V. IMPACT OF THE DEFINITIONS OF DIETARY FIBER AND UNRESOLVED ISSUES

Adoption of these proposed definitions will have significant impact in a variety of areas. In particular, major developments and modifications will be needed in the area of fiber analysis, and additional research into physiological actions of many fibers will be necessary. The results of these new efforts will be reflected in food composition databases and on the nutrient label, and resources and collaborative efforts will be needed from the food industry, research and analytical scientists, and governments.

However, these definitions are a true improvement over existing definitions because they begin to recognize fiber as a nutrient with demonstrable health effects and lessen the emphasis on fiber as a constituent of food requiring quantitation; this improvement warrants the adaptations that will have to occur. Anticipated changes and unresolved issues are the focus of this section.

Impact on Analytical Methodology

The proposed definitions, based on health benefits and physiological considerations rather than on analytical methods, will undoubtedly have major impact on the analysis of fiber. Analytical methods are needed that will fit with the definitions, not the reverse. This approach to defining fiber recognizes dietary fiber as a nutrient, rather than merely as an analytically measured food constituent.

The Panel was not charged with proposing methods for fiber analysis that would be consistent with the new definitions. It was, however, charged with proposing definition(s) that would take into consideration possibilities for analysis. It is anticipated that analysis for the proposed fiber definitions will be approached from two directions concurrently. One will explore development of new methods of characterization and analysis, and the other will involve modification of existing methods to accommodate the new definitions. It is also recognized that the ideal analytical approach would be to have methods for *Dietary Fiber* and for *Added Fiber*, with the sum of the two results being *Total Fiber*. Current methodology, including approaches for specific *Added Fibers*, are reviewed in Appendix C, with overall approaches outlined below.

Several changes to current methods are needed to obtain values for *Dietary Fiber*. *Dietary Fiber* now includes all naturally occurring resistant starch, not just that portion measured by current enzymatic-gravimetric methods. Thus, methodological modifications are needed that extract all resistant starch from fiber and then measure this fiber. Complete extraction of resistant starch from fiber has been accomplished by some analytical methods, and it is likely that complete starch removal can be accomplished by incorporating either additional enzymes that hydrolyze starch or the solvent dimethyl sulfoxide into the current procedures. Several methods for specifically measuring resistant starch are now under evaluation, and some approaches are likely to measure that fraction resistant to the actions of the human stomach and small intestine and therefore, be suitable for application to all foods. Consideration should be given to methods that not only determine resistant starch, but also measure digestible or total starch in the same assay so that a portion of the total starch is not recovered in more than one starch fraction. Naturally occurring oligosaccharides inherent in foods containing *Dietary Fiber* need to be captured during analysis. Since most oligosaccharides are not recovered by ethanol precipitation, it may be necessary to recover them from the ethanol soluble fraction on the basis of molecular weight by chromatography or dialysis.

Current fiber analysis methods recover animal polysaccharides as dietary fiber. Thus, for those foods containing any animal carbohydrates, methods for their analysis are needed so they can be subtracted from the *Dietary Fiber* value. A general method applicable to all animal carbohydrates that would distinguish them from plant carbohydrates is difficult to envision. For those *Dietary Fibers* containing animal carbohydrates, however, it may be possible to use specific enzymatic steps to hydrolyze glycosaminoglycans (i.e., mucopolysaccharides), glycoproteins, or other carbohydrates in cartilage for subsequent quantitation. Perhaps an amount of animal-derived carbohydrates in *Dietary Fiber* could be defined below which the animal carbohydrate could be disregarded. For example, if 10 percent or less of the *Dietary Fiber* were from animals, it would not have to be determined and subtracted from the *Dietary Fiber*.

Some possible approaches for analyzing for *Dietary Fiber* that utilize unmodified current methods of analysis include:

a. Using gravimetric methods:
    1. gravimetric methods (AOAC methods 985.29, 991.43, 992.16, 993.21)
    2. subtract resistant starch
    3. subtract nondigestible, animal-derived carbohydrate
    4. add naturally occurring resistant starch
    5. add naturally occurring oligosaccharides

b. Using the method of Theander:
    1. method of Theander
    2. subtract resistant starch
    3. subtract nondigestible, animal-derived carbohydrate
    4. add naturally occurring resistant starch
    5. add naturally occurring oligosaccharides

c. Using the appropriate method of Englyst:
    1. method of Englyst (colorimetric, GC, or HPLC)
    2. subtract nondigestible, animal-derived carbohydrate
    3. add lignin
    4. add naturally occurring resistant starch
    5. add naturally occurring oligosaccharides

The fibers that are included in the definition of *Added Fiber* could be analyzed using methods for each specific compound that have been or could be developed, generally using GC or HPLC for quantitation after the *Added Fiber* has been isolated, typically by chromatography or dialysis. In some instances, *Added Fiber* could be determined enzymatically, for example, as mixed linkage β-glucan is now (McCleary and Codd, 1991). Existing analytical methods for *Total Fiber* would be suitable for those *Added Fibers* that are quantitatively recovered by the method.

