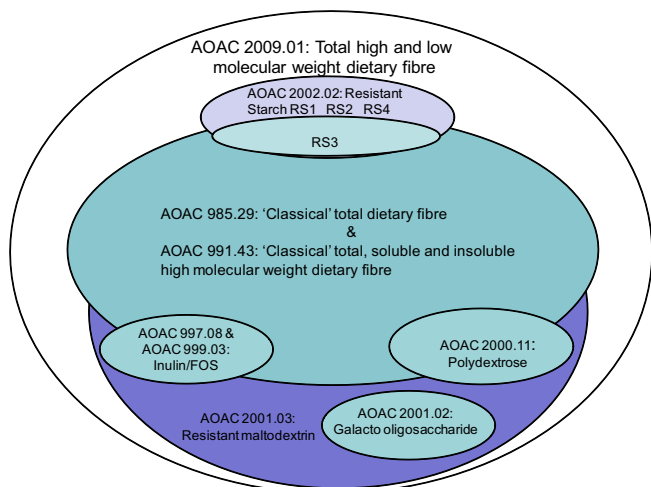


Fig. 2. Schematic overview of analytical methods for dietary fibre fractions.

the sum of insoluble and soluble fractions is measured directly. However, these methods appeared to be inappropriate for the determination of the upcoming new category of low molecular weight dietary fibres (LMWDF) such as inulin, fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS) and polydextrose. Another drawback of the classical methods is that only the RS3 type of resistant starch (retrograded starch/amylose, the predominant RS type in most food products) is measured and not the RS1, RS2 and RS4 categories of resistant starch.

Therefore, in contrast to AOAC985.29 and 991.43 measuring total dietary fibre, specific AOAC methods were developed to measure the different dietary fibre constituents separately. All available methods make it complex to select the correct dietary fibre measurement in an unknown sample. Unfortunately applying both the classical and specific methods is no solution because there is considerable overlap between several of these methods (Brunt, 2009). Fig. 2 gives an overview of available analytical methods for total dietary fibre and dietary fibre fractions, including the overlap between several methods.

In the quantification of long chain inulins AOAC985.29 and 991.43 overlap with AOAC997.08 and 999.03. Also the AOAC2001.03 method for resistant maltodextrin and the AOAC2000.11 method for polydextrose have a considerable overlap with both AOAC985.29 and 991.43. Additionally AOAC2001.03 overlaps with the inulin/FOS (AOAC997.08 and 999.03), GOS (AOAC2001.02) and polydextrose methods (AOAC2000.11). And as mentioned earlier, RS3 is measured both with the two classical methods and AOAC 2002.02.

In 2007 an integrated method for the determination of total HMWDF, LMWDF and resistant starch was described (McCleary, 2007; McCleary et al., 2010). The method is more or less a combination of AOAC2002.02 (for the sample pre-treatment), AOAC985.29 (for quantization of HMWDF) and AOAC2001.02 (for quantization of LMWDF). This procedure is now known as the AOAC2009.01 total dietary fibre method (McCleary et al., 2010). The benefit of this new method is that it eliminates the need to apply both AOAC985.29 for total dietary fibre and specific methods for measuring RS types 1, 2 and 4 and LMWDF. Recently food producers noticed often to their surprise that added LMWDF was not measured with the AOAC985.29 standard method (Brunt, 2009).

A recent investigation shows an imperfection in the AOAC2009.01 method for high starch containing matrices (Brunt & Sanders, 2012). It appeared that in those matrices the available starch and maltodextrins were not fully converted into glucose and maltose by the enzymatic hydrolysis. This results in minor amounts of residual malto-oligosaccharides still present in the

LMWDF fraction, which will erroneously be quantified as LMWDF. This error could easily be eliminated by introducing an extra hydrolysis step in the analytical protocol. Details are presented elsewhere (Brunt & Sanders, 2012).

It is important to notice that applying the AOAC2009.01 method in any case for grain based sample matrices, results in significantly higher total dietary fibre content than previously measured with the classical AOAC985.29 method. It is shown that these samples 'by nature' contain LMWDF and that HMWDF by AOAC2009.01 equals total dietary fibre as determined by classical AOAC985.29 and or AOAC991.43 methods (Brunt & Sanders, 2012).

