New Insights into Dietary Fibre

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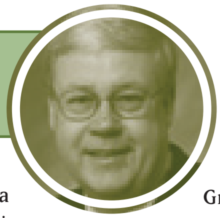
INTRODUCTION

JON A. STORY, PH.D.



Jon Alan Story completed his undergraduate work in zoology, with minors in chemistry and education, at Iowa State University in 1968. He received his Master of Science degree in 1970 and Doctor of Philosophy degree in 1972, also from Iowa State University. Dr. Story completed postdoctoral work in lipid biochemistry at the Wistar Institute in Philadelphia where he remained as a staff member until 1977 when he came to Purdue's Department of Foods and Nutrition. Dr. Story is currently Professor of Nutritional Physiology in that department and Associate Dean of Purdue's Graduate School.

His research interests involve nutritional regulation of cholesterol and bile acid metabolism focusing primarily on the role of dietary fibre in regulation of the enzymes involved in sterol balance. His work in the Graduate School focuses on implementing programs that encourage interdisciplinary graduate study. He has served on the editorial board of the Journal of Nutrition and several other journals and as a member of the Board of Scientific and Policy Advisors of the American Council on Science and Health. In 2001 he served as part of the Panel on the Definition of Dietary Fiber appointed by the Food and Nutrition Board of the Institute of Medicine as a part of the Dietary Reference Intakes.

HISTORICAL OVERVIEW

The definition of dietary fibre has been a point of discussion since fibre was "rediscovered" as an important component of our diets in the early 1970s. The early definition *["...remains of plant cell walls that are resistant to digestion (hydrolysis) by enzymes of man"]* and *its modified form ["...plant polysaccharides and lignin which are resistant to hydrolysis by digestive enzymes of man"]* (Trowell et al., 1976) were used to define a range of attributes, from more functional to purely analytical.

The scope of these definitions explains the confusion that exists among scientists and consumers as to the identity of dietary fibre. Unlike other nutrients, there is no obvious analytical method that can help to define dietary fibre. The definition of dietary fibre is more of a physiological concept, i.e., "...plant cell wall components that are not digestible...", and thus there has been disagreement as to a widely accepted analytical definition.

In 2000, two new definitions appeared which were more specific in enumerating the active compounds included in dietary fibre (i.e.: polysaccharides, oligosaccharides, lignin, associated phytonutrients) but also allocated the need for some "beneficial physiological effect", such as laxation, blood glucose attenuation, or blood cholesterol attenuation. These new definitions opened the door for inclusion of a variety of highly purified oligosaccharides (e.g.: oligofructose, inulin) as dietary fibre so long as they retained one of these physiological effects. It was in this context that the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (DRI) appointed the Panel on the Definition of Dietary Fibre to revisit the definition of dietary fibre as a first step towards determining a DRI for this nutrient. Using the Panel's definition and available data on the physiological effects of dietary fibre, the Committee issued a DRI in 2002. This review will examine the DRI, the definition upon which it is based, and the impact both may have on consumer understanding of dietary fibre and its role in our diets, product development, and basic research into the effects of dietary fibre on chronic disease.

THE DEFINITION

The result of the DRI review was a two-part definition for dietary fibre. The first part was similar to the original "physiological" definition of dietary fibre, the second part included a requirement for demonstration of beneficial physiological effects, and the sum of these two was equivalent to total fibre. Specifically:

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.

Several inconsistencies in previous definitions, as well as potential problems that might arise as a result of a new definition, were considered by the Panel in constructing this two-part definition.

RATIONALE FOR THE DEFINITION

By incorporating the more traditional definition for dietary fibre the Panel recognized that there is some inherent benefit in the complex structure of which integrates all the plant polysaccharides and lignin in the plant cell wall and within plant cells. The three-dimensional structure of plant cells remains intact and provides some of the physiological benefits attributed to dietary fibre. The bulk added to our diets by these plant cell walls reduces the caloric density of the diet and adds to the water holding capacity of the intestinal contents, thus improving intestinal function. Additional nutrients are included in foods high in dietary fibre that would not be available when these polysaccharides are isolated. These benefits would remain in spite of processing but would be lost if the polysaccharides were removed and provided as a supplement, or added back to foods. This would suggest that with or without proven beneficial physiological effects, foods high in dietary fibre would provide nutritional benefits. In fact it is often difficult to separate the effects of dietary fibre from the effects of the foods in which they are contained.

