Assessment of Carbohydrate Availability, Fermentability, and Food Energy Value in Humans Using Measurements of Breath Hydrogen

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ABSTRACT
Measurements in humans of their breath hydrogen is sometimes used to assess the availability, fermentability, and food energy value of carbohydrates that, to an unknown extent, resists small intestinal digestion and fermentation in the large intestine. Here I outline that the method is utterly flawed and conclude that it is unsuitable for making claims as to the availability, fermentability, and food energy value of carbohydrates. More traditional methods, although more demanding of time and effort, can be used. Otherwise further development of methodology is essential to avoid undue risk of bias.

The July 30, 2020, online issue of the Journal of American College of Nutrition includes unproven claims concerning the fermentability and food energy value of Promitor® fiber—also somewhat misleadingly called “soluble corn fiber” or “SCF” (1), misleading to the extent that it is not a fiber naturally present in corn—it is generated by partial modification of corn starch to create Promitor® fiber. This fiber is therefore a non-intrinsic, non-natural, artificial fiber, which for food labeling purposes would be called an added or supplemental dietary fiber (if approved) alongside some other synthetic and artificial dietary fibers (2).

The basis of the authors’ claim (1) is that Promitor® fiber when ingested by their human participants gave rise to little or no additional hydrogen gas in expired breath—hydrogen that is considered a marker of the occurrence of fiber fermentation by microorganisms in the colon. This led the authors to a seemingly logical (but unsubstantiated) claim that Promitor® fiber must essentially be poorly fermented and so have a low food energy value, claiming an undefined “available energy” value of 0.2 kcal/g (1).

Their (1) “available energy” was undefined because we do not know the routes of energy loss from Promitor® fiber or what the energy is thought to be used for. Energy losses may be to fecal energy (FE), urinary energy (UE), gaseous energy (in methane in addition to hydrogen) (GaE), surface energy (SE) (in hair and skin, often considered minimal in food or ingredient energy studies in humans), and heat energy (HE). These energy losses together with the gross energy (GE) content of foods, components and ingredients, allows “available energy” to be defined as energy used for either metabolizable energy (ME) (3–5) or net energy for maintenance (inclusive of physical activity) (NEm) (6) or production (growth, etc.) (NEp) (6) or net metabolizable energy (NME). The last (NME) accounts for differences among protein, fat, available carbohydrate, and fermentable carbohydrate with which metabolizable energy is used at a biochemical level (ATP and ATP equivalents) (5) and has been acknowledged to be a valid approach to derive food energy values (7) (8) should the NME system of food energy evaluation be adopted in food labelling or when used in research. Whatever definition applies, it is not determinable at present through measurements on breath hydrogen (see below).

By contrast with the claim of 0.2 kcal/g “available energy” for “SCF” (Promitor® fiber), conventional energy balance studies in animals have shown “SCF” to yield much higher metabolizable energy values: 2.6 kcal/g SCF85 in dogs (9), 1.8 kcal/g SCF70 in pigs (10), and 1.5 kcal/g SCF70 in roosters (10), the last of which is lowest possibly because roosters have the lowest fermentation capacity. It makes no sense that the “available energy” value for the fiber fraction in “SCF” (i.e., Promitor® fiber) is 0.2 kcal/g given that the two SCF products studied in animals purportedly contained either 70% or 85% Promitor® fiber. Meanwhile, these values in animals are little different to the 2 kcal/g for dietary fiber in mixed diets generally for persons in energy and nitrogen balance (3,11,12).

Unfortunately, the reason for the low breath hydrogen (and calculated “available energy” value) for Promitor® fiber has not been substantiated in their publication (1). This is because the study results can be due, in theory, to either (1) Promitor® “fiber” not reaching the colon at all or (2) a low level of Promitor® fiber fermentation or (3) a low level of hydrogen gas production for a given amount of Promitor®...
fiber fermented or (4) late fermentation beyond 10 hours, which is less than half the diurnal cycle needed to fully capture short-term results of fermentation, or (5) failure to adapt the population of colonic microflora to the presence of Promitor® fiber, which is a novel fiber. Other problems of interpretation include the following: (6) differential (test vs referent carbohydrate) loss of hydrogen to flatus, (7) differential loss of hydrogen to methanogenesis, (8) instability of baseline hydrogen excretion, (9) interpretation of negative incremental areas under the curve (iAUC), and (10) whether or not the dose-response iAUC is linear for both treatment and referent carbohydrates and fitted through the origin or not.

