Chemical redefinition of nutrients

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Summary

Growth in understanding of the chemistry and physiological effects of nutrients requires that there be periodic review of accepted nutritional terms so that more adequate information can be provided to consumers, thus facilitating better dietary habits. While data in food composition tables may be among the first to reflect research outcomes, compromise is necessary between provision of chemical detail and clarity of presentation, particularly for food labels. A process of discussion must occur between nutrition researchers, food scientists and dietitians before decisions are made that interface with the wider community. Some of the recent communications on fat, carbohydrate, dietary fibre, energy and folic acid are presented with the question as to whether now is an appropriate time to update some nutrient definitions.

Introduction

From the perspective of a food analyst, it appears that the already large discontinuity between nutrition science and its most public interface - food labels - is growing wider. While our understanding of molecular biology has exploded in recent times, we still measure food protein as some multiple of its nitrogen content. The literature has been generally humming with the latest properties of ω-x-fatty acids at the same time as fat in food is measured as total ether-soluble material. Many books have been written on the beneficial physiological effects of carbohydrates, previously considered 'unavailable', while we still calculate carbohydrate by difference.

Constant media exposure of significant research findings must create great frustration for consumers reading their favourite foods labels. On the other hand, some simplification of complex chemical systems is inevitable to provide more comprehensible nutrient 'indexes' or summaries, such as retinol equivalents. Furthermore, some measurement procedures have not been thoroughly scrutinised outside the research environment. Food composition databases may be the best repository for precisely detailed nutrition data. However, a review process is required before deciding when is the appropriate time to update more public nutrient definitions. The fact that further change is inevitable should not stifle the review process or prevent the use of interim measures. There will always be need for a balance between complex nutrition concepts and clear and concise terms that provide meaningful information to consumers.

In recent years, attention has been drawn to several micro-nutrients, arising from new understanding of nutritional significance and/or new methodologies, for example thiamin, folic acid and trace elements. Several macro-nutrients have also been undergoing review, with direct implications for nutrition labelling, for example fat and carbohydrates such as starch and oligosaccharides. The question is whether there is a ready combination of established nutrition science, analytical methodology and suitable characterisation for food labels.

Fat

For food analysts, fat has been traditionally defined simply as 'ether-soluble material' derived from a range of analytical procedures. This has led to problems, one of which has been caused by selection of inappropriate extraction procedures for particular foods. Overestimation of total fat for example occurs by co-extraction of condensed sugars from high-sugar-foods, using acid hydrolysis without clean-up of the fatty residues. Total fat is underestimated when simple ether extraction procedures are used for foods that require prior hydrolysis (by acid or enzyme) to release a significant proportion of bound fatty material. Another concern is overestimation due to inclusion of phospholipids in gravimetric 'total' fat resulting in double counting of phosphorus.

These problems were among the reasons for the Association of Official Analytical Chemists (AOAC) International Labelling Taskforce (Int.) to recommend a definition of fat that was subsequently adopted by the Food and Drug Administration (FDA) for USA nutrition labelling purposes. Fat is defined as 'the sum of all fatty acids obtained from a total lipid extract of the food matrix expressed as triglycerides' (1). This accounts for the components of food for which an energy value of 37 kJ/g can be ascribed. An analytical procedure involving acid-hydrolysis followed by gas-liquid chromatographic (GLC) measurement of triglycerides as fatty acid methyl esters has recently undergone AOAC Int. collaborative study (2). While this definition is chemically precise, among the outcomes of the change are lower apparent fat contents in plant foods where there is a significant phospholipid and glycolipid content and other minor lipids such as sterols and terpenes are no longer included. This definition should not cause neglect for the nutritional significance of phospholipids or particular components such as w-3 or w-6 unsaturated fatty acids.

In Australia it is not mandatory to measure the proportions of saturated and unsaturated fat for food labelling as is required in the USA, so relatively few local food laboratories would be equipped to undertake immediate analysis in support of such a change in methodology. Any consideration of such an updated definition should include costs of equipment and method implementation as well as implications of changes to apparent fat levels in foods.

Carbohydrate

Similar to the case with fat, the present definition for carbohydrate, laid down in the Australian Food Standards Code (AFSC) for food labelling purposes, is fairly simple or crude, namely 'carbohydrate by difference' (AFSC A1, (13)) (3). Carbohydrate is calculated as the difference from 100 of the sum of the moisture protein, fat and ash contents of a food. The total carbohydrate figure includes dietary fibre. This total carbohydrate value is then supplemented by separately labelling the sum of mono- and di-saccharides.

Alternative methods for total carbohydrate measurement, shown in Table 1 could sum the carbohydrate components such as: starch (including resistant starch), sugars, oligosaccharides and non-starch polysaccharides. To define available carbohydrate as a similar sum, measurements are necessary to distinguish available fractions of all such components. It is apparent that such an approach presents many analytical problems and the list may become more complicated arising from further research.

Table 1. Alternative carbohydrate definitions

By difference	Total	Available
100 - % Protein - % Fat - % Ash - % Moisture	Sum of: Starch (total) Glycogen Mono- & disaccharides Sugar alcohols Non-starch polysaccharides Oligosaccharides	Sum of: Starch (total - resistant) Glycogen Mono- & disaccharides, some sugar alcohols

So, while 'carbohydrate by difference' may appear to be a crude concept, it is in fact inexpensive and rugged while the alternatives have not generally undergone analytical validation at this stage. Another perspective of this debate is seen in the search to chemically define 'complex carbohydrate' for labelling purposes in USA. Interestingly, evaluation of an assay for complex carbohydrate (as the sum of available starch and dietary fibre) gave results in close agreement with a difference calculation (100 - moisture - protein - fat - ash - mono- and di-saccharides) (4).