What you need to know:

Although the new definition for dietary fibre highlights how physiological benefits can be derived from either intrinsic sources or isolated sources of dietary fibre, foods that are naturally high in dietary fibre (i.e.: intrinsic sources) still offer better nutritional value;

Although the new definition of dietary fibre suggests replacing the terms soluble and insoluble by viscous and fermentable, respectively, the scientific community has been slow to adopt this new terminology. By consequence, consumer education, while possible, will pose new and exciting challenges for nutrition professionals.

Conversely, functional fibre, as defined, would not necessarily retain any of its *in situ* benefits. Some isolated polysaccharides (e.g., pectin) retain effects on blood cholesterol levels or glucose modulation but hydrolysis of these polysaccharides to shorter chain lengths reduces or eliminates these effects. Synthetically manufactured polysaccharides or resistant starch do not necessarily have inherent physiological benefits. These materials are chemically similar to the polysaccharides included as dietary fibre and this should be considered for inclusion in total fibre but potentially do not have the same benefits. They also do not have the inherent benefits of being a part of the plant cell wall, as was discussed above for intact, intrinsic polysaccharides. It was determined that, in order to be included as a part of total fibre, these functional fibres needed to have demonstrated beneficial physiological effects. Thus the functional fibre category of total fibre could include any polysaccharide which has a demonstrated beneficial physiological effect.

As a part of the definition of dietary fibre, the Panel also recommended discontinuation of the use of the terms "soluble" and "insoluble" as descriptors of the physicochemical properties of dietary fibre components that have been used in relation to their physiological functions. There are many exceptions to the generalization that soluble components have beneficial effects on blood glucose or lipid levels, for example. The terms "viscous" and "fermentable" were suggested as replacements.

Viscosity is a characteristic which has been related to a variety of effects on intestinal absorption of nutrients, including glucose and cholesterol, and is more consistently related to attenuation of blood glucose and blood cholesterol levels, for example.

Fermentability of dietary fibre components in the colon has also been related to some of the beneficial physiological effects more consistently than solubility/insolubility. As these terms become more widely used and understood by consumers and health professionals, a more precise use of dietary fibre and/or functional fibre will result.

Table 1: Examples of Viscous and Fermentable Fibres

Viscous	Fermentable
Psyllium	Wheat bran
Oats	Inulin
Pectin	Oligofructose
Guar	

Unlike some other definitions, specific physiological effects were not made a part of the basic definition. Current evidence would suggest several common effects, i.e., laxation, lowering of blood cholesterol level, modulation of blood glucose levels, but naming specific effects would result in an unnecessary narrowing of the scope of the definition.

IMPACT OF THE DEFINITION

1. Analytical concerns — how do we identify the two categories of fibre?

The most commonly expressed concern for the new definition has been for analytical difficulties in precisely determining the two categories of fibre. Analytically, the source of many polysaccharides cannot be determined to be intrinsic or extrinsic and, as a result, this requirement of the definition is suggested to be impossible to regulate. There is no one analytical method that can determine all of the carbohydrates that are to be included in any of the definitions of dietary fibre. As a result multiple methods must be employed to provide a complete picture of the dietary and functional fibre. Since the polysaccharides have no characteristic allowing separation of those that originated in a plant material from those isolated, and/or modified, in foods with a mixture of dietary and functional fibre, separation of the amount of intrinsic vs. extrinsic polysaccharide would depend upon the ingredients used in that food product.

2. Consumer guidance — how do we reduce confusion?

Related to these analytical concerns is the opinion that the polysaccharides involved are the same whether they are intrinsic and intact or isolated and purified, i.e. their chemical composition is the same. This, of course, is true, if we were interested only in the polysaccharides involve. As we mentioned earlier, the consumption of dietary fibre as a part of the foods we eat provides us with a host of other nutrients and other compounds that may be an important part of the health effects of dietary fibre. Epidemiological studies that indicate a beneficial effect of dietary fibre were based on consumption of whole foods, not isolated polysaccharides. So in defining a dietary component and recommending food intake patterns to provide adequate amounts of that dietary component, it would seem important to consider the "whole package" in our recommendations. Thus this two-part definition provides guidance for consumers to use in choosing a diet with adequate fibre as a part of the foods they consume or as isolated components of fibre with the understanding that the two will not be equivalent in their nutritional impact. This is an important concept that, in spite of the difficulty it may cause analytically, should be addressed in educational programs concerning this definition and the DRI.

