Medallion Laboratories
ANALYTICAL PROGRESS

Total Dietary Fiber

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In the 1970's, a paradigm shift occurred in the thinking of medical and nutrition researchers that profoundly impacts their respective scientific communities to the present day. No longer was fiber nonnutritive and unimportant; now fiber played a significant physiological role, just lowering fat intake was insufficient for a well rounded healthy diet. Research on dietary fiber (DF) spilled over into many other areas, including a significant rethinking of the dietary regimen for diabetics to help reduce the symptoms of that disease. The research effort continues with indications that not only low fat and high fiber are good for well being, but a complex of carbohydrates, including those with slow digestibility, are important.

DEFINITION OF DIETARY FIBER

Total Dietary Fiber (TDF)
The evolution of the definition of TDF is interesting to trace. For decades there was *crude fiber* (CF), "the residue of plant (based) food left after extraction with solvent, dilute acid, and dilute alkali" (Williams and Olmstead, 1935). Since CF does not include many of the fiber components we normally associate with the physiological activity of fiber, a more appropriate definition was needed, i.e. it was obvious a broader term including these components was necessary. The term "dietary fiber" was first applied by Hipsley (1953) as a shorthand term for the constituents of the plant cell wall. This new term "dietary fiber" clearly was an attempt to distinguish something above and beyond CF. Between 1972 and 1976, Trowell and Burkitt adopted the term in conjunction with medical hypotheses they were developing, their "dietary fiber hypotheses" (Burkitt et.al., 1972; Trowell, 1972; Trowell, 1974; and Trowell et.al., 1978). The term was used to describe the remnants of plants resistant to hydrolysis by human alimentary enzymes. Thus, it was a physiological-botanical description, related to plant material indigestibility in the human small intestine, plant cell walls being the major source. Edibility was implied, and, because scientists do not work in a vacuum, probably certain other obvious properties such as the stringy fiber of celery, the edible peels on fruits, or the resistance of cereal grain bran to grinding were also implicit in the definition. Trowell and Burkitt postulated an inverse relationship between DF consumption and the incidence of colon cancer and heart disease. Publication of the hypotheses led to numerous DF research projects in nutrition, analytical, and food technology.

In 1976, the DF definition was broadened (Trowell et al. 1976) to a physiological-chemical definition including all undigestible dietary polysaccharides in addition to the other fiber components. These nondigestible polysaccharides were included in the definition because they were found to have the physiological actions that we attribute to DF, but could not necessarily be chemically identified as having their origins in the cell wall. The 1976 definition gained wide acceptance and became the basis definition for the current AOAC International Official analytical methods.

The current working definition of DF is "Dietary Fiber consists of the remnants of plant cells, polysaccharides, lignin and associated substances resistant to hydrolysis (digestion) by the alimentary enzymes of humans." This physiologically based definition has many advantages over a definition based strictly on the analytical chemist's ability to analyze a fraction of the food. Common sense, based on our own eating experiences, tells us what DF is, the fibrous, coarse textured, or gummy nondigestible portion of our food that affects the comfort of our digestive system and the makeup of our bowel output. We already know what DF is; the definition puts it in formal terms. The definition is flexible. As the knowledge base on DF increases, the entities that are included in the definition can be changed based on the judgment of the experts working in the field. Finally, the methods used to determine DF can be developed, improved, and modified based on new knowledge, to ever more closely match the definition, rather than the definition needing to be changed following advancements in methodology.

"DIETARY FIBER CONSISTS OF THE REMNANTS OF THE PLANT CELLS, POLYSACCHARIDES, LIGNIN AND ASSOCIATED SUBSTANCES RESISTANT TO HYDROLYSIS (DIGESTION) BY THE ALIMENTARY ENZYMES OF HUMANS"

This allows for the continual method improvement with the ultimate goal, the exact analytical replication of the human alimentary digestive system. The definition serves as a "gold standard" to whichanalytical methods strive. Over the past two decades, methods that meet this definition have evolved and been accepted worldwide (Prosky and DeVries, 1992).