More recently, as was presented at the 5th International Dietary Fibre Conference in Rome in 2012, the AOAC2011.25 method being an extension of AOAC2009.01 is under development (SIDFC, 2012). In the AOAC 2011.25 method the HMWDF fraction is split into a soluble HMWDF and an insoluble HMWDF part of which the sum equals the HMWDF content as measured with the AOAC2009.01 method. This situation resembles that of AOAC991.43 being an extension of AOAC985.29 and differentiating between soluble and insoluble fractions.

4. Food composition databases

Most food composition databases include and publish total dietary fibre. Developments on definition and analytical methods for dietary fibre are reflected in food composition data. Since 1985 most data are produced by the AOAC985.29 and AOAC991.43 dietary fibre methods (DeVries, 2010; EFSA, 2010; Greenfield & Southgate, 2003).

In the European Prospective Investigation into Cancer and Nutrition (EPIC) project Deharveng et al. compared the food composition tables of nine European countries regarding availability, definition, analytical methods and value documentation (Deharveng, Charrondi re, Slimani, Southgate, & Riboli, 1999). Dietary fibre was one of the nutrients that were found not to be comparable between countries.

In 1999 dietary fibre values in the databases under evaluation were mainly produced by (a) AOAC methods (based on the Prosky method), measuring non-starch polysaccharides (NSP), lignin and resistant starch (type RS3); (b) Englyst-type methods measuring dietary fibre, defined as NSP. Lignin, waxes, cutins and resistant starch are not included; (c) 'By difference' method calculating total dietary fibre as 100-(water + protein + fat + ash + available carbohydrates). Dietary fibre calculated in this way strongly depends on how carbohydrates are measured or calculated, e.g. are oligosaccharides such as inulin excluded from the available carbohydrates or erroneously included. Dietary fibre by difference does include resistant starch; (d) Southgate-type methods measuring NSP, lignins and some starch.

Deharveng concluded that the use of several incompatible methods makes it extremely difficult to compare dietary fibre intake between countries and even within countries if values from several sources are used (Deharveng et al., 1999). The values obtained by Southgate-type methods should in principle be similar to those measured by AOAC-type methods. The AOAC and related methods give higher values than the Englyst-method because they include lignin and resistant starch type RS3 (Deharveng et al., 1999). The 'by difference' method, which was not used very often, is very imprecise. The results reflect all uncertainties and errors associated with the determination of the other components, including available carbohydrates for which similar problems with respect to analytical methods and definitions occur.

Since then a lot of work has been done to improve food composition databases both by EuroFIR (www.eurofir.net) and INFOODS (www.fao.org/infoods/). Improvements were made by filling in

missing values and by adding more complete and standardised value documentation, including references and analytical or calculation methods for each individual data point (EuroFIR, 2010). In 2011 Southgate-type values are not included in the published UK tables anymore. However in many food composition tables old values are still being used due to the lack of new values. This includes Southgate and Englyst values, as values are often borrowed from foreign food composition tables. It is therefore expected that incomparability of dietary fibre values is still a problem.

Until new values are produced with validated new methods the current values in food composition databases can and must be used in order to estimate dietary fibre intake as accurate as possible.

5. Discussion on current and new challenges

5.1. Identification of dietary fibre in food composition databases

To correctly exchange and compare dietary fibre data in food composition databases it is essential to unambiguously identify and encode the dietary fibre value it concerns. This was clear from the work of Deharveng and is also emphasised by the developments in analytical methodology, with new methods measuring more specific dietary fibre fractions.

It can be discussed whether or not total dietary fibre measured by AOAC2009.01 or modifications should be encoded with the same component code as dietary fibre determined by AOAC985.29 or 991.43. Strictly taken it must be considered that these components are not identical, as LMWDF and most RS types are included in AOAC2009.01 and modifications, but not in AOAC985.29 or AOAC991.43. However, previously total dietary fibre values resulting from different analytical methods were not treated consequently as different components in food composition databases. And most users of food composition data require one value for total dietary fibre per food item, rather than having to choose between several slightly different and possibly overlapping total dietary fibre values. From the food database management perspective treating total dietary fibre values from both methods as different components will imply that there will be many missing values for the AOAC2009.01 method or modifications for a considerable period of time. Assumptions will need to be made to fill in these missing values. Or both components need to be merged just before disseminating the data in food composition tables or by the end-users. It is likely that such approaches induce uncertainties that equal or exceed the possible errors from combining values from the new and classical AOAC methods in food composition databases.