The possibility that more than one *Added Fiber* might be in a food product also needs to be addressed. In this case, different *Added Fibers* may be distinguished by their specific method of analysis. Alternately, they may be distinguishable on the basis of monosaccharide composition or by enzymatic hydrolysis. For example, mixed linkage β-glucan could be measured enzymatically, as it currently is. Monosaccharide composition data would be available only if the fiber was isolated from the food matrix, acid hydrolyzed to yield the constituent carbohydrates, and those monosaccharides individually quantitated by GC or HPLC. A knowledge of the monosaccharide composition of the individual *Added Fiber* is required for this approach. *Total Fiber* analysis, analysis for individual *Added Fibers* by specific methods, and formulation or recipe information may be needed for analysis of complex mixtures of *Added Fibers*.

The most challenging analytical issue is the analysis of food products for fiber when they contain both *Dietary Fiber* and *Added Fiber*. It is likely that a combination of existing and new methods, similar to what has been illustrated above, will be needed to effectively separate and quantitate these two types of fiber when they occur in the same food vehicle. A measurement of *Total Fiber* is still possible, but formulation information and analyses for specific *Added Fibers* by appropriate methods may need to be combined with analytical data to distinguish *Dietary Fiber* and *Added Fiber*. However, it may be more practical to determine *Total Fiber* using either current methods or modifications of current methods for *Total Fiber* and to follow up with continued development of methods to determine *Added Fibers*.

While development of new methods requires dedicated input from industry, academia, and government, the exploration of using more modern analytical approaches for the analysis of *Dietary Fiber* and *Added Fiber* is encouraged. Methods already exist that specifically and accurately measure fiber-derived polysaccharides by determining the amounts of their constituent neutral monosaccharides by GC or HPLC and the acidic polymers that comprise pectin by a colorimetric assay. The incorporation of a step using dimethyl sulfoxide, as is done in the Englyst methods, could extract all starch from fiber. An additional analysis to measure naturally occurring resistant starch would be needed for foods. For foods containing oligosaccharides or other ethanol soluble carbohydrates, an additional step would be needed whereby these carbohydrates would be recovered from the ethanol on the basis of molecular weight, using column chromatography or dialysis; they could be combined with the fiber-derived carbohydrates for quantitative analysis. Conceivably, a multi-part procedure could be developed and approved, and only those steps relevant to the fiber source being analyzed would need to be performed.

Impact on Recommended Levels of Intake

It is not anticipated that these definitions would significantly impact recommended levels of intake. However, information on both *Dietary Fiber* and *Added Fiber* would more clearly delineate the source of fiber and the potential health benefits. Although these two categories of fiber would be listed separately, the *Total Fiber* recommendation would reflect the sum of the two. The rationale for summing the two is that naturally occurring *Dietary Fiber* has known, although difficult to delineate, health benefits, and substances presented as *Added Fiber* could not be included on the label without a demonstrated beneficial physiological effect. Thus, *Added Fiber* should contribute to human health just as *Dietary Fiber* does and should count toward the total recommended level of intake. It is also possible that where the physiological benefits of each type of fiber, *Dietary Fiber* or *Added Fiber*, are well characterized, separate recommendations for intake could be constructed.

A separate issue involves potential Tolerable Upper Intake Levels (UL) for fiber. The possible adverse effects of fiber, including *Dietary Fiber* and *Added Fiber*, will be reviewed in the upcoming report that will provide Dietary Reference Intakes (DRIs) for macronutrients. It may be possible to concentrate large amounts of *Added Fiber* in foods, beverages, and supplements. Since the potential adverse health effects of *Added Fiber* are not completely known, they should be evaluated on a case-by-case basis. In addition, projections regarding the potential contribution of *Added Fiber* to daily *Total Fiber* intake at anticipated patterns of food consumption would be informative.