Subsequent to 1976, consumer interest and public policy on DF have changed, focusing on DF's unique physiological functions and potential health benefits. To determine if an update of the current definition of DF is needed, two international surveys on DF definition and analyses were recently conducted by AOAC Associate and General Referees for dietary fiber (Lee and Prosky, 1995, 1996). The majority of scientists surveyed support the continued use of the current definition. Since the original consensus agreement on a definition, there have been attempts to eliminate or restrict it, by say, limiting dietary fiber to only cell wall materials, or to some aspect such as nonstarch polysaccharides. These attempts have been unsuccessful; correlations found between improved health status and DF consumption do not hold true using these restricted definitions.

Insoluble Dietary Fiber(IDF)

IDF is insoluble in an aqueous enzyme solution as representative of the alimentary enzyme solution of humans as can be set up in a laboratory. IDF makes up about 2/3 of the fiber in most foods.

Cellulose-Cellulose, the primary component of IDF, is insoluble in cold and hot water, dilute acid, and dilute alkali. It is the most abundant carbohydrate structural material in nature, making up the cell walls of most plant materials, typically one half of the plant's mass. This linear polymer of *beta*-D-glucose molecules linked in the 1,4-positions, is undigestible in the human system because humans do not have enzymes that hydrolyze *beta* linkages. In contrast, starch, the major source of energy for humans, is also a pure glucose polymer with mostly 1,4-linkages (and occasional 1,6-linkages), has *alpha* linkages. Starch is very digestible and its particular linkages result in the molecule of helical conformation as opposed to being flat and linear. This makes starch water soluble and interactive with other molecules such as free fatty acids.

Hemicellulose-Those unfamiliar with fiber might wrongly assume that hemicellulose is similar to cellulose. The term hemicellulose appears to be a historical usage relating to solubility properties. Both cellulose and hemicellulose are insoluble in cold and hot water, and dilute acid, therefore, hemicellulose was probably thought to related to cellulose. Hemicellulose is distinguished from cellulose by its solubility in dilute alkali. The name hemicellulose applies to a variety of heterosaccharridic polymers which tend to be small (50-200 saccharide units) with branching present usually consisting of more than two sugars. Predominant monomers are xylose, arabinose, mannose, glucose, and galactose. Arabinoxylans found in cereal grains are an excellent example of hemicellulose. Part of hemicellulose is quantitated as IDF, part as soluble dietary fiber (SDF).

Resistant Starch-Resistant starch, when eaten by humans passes undigested through the small intestine and into the large bowel where it is fermented or excreted. This fermentation energy source may be significant for maintaining colonic health. The relative amount of undigested starch can vary from food to food and person to person, however the "resistant starch" quantitated with DF using the Official Methods for fiber is resistant in all cases.

Lignin-Lignin results when polyfunctional phenols are polymerized with ether and ester linkages during plant growth, intimately forming with and infiltrating the cellulose of cell walls, resulting in a hard, rigid matrix of tremendous strength. At sufficient lignin concentration, plant tissues become "lignified" or "woody" to the point of being inedible (wood, a highly lignified tissue has a strength greater than steel on a weight basis). Lignin is an important component of DF, making the fiber hydrophobic, resistant to enzymatic breakdown in the small intestine and bacterial breakdown in the large intestine. It is almost completely recovered in the feces. Lignified tissue in food offers unique textural properties, although they are not always considered desirable.

Cutin-This waxy hydrophobic layer made up of highly hydrophobic long chain hydroxy aliphatic fatty acids polymerized by ester linkages is resistant to digestion and can be recovered in fecal material. A number of the fatty acids have trifunctionality, resulting in polymer crosslinking and branching. Ester linkages also occur between the cutin and other cell wall polymers such as hemicelluloses (Deas and Holloway, 1977).

Suberin-Kulattukudy (1981) indicates the scanty evidence available allows only conjecture regarding the structure of suberin as a highly branched and crosslinked (by ester linkages) combination of polyfunctional phenolics and polyfunctional hydroxyacids and dicarboxylic acids. Like cutin, it is chemically linked to cell wall carbohydrate polymers especially through its lignin forming components (*p*-coumaric and ferrulic acids). As evidence of the intimate interaction between suberin and other DF components only suberin enriched preparations, not pure ones, have been obtained in the laboratory.