A suggestion could be to distinguish dietary fibre values into HMWDF and LMWDF in food composition databases. Both values are available from the AOAC2009.01 method or modifications and total dietary fibre is calculated by summation. If the trend seen by Brunt (Brunt & Sanders, 2012) is confirmed in further research, this would imply that the current total dietary fibre values measured with AOAC985.29 or 991.43 are similar to HMWDF measured with AOAC2009.01. Until new research yields up-to-date values for HMWDF and LMWDF, the 'classic' values could still be used for HMWDF. This would prevent for too many missing values in the food composition databases.

A standardized tool to identify components is the EuroFIR component identifier, maintained in the EuroFIR thesaurus (EuroFIR, 2010). As is shown in Fig. 1, where the EuroFIR component identifier is given between brackets [], for some dietary fibre fractions codes are still missing. For correct and complete component identification the EuroFIR component thesaurus needs to be updated. The EuroFIR component identifier for total dietary fibre is [FIBT], but depending on the method used and the dietary fibre fractions

included the meaning can vary. If both HMWDF and LMWDF are to be included in food composition databases, identifiers for HMWDF and LMWDF need to be introduced. Additional information on the analytical method applied needs to be documented as well. INFOODS has developed tags to identify components in food composition databases that include the method of analysis within the tag.

5.2. Dietary fibre and energy

In 2008 the EU directive on food labelling 2008/100/EC (European Commission, 2008) stated that dietary fibre needs to be included in the energy calculation of foods because about 70% of the dietary fibre is fermented in the colon providing about 8 kJ (2 kcal) per gram of dietary fibre.

Applying this guideline to food composition data implies that the energy value of foods becomes somewhat higher, as was seen in the 2011 version of the Dutch Food Composition Database (NEVO, 2011).

Application of the AOAC2009.01 method or modifications will yield higher dietary fibre values for those foods containing resistant starch and LMWDF. Total available carbohydrates very often are calculated by difference. Applying this approach the amount of calculated total available carbohydrates will then be lower, because when using the classic AOAC985.29 or AOAC991.43 methods these resistant starch and LMWDF dietary fibre fractions were calculated as available carbohydrates. In case sugars, available malto-oligosaccharides and available starch are analysed with total available carbohydrates calculated by summation, the amounts will not change when using new analytical methods for dietary fibre determination.

Some energy calculations are shown in Table 1 using data from dietary fibre analyses by AOAC985.20 and AOAC2009.01 (Brunt, 2010 personal communication; Brunt & Sanders, 2012), available carbohydrates by difference and macronutrient values from the Dutch Food Composition Database (NEVO, 2011). The calculated differences in total energy are very small or negligible. For individual foods containing higher amounts of resistant starch and LMWDF differences can be more relevant. To study the effect on total energy intake more data on dietary fibre content including resistant starches and LMWDF is needed.

In 2011 6 out of 25 European food composition databases accounted for dietary fibre in the total energy values and 7 did not, according to the information available through their online databases. For other databases no information about energy calculation was available (www.eurofir.net).

5.3. Update dietary fibre values in food composition databases

It is a challenge for food composition database compilers to update dietary fibre values according to the current EU and/or Codex definitions. At the moment no analytical method is defined mandatory in the EU since due to the increasing use of (soluble) LMWDF and resistant starches in foods the AOAC985.29 and AOAC991.43 methods were withdrawn from legislation. The new AOAC2009.01 method or modifications (Brunt & Sanders, 2012) seems to be the appropriate future way to produce analytical values yielding higher total dietary fibre content due to resistant starch and LMWDF.

European food composition databases contain over 39,000 food entries altogether (EuroFIR, 2010). Due to the high costs it will not be possible to re-analyse all these foods using newly developed methods for dietary fibre analysis. Analysing high priority foods based on frequency and amount of consumption would be an option. This will also mean a high financial burden for many national food composition databases. Dietary fibre values for foods with

Table 1

Expected energy values calculated for some foods, based on analytical values for dietary fibre and on the Dutch NEVO food composition table for other macronutrients.