It should be noted that there is potential for confusion over compliance with Australian regulatory requirements in labelling of carbohydrate content in foods. One of the alternatives for food manufacturers in preparing Nutrition Information Panels is to derive appropriate nutrient values from 'generally established and accepted data' such as Composition of Foods Australia (COFA) (5). However COFA's available carbohydrate values are calculated as sums of 'starch' (and glycogen), mono- and di-saccharides and sugar alcohols contents (without the inclusion of total dietary fibre). Does this mean that manufacturers who wish to employ this alternative need to obtain the tabulated food's ash content (not provided in abridged tables), in order to calculate carbohydrate by difference values for labelling purposes?

Dietary Fibre

It is more than two decades since epidemiological observations prompted Burkitt and Trowel to recommend recognition of health benefits derived from consumption of previously denigrated indigestible food components (6). In the intervening years several analytical techniques have received inter-laboratory validation, but there is still debate as to which method is the 'best'. For food labelling in Australia the first AOAC Int. enzyme-gravimetric method for total dietary fibre (TDF) (7) is prescribed by the AFSC. This measure includes non-starch polysaccharides as well as some or all of the resistant starch, lignin, some browning products, and other minor plant components that are associated with fibre, eg cutins, phenolics. These individual components can be separately analysed from the fibre residue if desired. Australian food tables (COFA) also include measurements by the enzyme-chemical method of 'fibre' as non-starch polysaccharides (NSP) (8) for a range of foods. The details of monosaccharide components in most NSP analyses allows an estimate to be made of the nature of the original plant polysaccharides. This is only an estimate, because when food formulations are not known, it is possible that isolated monosaccharides could have originated from one of several polysaccharides. Separate analyses would be required to individually assay resistant starch and other, fibre-associated materials.

Which fibre method is best, or which is the favourite fibre definition, depends on which is the preferred approach out of (a) isolation of 'pure chemical entities', an index of plant cell walls (NSP) or (b) the sum of 'physiologically indigestible residues', an index of food's unavailable carbohydrate (TDF). There are valid arguments on both sides. Further, both of the above methods have important limitations such as their failure to measure most unavailable oligosaccharides, since these are not precipitated in the 80% ethanol/water commonly used to precipitate 'soluble' fibre. As for resistant starch, this is clearly an important unavailable carbohydrate with fermentation characteristics in the bowel similar to soluble dietary fibre (9). However, separate measurement is ideally required where test materials retain the same intact food structures that humans ingest (10). Physiological-type starch degradation can then isolate resistant starch. However, this approach must re-open the wider question of digestibility of all nutrients from 'intact' ingested food materials. It is interesting that this approach has also been proposed by workers studying glycaemic index (11). In addition, there is scope for development of methods to assay individual polysaccharides, analogous to present specific methods for b-glucan assay (12).

Energy

Energy factors of 17, 37 and 17 kJ/g are presently recognised in Australia for protein, fat and carbohydrate, respectively (3, 5), although, they should be understood as working approximations of actual factors that vary depending on the particular food, types of processing, interactions between foods and individual variations. Nevertheless, it could be proposed that energy factors be reconsidered in the light of the USFDA chemical definition for fat and new understandings of 'unavailable' carbohydrates (dietary fibre) and their associated energy factors which are summarised in Table 2.

Table 2. Summary of energy values of dietary fibre components

Fibre component	Energy value kJ/g	Reference
Non-starch polysaccharides		
cellulose	0	(13)
wheat bran	4	(14)
oat bran	13	(15)
psyllium	4	(14)
inulin	5	(16)
Resistant starch	5	(17)
Oligosaccharides		
oligofructose	5	(16)
polydextrose	4	(3)
Sugar alcohols		
lactitol	9	(3)

In Australia dietary fibre is not separated from other carbohydrates in normal energy calculations, thus dietary fibre is assumed to have the same energy factor as available carbohydrates. By comparison, in UK non-starch polysaccharides are ascribed an energy factor of zero and in USA 'insoluble' dietary fibre is ascribed an energy value of zero (18). Concern over standardisation of factors and recognition for resistant oligosaccharides is illustrated in a 1995 application to the National Food Authority that dietary fibre be subtracted from carbohydrate as well as to ascribe an energy value of 4 kJ/g to inulin and oligofructose (19).

Folate

Several practical issues cloud the picture of folate and its important nutritional roles. There appears to be a range of biological activities for various folates, with synthetic folic acid having higher biological activity than natural folates (20) and polyglutamyl folates are less active/well absorbed than monoglutamate forms (21). There also have been problems with analytical procedures, especially with deconjugation of natural folates (22, 23). If there is a need to measure total natural folates there may also need to be some calculation of 'folate equivalents' to derive the most accurate 'physiological' sum for total folate.

A contrary position

Running counter to the movement towards more precise or analytical definition of nutrients is the holistic approach which argues against 'nutrients' as such and in favour of 'foods'. This case is accumulating strong supporting evidence for example: failure of isolated nutrients to show the same effects as foods containing the same nutrients (eg b-carotene (24)), refined foods compared with minimally processed foods (whole grain cereals)(25) and isolated plant fibre components compared with the original plant materials and the fibre-associated phytochemicals. Supporters of this case may also point to undue emphasis of negative properties of food components that ignores positive aspects, eg the property of binding to nutrients of phytate and tannin, without consideration of their antioxidant properties (26).

Conclusions

It is important to continue discussions over the nature of nutrients and the best methods for measurement or characterisation. It is just as important to accept that the same degree of definition is not required in every context, so that nutrients in dietary guidelines do not need to be as specific as those in nutrition research or health studies. While it is clear that much more is yet to be learned about the chemical and physiological properties of most nutrients, it may nevertheless be opportune to differentiate energy factors of major food carbohydrate constituents.

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