Most probable among these reasons is a combination of numbers 3, 4, and 5, with 6 to 10 adding to possible bias and variability in results. However, in regard to possibility number 1, Canene-Adams et al. cite (1) an FDA document recognizing “soluble corn fiber” as dietary fiber (13). But in regard to number 2, there is no conventional evidence in this document (1) supporting the supposed resistance of Promitor® fiber to fermentation such as the retrieval of Promitor® fiber from stools.

If all the Promitor® fiber, reached the colon there is a particular concern. One must ask: Do the two carbohydrates (Promitor® fiber and inulin as referent) yield the same amount of breath hydrogen per unit amount of these carbohydrate fermented in vivo? It is clear that different non-digestible carbohydrates yield very different amounts of hydrogen gas when fermented by human colonic microorganisms, both in vitro and in vivo, per unit amount fermented (14–16). Further, relevant observations with dietary fiber from mixed diets has also led to the conclusion that breath hydrogen is of limited value for assessing the extent of fiber fermentation or its fermentability (17–19). The Life Science Research Office (LSRO) in 1994 (20), citing others (21,22), also refers to differences in the stoichiometry for breath hydrogen production from different nondigestible but fully fermentable carbohydrates, isomalt, lactitol, and lactulose. LSRO (2000) did similarly when addressing the food energy values of two soluble dietary fibers (23).

Notably, among a variety of different non-digestible carbohydrates, the stoichiometry relating breath hydrogen exhalation to fermentation in vivo correlates well with the stoichiometry in vitro (14). The overwhelming conclusion is that without calibration of the breath hydrogen response for this stoichiometry for both Promitor® fiber and its referent, inulin—which is a fully fermentable fiber—the fermentability and food energy value of the Promitor® fiber cannot be calculated from measurements of breath hydrogen excretion. Even then, there are potential problems because mixtures of different fermentable carbohydrate may not increase breath hydrogen in amounts expected from the sum of the breath hydrogen responses to the individual fermentable carbohydrates (14).

There are at least two implications should Promitor® fiber be so poorly fermented as to have an “available energy” of only 0.2 kcal/g in humans. First, such a poor fermentability would exclude the fiber as a useful prebiotic since prebiotic carbohydrates by definition must be, as recently defined by consensus, “a substrate that is selectively utilised [fermented] by host micro-organisms conferring a health benefit” (24). Second, such a poorly fermented fiber would also exclude an improved calcium absorption via short-chain fatty acid production and acidification of the colonic environment, which is the most accepted mechanism for this effect with other fibers by the FDA and others (13,25), yet there are several published papers claiming this effect for “SCF” or Promitor® fiber (20) implying that this fiber could be substantially fermented.

In conclusion, the fermentability and food energy value of Promitor® fiber in humans remains unknown at present. This applies also to other non-digestible carbohydrates that have only been assessed for a food energy value using breath hydrogen responses (26,27) and to the use of breath hydrogen to quantify another aspect of energy availability, that is, small-intestinal digestibility of carbohydrates (28). Further, “available energy” is a useful umbrella term (4,7,29), though by itself it is too nebulous to define the measure of energy availability targeted or what the energy is used for.

Disclosure statement

The author holds shares in Independent Nutrition Logic Ltd., a consultancy. He and his wife have benefited from research grants, travel funding, consultant fees, and honoraria from the American Association for the Advancement of Science (USA), the All Party Parliamentary Group for Diabetes (London, UK), Almond Board of California (USA), BENEÖ GmbH (DE), Biotechnology and Biosciences Research Council (UK), British Nutrition Foundation (UK), Calorie Control Council (USA), Cantox (CA), Colloides Naturel International (FR), Coca Cola (UK), Danisco (UK & Singapore), Diabetes Nutrition Study Group (EASD, EU) and their Dietary Guidelines Committee, DiabetesUK (UK), Elsevier Inc. (USA), European Commission (EU), European Polyp Association (Brussels), Eureka (UK), Food and Agricultural Organization (Rome), Granules India (Ind), General Mills (USA), Health Canada (CA), Institute of Food Research (UK), International Carbohydrate Quality Consortium (CA), Institute of Medicine (Washington, DC), International Life Sciences Institute (EU and USA), Life Sciences Research Office, FASEB (USA), Nutrition Society of Australia, Knights Fitness (UK), Leatherhead Food Research (UK), LighterLife (UK), Matsutani (JPN), Medical Research Council (UK), MSL Group (UK), Porter Novelli (UK), Sudzuker (DE), Sugar Nutrition/WSRO (UK), Tate & Lyle (UK), The Food Group (USA), WeightWatches (UK),Wiley-Blackwell (UK), and the World Health Organization (Geneva).

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