Impact on Food Composition Databases

More information on food carbohydrates will be required with these new definitions, much in the way that more detailed information on protein (i.e., amino acids) and fat (i.e., fatty acids) has been incorporated into food tables.

Values for *Dietary Fiber* and *Added Fiber* would be listed under *Total Fiber*. Each of these categories could be further divided and contain data on constituents. Constituents under *Added Fiber* could include isolated, modified, and synthesized carbohydrates, such as mixed linkage β-glucans, pectins, celluloses, some resistant starches, gums, and oligosaccharides. Constituents under *Dietary Fiber* could include intrinsic and intact celluloses, hemicelluloses, pectins, lignin, resistant starches, and mixed linkage β-glucans. Given the difficulty in developing methods that provide physiologically relevant values, no data for the amounts of soluble and insoluble fiber would appear in the food composition tables. At least three values would be listed in the food composition database: *Total Fiber*, *Dietary Fiber*, and *Added Fiber*. As noted earlier, current methods may need to be modified and new methods will need to be developed to provide these compositional data.

Impact on Dietary Fiber Research

Although many aspects of the health benefits of fiber and fiber-containing foods remain poorly understood and in need of investigation, four areas of research are particularly relevant to the proposed definitions. First, research to identify and meaningfully and reproducibly assess established physiological effects of fiber on laxation and blood glucose and cholesterol concentrations, or other possible beneficial effects, is needed for a material to be classified as *Added Fiber*. Second, research is needed to develop and evaluate appropriate methods to measure viscosity and fermentability in such a way that the in vitro data obtained can be related to in vivo action. Third, there is a need to continue research that identifies and characterizes new and emerging physiological effects of existing fibers. Finally, discovery and characterization of new materials that could be classified as *Added Fiber* should continue.

Although the proposed definitions do not outline the nature and extent of demonstrating a beneficial health effect for *Added Fiber*, it is anticipated that research designs used to characterize the established physiological effects on laxation and blood glucose and cholesterol concentrations can form the basis for developing standard protocols and criteria to determine whether an *Added Fiber* demonstrates one of these beneficial physiological effects. In addition, the possibility of using analytically determined viscosity and fermentability as part of the evaluation process needs to be explored. Using all of these avenues for evaluation will encourage the development of new *Added Fibers* and broaden the diversity of materials with special health benefits.

The intention of replacing the concept of soluble and insoluble fibers with viscous and incompletely fermented fibers is to bring into use analytically obtained characteristics that have physiological relevance. Appropriate standards and controls need to be identified, as do conditions of experimentation, such as time, temperature, and concentration. Also, procedures need to be applied to the fiber and not the food, as food products may be made viscous through other ingredients and processing.

Similarly, an in vitro system that accurately reflects the rate and extent of fermentation of a material in the human large intestine will need to be devised and evaluated for application to *Added Fibers*. The relevance of a proposed analytical approach to in vivo behavior will need to be determined in a variety of circumstances. The analytical procedure will also need to be evaluated for ruggedness, relevance to various in vivo situations, and analytical accuracy and precision.

Several areas are emerging as potential physiological effects of *Dietary Fiber* and *Added Fiber*. More research could be conducted on the potential use of *Dietary Fiber* and *Added Fiber* in weight control, as certain fibers reduce food intake and possibly the amount of metabolizable energy available. In addition, there are alleged physiological effects of dietary fibers where too few data now exist to demonstrate a role conclusively, but which will have great relevance should the link between fiber and physiological effect be clearly established. These include the effects of fiber on colonic ecology, gut hormones, and the immune system.

In addition, the relationship between the biochemical characteristics of *Dietary Fibers* (e.g., monosaccharide composition, biologically active plant cell wall fragments [arabinoxylans], and linkages between carbohydrate moieties and other cell wall components like lignin) and physiological events need further clarity and are deserving of enhanced research activity. In the case of oligosaccharides, their role as *Dietary* or *Added Fiber* versus serving as osmotically active agents in the gut needs to be clarified. Acute and rapid changes in colonic lumenal fluid, such as what is produced by sugar alcohols, has not traditionally been a mechanism of action for fiber. The proposed definitions include nondigestible carbohydrates of low molecular weight (oligosaccharides of three or more sugar residues), and research is needed to determine the relative benefits and risks of relatively large amounts of low molecular weight fiber oligosaccharides.