3. Knowledge gaps — how do we build on existing research?

Associated with development of solutions for these analytical problems will be development of a complete set of data for dietary fibre, functional fibre and total fibre for use by consumers and researchers. Development of a fibre food database will require a significant amount of time and money even after agreement on the method to be used. But the information provided will be an important advancement in research and application of the role of fibre in nutrition. In addition to research needed for development of appropriate analytical methodology this definition will also stimulate research into the physiological effects of dietary fibre components in order to expand the breadth of functional fibres available. As a result of these lines of research, consumers will have an opportunity to select foods rich in dietary fibre if selecting a general diet with a lower caloric density or to promote good intestinal health. If a consumer needed a specific dietary fibre for a specific disease risk, a food with appropriate functional fibre content could be selected.

Thus, the information and products available to consumers and to health professionals for specific needs would be greatly improved.

Development of new products utilizing carbohydrates currently not included as dietary fibre as a result of their analytical properties will also be stimulated. Addition of labelling information for the new definition on these and other new products will provide a forum for education of the consumer about the specific roles of functional fibre components as well as the expanded benefits of foods containing dietary fibre. Health professionals and the food industry should both benefit from this educational process.

DIETARY REFERENCE INTAKES

The Panel's definition of dietary fibre was an essential part of the development of a DRI. Since there is no single biochemical response that can be used to determine adequacy of the level of dietary, functional or total fibre in the diet, several physiological responses were considered as a means of determining a required intake level. Beneficial physiological effects used in this effort included laxation, normalization of blood lipid concentrations, and attenuation of blood glucose responses.

After consideration of these data it was determined that effects of dietary fibre on coronary heart disease, supported by effects of dietary fibre on Type II diabetes and more specific effects of functional fibre would be used. It was impossible to determine an Estimated Average Requirement (EAR) since effects occur over a wide range of intake levels. Earlier recommended intake levels have used a variety of units, e.g. g/day, g/1000 kcal, g/kg body weight. Based on these considerations the Panel set an Adequate Intake (AI) based on food intake levels, i.e. g/1000 kcal using energy RDAs as a food intake base. The AIs by age and gender are listed in Table 2.

Table 2: Recommended Adequate Intakes for Total Fibre

Age	AI for males g/d	AI for females g/d
1-3	19	19
4-8	25	25
9-13	31	26
14-18	38	25
19-30	38	25
31-50	38	25
51-70	30	21
>70	30	21
Pregnancy		28
Lactation		29

Recommendations were based on a number of epidemiological, clinical and mechanistic studies in humans. In all cases the studies used in consideration of these recommendations measured or employed dietary fibre rather than an isolated polysaccharide. Intakes sufficient to result in a significant alteration of coronary heart disease or disease risk ranged from 12.9-14.45 g/1000 kcal. Taken collectively the average intake of dietary fibre was 14 g/1000 kcal, the amount used in determining the AI for total fibre. It was suggested that the benefits would vary depending on the source of dietary fibre consumed, with the greatest benefit derived from some grains (e.g. psyllium) or from functional fibres with demonstrated potential (e.g. pectin).

Intake levels in the US, based on the Continuing Survey of Food Intakes by Individuals (CSFII), are estimated to be approximately 17 g/d for men and 13 g/d for women. Canadian intakes are similar. The DRI that has been recommended would suggest more than a doubling of dietary fibre intake, a suggestion that has been made in previous efforts to make intake recommendations for dietary fibre. Although this seems to be a difficult dietary change, making appropriate food choices throughout the day can accomplish changes in dietary fibre intake of this magnitude (see Table 5 in From Research to Practice).

DIETARY FIBRE AND CHRONIC DISEASE

1. Gastrointestinal health

In spite of the attention often given to the relationship between dietary fibre and chronic disease, the most consistent beneficial effect of dietary fibre is on intestinal function. Several characteristics of dietary fibre increase the bulk of the intestinal contents while resulting in a softer consistency. Water held by the three dimensional structure of the plant cell walls adds to the bulk, and the fermentation of dietary fibre components results in production of short chain fatty acids that act as osmotic agents and further soften intestinal contents. These changes result in a reduction in the force needed to propel the contents along the intestine, improving regularity, reducing risk of development of diverticular disease, and generally improving colonic function.