	Currant bread ¹		White bread ²		Muesli fortified with dietary fibre ¹		Apple sauce ²		Orange juice ²		Raw pasta, white ²	
	AOAC 985.29	AOAC 2009.01	AOAC 985.29	AOAC 2009.01	AOAC 985.29	AOAC 2009.01	AOAC 985.29	AOAC 2009.01	AOAC 985.29	AOAC 2009.01	AOAC 985.29	AOAC 2009.01
	g/100 g											
Protein	13.5	13.5	9.0	9.0	10.8	10.8	0.2	0.2	0.7	0.7	12	12
Fat	3.7	3.7	1.6	1.6	9.4	9.4	0	0	0	0	2	2
HMWDF ³	6.6	6.8	3.0	3	11	11	1.4	1.2	0.7	1	6.7	6.5
LMWDF ³		4.7		1.1		9.4		1.4		1.4		2.1
Sorbitol	1.4	1.4										
Isomalt						3.2						
Available carbohydrates	39.7	34.1	49.1	48.0	64.0	51.4	11.0	9.8	9.0	7.3	69.3	67.4
	kcal/100 g											
Energy excl DF ^{4,5}	249	227	247	242	384	341	45	40	39	32	343	336
Energy incl DF ^{4,5}	263	250	253	251	406	382	48	45	40	37	357	353

¹ Complete profile analysed by Brunt, Eurofins (personal communication, 2010). Available carbohydrates are calculated by difference (100 – moisture-protein-fat- sugar alcohols- dietary fibre- ash). It is assumed that components other than dietary fibre and carbohydrates remain similar.

² Dietary fibre analysed by Brunt, Eurofins (Brunt & Sanders, 2012); protein and fat taken from NEVO-online 2011 (NEVO, 2011). Available carbohydrates calculated by difference using analytical DF data from Brunt and other components from NEVO-online 2011. It is assumed that components other than dietary fibre and carbohydrates remain similar.

³ HMWDF = high molecular weight dietary fibre; LMWDF = low molecular weight dietary fibre.

⁴ DF = total dietary fibre.

⁵ Energy conversion factors; protein*4, fat*9, dietary fibre*2, sorbitol and isomalt*2.4, carbohydrate*4.

lower priority could be imputed by copying from similar foods, recipe calculations and estimations.

Discarding 'classic' AOAC985.29 and AOAC991.43 values from food composition databases is not an option as the number of missing values would be too high to correctly estimate dietary fibre intakes. Even in food composition tables that are reasonably filled with dietary fibre values, missing values treated as zero made up to 25% differences in dietary fibre intakes in 2002 (Charrondiere, Vignat, & Riboli, 2002).

For most countries it is likely that dietary fibre values will be updated gradually using the analytical values as they become available from research projects and from the food industry.

Therefore in most food composition databases 'classic' dietary fibre values measured by AOAC985.29 or AOAC991.43 will be used together with the 'new' AOAC2009.01 values. To be able to make distinctions between dietary fibre values from several sources, careful documentation is needed and all necessary information needs to be provided to the database compilers together with the values.

Some food composition databases might include soluble and insoluble dietary fibre as separate entities. As mentioned by EFSA with reference FAO/WHO this differentiation is method-dependent. The correlation between solubility and fermentability is not very straight forward and solubility does not always predict physiological effects. As FAO/WHO in 1998 proposed to phase out the distinction between soluble and insoluble dietary fibre there is in general no indication to include them in food composition databases (EFSA, 2010; FAO/WHO, 1998; FAO/WHO, 2003).

As described earlier applying AOAC2009.01 will affect the total amount of available carbohydrates provided that these are calculated by difference. It has to be kept in mind that when using AOAC2009.01, the LMWDF and resistant starch fractions are no longer calculated as part of the available carbohydrates. This means that available carbohydrates and subsequently total energy also need to be reconsidered (re-analysed/re-calculated and corrected) when updating dietary fibre data for food composition databases.

Food database compilers need to be aware that when working with data on individual dietary fibre fractions these values cannot be added up to get the total amount of dietary fibre since there is

considerable overlap between some of the methods as can be seen in Fig. 2.