Accurate, repeatable measures of colonic health must be established. For instance, little is known about the metabolic activities of the microbes in the human large intestine that may be exposed to atypical substrates or, in certain instances, subjected to starvation conditions. Indeed, data collected using molecular-based systems for identification of microbes may result in a reevaluation of what is presently accepted about the microbial ecology of the gut, most of which has been determined by plating techniques. What are the rates and extents of substrate fermentation that optimize conditions in the lower gut vis-a-vis health status? Further, the long-term consequences of crowding out certain strains of bacteria by feeding particular dietary fibers are unknown. Questions such as these must be answered to improve understanding of the effect of fiber on colonic health status.

Impact on Development in the Food Industry

Despite the established fact that dietary fiber is considered a healthful part of the diet, dietary fiber intakes in the United States are only about half of recommended levels (Alaimo et al., 1994), and surveys indicate that the majority of Canadians are not concerned with the amount of fiber in their diet (Federal, Provincial and Territorial Advisory Committee on Population Health, 1999). Chronic inadequate fiber intakes give manufacturers reason to supplement foods with fiber and to market fiber supplements. In the United States, consumers recognize dietary fiber as a positive component of the food supply, and its inclusion on a food label is thought to have significant impact. In particular, concentrating a desirable material as an *Added Fiber* will allow the health benefits of its presence in the product to be emphasized.

Because *Dietary Fiber* is the fiber that occurs naturally in plant foods, labeling for fruits, vegetables, whole grains, legumes, and nuts will continue unchanged under the proposed definition in both the United States and Canada. This could lead to increased utilization of natural plant foods in food products, which is in keeping with recent dietary recommendations to consume more grains, especially whole grain, fruits, and vegetables (Health Canada, 1997b; USDA/DHHS, 2000). Since the proposed definition of *Dietary Fiber* includes naturally occurring resistant starch, starchy foods such as legumes or pasta may also be utilized to a greater extent in food products to provide *Dietary Fiber*.

Currently in the United States, to claim that a product contains dietary fiber requires that the fiber content be based on accepted AOAC methods. Inulin, polydextrose, resistant starch, and some other isolated carbohydrates are not assayed by these methods. Therefore, under current regulations, these substances do not qualify as dietary fiber. However, many manufacturers have conducted clinical studies that show their products have positive physiological properties similar to those of accepted fiber sources; many of these substances now may be eligible to qualify as *Added Fiber* under the new definitions. For new and untested materials, demonstration of a beneficial physiological effect will be necessary for the substance to qualify as an *Added Fiber*. Research has supported three health benefits (attenuation of blood glucose and cholesterol concentrations and improved laxation) of *Added Fiber*. Although protocols to demonstrate efficacy of a new product are not specified as part of the proposed definition, it is recognized that food manufacturers will need information on the characteristics and types of studies required to demonstrate beneficial physiological effects. It is also recognized that the food industry will have to allocate resources to substantiate the beneficial health effect of an *Added Fiber* product.

Impact on Nutrition Labeling

Adoption of the proposed definitions will have a positive, informative impact on nutrition labeling. The current system of labeling for dietary fiber—dietary fiber, insoluble and/or soluble—will be replaced by two values: *Dietary Fiber* and *Added Fiber*. After an education process, consumers will learn that both *Dietary Fiber* and *Added Fiber* are considered to play a role in health. *Dietary Fiber* will include plant foods in which the fiber is relatively intact and nutrients other than fiber that are present and may contribute significantly to the attributed overall health effects. *Added Fiber* will contain only those fibers shown to have positive health benefits. It is assumed that the food industry will promote the health benefits of their *Added Fibers*, and therefore, consumers will be able to anticipate the types of beneficial effects that may occur if they consume foods containing these *Added Fibers*. In the future it is anticipated that the specific types of *Added Fibers* will be part of the food label, thus providing the consumer and health professional with additional information. *Total Fiber* will be the sum of *Dietary Fiber* and *Added Fiber*, so if the consumer wants to know the total amount of fiber per serving this value will provide that information. Since it is recommended that the current designations "soluble" and "insoluble" dietary fiber be eliminated from the label, their removal will provide space for the inclusion of *Dietary Fiber* and *Added Fiber*.

As discussed earlier, a separate issue regarding nutrition labeling centers on accurate analytical verification of the division of *Total Fiber* into *Dietary Fiber* and *Added Fiber*. In addition, dietary fiber is currently assigned an energy value of 0 kcal/g if it is insoluble and 4 kcal/g if it is soluble. Although not a task of this report, the complexity of assigning these somewhat arbitrary energy values to dietary fiber is discussed in detail in Appendix D.