2. Cardiovascular disease

Epidemiological links between dietary fibre consumption and cardiovascular disease (CD) have led to a 30-year search for the precise mechanism for this observation. Using changes in blood lipid levels as a marker of risk, it soon became obvious that all sources or components of dietary fibre do not have the same effects. In general, viscous, fermentable sources (e.g. cereals such as oats or beans) or components of dietary fibre (e.g. pectin, psyllium hydrocolloid, guar gum) are most effective in lowering plasma cholesterol levels. Mechanisms suggested for this relationship generally revolve around the ability of these fibres to disrupt enterohepatic circulation of bile acids, as a result of their viscosity, and/or effects of absorbable products of fermentation in the colon.

3. Colorectal cancer

As with CD, the epidemiology of the early 70s stimulated the study of the relationship between dietary fibre and colorectal cancer (CRC) and, as with CD, not all fibres have the same effects on CRC risk. Early studies suggested a stronger link between the less viscous sources of dietary fibre (e.g. cereal grains such as wheat bran) as a result of their water holding capacity and bulking properties and the resultant dilution of potential carcinogens or promoters in the colon. However the environment in the colon is much more complex than this hypothesis would suggest. The interrelationship between dietary fibre, colonic bacteria, and the colonic mucosa is not well understood but is the key to understanding the dietary fibre-CRC link. Products of fermentation of dietary fibre components (e.g. butyrate) or secondary bile acids that arise from the action of bacteria in the colon are involved in signalling pathways that regulate proliferation and apoptosis (programmed cell death) of colonic mucosal cells. In addition, there is some evidence that compounds associated with dietary fibre (phytochemicals) are also involved in regulating cell proliferation/apoptosis in the colon. With the advent of molecular methods for identification of populations of bacteria in the colon a new approach to understanding this complex interrelationship is now possible.

4. Type II diabetes

Viscosity of dietary fibre is also suggested to be involved in its involvement in type II diabetes. Viscosity reduces the rate and sight of absorption of glucose from the intestine thus reducing the need for insulin. In addition to this physical effect on glucose absorption the more viscous, fermentable sources of dietary fibre are suggested to increase insulin sensitivity, adding to the reduction in insulin levels. However, glycemic response to dietary fibre containing foods is not consistently related to the viscosity suggesting this system is also much more complex than this hypothesis suggests.

Table 3: Summary of the Health Benefits of Viscous and Fermentable Fibres

Viscous	Fermentable
Gastrointestinal health	Gastrointestinal health
Cardiovascular disease	Colorectal cancer
Type II diabetes	

Conclusions

This new suggested definition of dietary fibre combines quantification with functionality to improve the accuracy and usefulness of information provided to the end users (research scientists, industry, consumers). This information should improve our ability to educate consumers about the role of dietary fibre in their diets and in altering the risk for several chronic diseases.

Although the definition will cause some reassessment of analytical methods and development of new methods, the efforts will be more than compensated for by the improvement in accuracy and usefulness of information available to users.

Recommended References:

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FROM RESEARCH TO PRACTICE

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Nutrition Facts
Serving 1/3 cup (28 g)

Amount per serving	Cereal	With 1/2 Cup 1% Milk
Calories	70	130
	% Daily Value	
Fat 0.5 g†	**1** %	**3** %
Saturated 0 g + Trans 0 g	**0** %	**4** %
Cholesterol 0 mg	**0** %	**2** %
Sodium 190 mg	**8** %	**11** %
Potassium 250 mg	**7** %	**13** %
Carbohydrate 23 g	**8** %	**10** %
Fibre 12 g	**48** %	**48** %
Sugars 8 g		
Starch 3 g		
Protein 3 g		
Vitamin A	0 %	8 %
Vitamin C	0 %	0 %
Calcium	2 %	15 %
Iron	25 %	25 %
Vitamin D	0 %	25 %
Thiamin	45 %	50 %
Riboflavin	4 %	15 %
Niacin	10 %	15 %
Vitamin B6	10 %	15 %
Folate	8 %	10 %
Vitamin B12	0 %	25 %
Pantothenate	6 %	10 %
Phosphorus	15 %	25 %
Magnesium	30 %	40 %
Zinc	15 %	20 %

† Amount in cereal.