5.4. Dietary fibre content claims

To claim that a food is a 'source of fibre', the food should contain at least 3 g of fibre per 100 g (or 1.5 g of fibre per 100 kcal). To claim that a food is 'high in fibre' this should be at least 6 g per 100 g (or 3 g of fibre per 100 kcal) (European Commission, 2006). Using AOAC2009.01 or modifications instead of AOAC985.29 or AOAC991.43, for foods containing resistant starch and LMWDF, the total dietary fibre content will increase and may be sufficiently high to bear a dietary fibre content claim. For example the dietary fibre content of white bread determined by AOAC2009.01 has gone up to 4.1 g/100 g which would allow for the claim of 'source of fibre' (Brunt & Sanders, 2012). The levels for source of and for high in fibre were already used years before the new definitions were in place. However, since Codex officially adopted these levels together with the new definition of dietary fibre, proposals for raising these fibre content claim levels are not expected.

5.5. Dietary fibre definition and analysis

The Codex definition leaves the decision of including carbohydrates from 3 to 9 monomeric units to national authorities. Carbohydrate oligomers with 2 and 3 monomeric units can easily be differentiated analytically, whereas differentiation between 9 and 10 units tends to be more complicated. From the analytical perspective the choice made by the EU and other countries to include non digestible carbohydrates from 3 monomeric units in the dietary fibre definition is the preferred choice.

Analytical complications may also arise from the statement in the definition that added carbohydrates, when analysed as fibre, can only qualify as dietary fibre if they 'have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities'. As yet, Codex nor the EU have developed criteria or guidance notes for implementation of this part of the dietary fibre definition.

An analytical problem may arise for added fibres when EFSA would consider not to define added fibres without an approved

health claim as dietary fibre, although they are analysed as fibre. For example, insulin (submitted health claim not approved (EFSA, 2011)) and cellulose (no application made for a health claim), when added to a food should not be included in the total amount of dietary fibre listed on the product label. In many foods, these fibres – as well as other fibres that can be added – also occur as part of the total amount of fibre naturally present; however this differentiation cannot be made analytically. Food producers, with knowledge of product formulation can subtract for labelling purposes the added fibre from the total dietary fibre level analytically measured. However, laboratories, food inspection agencies or food composition database compilers without knowledge of the product recipe cannot, which makes it impossible for them to correctly identify the total dietary fibre level according to the definition.

From the analytical perspective a preferred option would be to acknowledge –as a benefit to health– the fact that dietary fibres have a lower caloric value than other carbohydrates.

Recommendations for total dietary fibre intake are based on research using data from the classical AOAC methods (985.29 or 991.43), which cover mainly the HMWDF fractions. Future analytical work will probably generate an over-all picture of the differences in fibre content and in types of fibre –HMWDF and LMWDF– of foods and diets when analysed with the classical and the new AOAC methods. With such an overview in place, dietary recommendations for total dietary fibre intake could be reconsidered.

6. Conclusions and recommendations

Working with dietary fibre data requires knowledge on analytical methodology, definitions, physical properties etc and above all awareness of the differences and possible errors induced by using previous and current approaches. Documentation of all available information, including the analytical method on each dietary fibre data point is essential to be able to compare, exchange and use dietary fibre data from several sources and to distinguish between data whenever needed.

It is needed to work on better understanding both for users and producers of dietary fibre values. Essential requirements are international consensus on the preferred definition and analytical methods for dietary fibre. Recent work on AOAC2011.25 for total dietary fibre shows that analytical methods for dietary fibre are still under development. For food composition databases it is recommended to wait with large scale measurements to update dietary fibre values until a more stable situation has been reached.

Achieving international consensus on component identification for total dietary fibre values from the ‘classic’ and ‘new’ AOAC methods is recommended.

Easily available and understandable overviews of the relation between carbohydrates and dietary fibre fractions and the analytical methods applicable to these components are important tools to improve the correct use of dietary fibre values. The need for training on these issues for all users and producers of dietary fibre data in food composition databases is emphasised.

The introduction of HMWDF and LMWDF in food composition databases, in addition to total dietary fibre, seems an acceptable

way to combine both ‘classic’ and ‘new’ analytical data on dietary fibre, if the assumption that current total dietary fibre values equals HMWDF as measured by the new methods proves correct. Missing data on LMWDF need to be filled in.

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