Following several years of development and consultation by Health Canada, Canada's new mandatory nutrition labelling regulations were enacted into law in December, 2002. Large food manufacturers have until December 2005 to fully comply with the law, and although manufacturers will have the option of listing all the nutrients found in their foods, calories and a core list of 13 nutrients will be mandatory on all labels. Fibre is one of these 13 core nutrients.

The new mandatory nutrition labelling laws also include new regulations for nutrient content claims and health claims, some of which pertain to fibre. Table 4 summarizes the nutrient content claims for fibre. As for health claims, Health Canada has not yet approved a claim for fibre; however, plans exist to approve a claim relating fibre-containing grain products, fruits and vegetables to a reduction in heart disease risk. In contrast, the U.S. Food & Drug Administration recognizes the following health claims for dietary fibre:

Fibre-containing grain products, fruits, vegetables and cancer;

Fruits, vegetables, and grain products that contain fibre, particularly soluble fibre, and risk of coronary heart disease;

Dietary soluble fibre, such as that found in whole oats and psyllium seed husk, and coronary heart disease.

The above claims have not been accepted by Health Canada and are not allowed under the new nutrition labelling laws.

Table 4: Summary of Fibre-Related Nutrient Content Claims in Canada

Claim	Requirements
Source of fibre	Food must contain ≥ 2g of fibre per serving and reference amount[1]
High source of fibre	Food must contain ≥ 4g of fibre per serving and per reference amount[1]
Very high source of fibre	Food must contain ≥ 6g of fibre per serving and per reference amount[1]

1. The Reference Amount is a value established by Health Canada for each product category in light of mandatory nutrition labelling regulations. Reference Amounts serve as the foundation for serving sizes, nutrient content claims, and health claims.

In addition to declaring nutrient content claims, food products can also declare some of the physiological benefits of dietary fibre. If a food like **All-Bran Original*** cereal contains at least 7g of dietary fibre from coarse wheat bran, it can claim to promote laxation or regularity.

Table 5: Dietary Substitutions to Help Meet the DRI for Dietary Fibre in Adult Men

	Energy kcal	Dietary Fibre g		Energy kcal	Dietary Fibre g
Breakfast					
Orange juice, 4 oz.	61	0.1		61	0.1
Cereal (Frosted Flakes), 0.75 cup	143	0.75	Cereal (All-Bran Flakes), 0.75 cup	128	3.8
Milk (skim), 1 cup	86	0		86	0
Toast, white 2 slices	129	1.1	Toast, whole-wheat, 2 slices	139	3.7
Margarine, 2 tsp.	68	0		68	0
Subtotal	487	2.0		482	7.6
Lunch					
Tossed salad, 0.75 cup	12	1.1		12	1.1
Salad dressing, 1 T	66	0		66	0
Ground beef, 0.25 lb., broiled	178	0	Chili, beans and beef, 0.75 cup	205	4.9
Bun, white	123	1.2	Whole-wheat bread, 1 slice	69	1.9
Catsup/mustard, 1 tsp. each	9	0.3	Margarine, 1 tsp.	34	0
Grapes, 0.5 cup	57	0.8		57	0.8
Milk (skim), 1 cup	86	0		86	0
Subtotal	531	3.4		529	8.7
Dinner					
Salmon, broiled, 3.5 oz.	148	0		148	0
Rice, white, 0.75 cup	181	0.4	Rice, brown, 0.75 cup	164	2.6
Broccoli, cooked, 1 med. stalk	50	5.2		50	5.2
Dinner roll, white, 2	168	1.7	Dinner roll, whole-wheat, 2	149	4.2
Margarine, 2 tsp.	68	0		68	0
Milk (skim), 1 cup	86	0		86	0
Ice cream, 0.5 cup	98	0.3		98	0.3
Subtotal	799	7.6		763	12.3
Snacks (2 during day)					
Saltines, 6	118	0.8	Crackers, whole-wheat, 6	108	2.4
Cheddar cheese, 1.5 oz.	171	0		171	0
Juice, 0.75 cup	78	0.4		78	0.4
Celery, 119 g	19	2	Carrots, 120 g	51	3.6
Spinach dip, 2 T	58	0.4		58	0.4
Cola, 12 oz.	153	0		153	0
Subtotal	597	3.6		619	6.8
Total for day	2414	16.6		2393	35.4

Modified from Food and Nutrition Board, Institute of Medicine (2002) Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Protein and Amino Acids (Macronutrients).

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