Soluble Dietary Fiber(SDF)

SDF is soluble in an aqueous enzyme system but precipitates upon the addition of 4 parts alcohol to the aqueous mixture. This is a traditional, not strictly physiologic definition, based on the use of alcohol to precipitate complex molecules from solution during analysis of simpler compounds such as sugars. A shortcoming of this approach is that fibers such as polyfructans, do not precipitate and thus are not quantitated. Additional Official Methods of Analysis have been adopted to quantitate these fiber fractions.

Pectins-The most widespread SDFs in foods are pectins (polygalacturonic acids) found in fruits, vegetables, legumes, and roots (i.e. sugar beets and potatoes) as storage polysaccharides. Commercial pectin is isolated from either apple pumice or from citrus peels (levels up to 30% on a dry wt basis). The functional groups of the polymer are present either as free carboxylic acids, methyl esters, or carboxylate anions (as sodium, potassium, or calcium salts). The degree of esterification is significant in defining the properties of pectins. There are still some differences of opinion regarding the molecular makeup of pectin. DeVries et. al. (1982, 1983) propose that pectin's unique properties result from a backbone of long sections of galacturonic acids, interrupted with a section of rhamnose having side chains of arabinose, galactose, glucose, and xylose. These chain interruptions result in a soft, water soluble molecule rather than a linear polymer with high intermolecular hydrogen bonding having properties similar to cellulose.

beta*-Glucans-beta* Glucans are undigestible mixed *beta* linkage (*beta* 1,3 interspersed with *beta* 1,4) glucose polymers less well known than the glucose polymers starch and cellulose. Adding the alternate positional linkages gives water soluble (mostly) food gums which upon hydration with water giving high viscosity solutions with relatively little shear and tensile resistance, compared to cellulose, which is essentially water insoluble, and has tremendous shear and tensile resistance, strong rugged, and durable enough to use for clothing and shelter. In the large intestine, *beta* glucans undergo extensive fermentation whereas cellulose passes through essentially unchanged. Grains are the primary source of *beta* glucans (Stuart et. al., 1987). Barley (2.0-9.0%-though typically 3-6%), oats (2.5-6.6%), and rye (1.9-2.9%) are highest, while wheat(0.5-1.5%), triticale (0.3-1.2%), sorghum (1%), rice (0.6%), and maize (0.1%) have lesser amounts. Ripsin et. al. (1992) showed that oat products consistently display hypocholesterolemic effects in controlled human studies. The relationship between oat consumption and heart health effects is strong enough that the US Food and Drug Administration has proposed to allow a cardiovascular health claim on the label of oat based foods (Anonymous, 1996). *Beta* glucans may be playing a significant role in the observed effects and are proposed as a marker entity for oats.

Galactomannan Gums-Soluble galactomannan gums are part of the hemicellulose fraction of the food, originating in leguminous plants such as guar and locust beans (also known as karob). These gums consist of a mannose polymer backbone to which are attached galactose side chains.

WHY DIETARY FIBER IS IMPORTANT

Dietary fiber intake really was not related to health status until the 1970's. British Surgeon Captain T.L. Cleave (1969) reported lower incidences of cancer in rural Africans consuming large amounts of food high in DF, but referred to the increased cancer in other populations as "the Saccharine Diseases", emphasizing the presence of highly processed foods in the diet. Medical experts Burkitt and Trowell suggested lack of whole foods in the diet was responsible for higher disease incidence, that the "dietary fibre" was removed during processing and used for animal feeds. Personal observations and epidemiological studies indicated an inverse relationship between DF intake and some forms of cancer and coronary heart disease, diverticulitis of the colon walls, appendicitis, gallstones, varicose veins, hiatus hernia, diabetes, hemorrhoids, and phlebitis. Emphasizing whole food consumption was not unique to the medical professionals mentioned above. In the US, around 1900, Graham (graham crackers are still a common food item) and Kellogg (founder of the Kellogg company) emphasized the importance of eating whole grain products. The term "dietary fiber", was not available to link a specific dietary component to the health status they felt whole grains promoted. Recognition of their efforts did not occur until the refocused attention of the 1970's.

Health benefits are often attributed to DF *per se*, but it is often difficult to attribute the effects solely to increased DF consumption. Increases in DF intake occur by increasing consumption of high fiber foods which may have other cofactors present that singly or in concert exert positive effects. For example, for coronary heart disease, those on high fiber diets showing a reduced risk often are consuming low fat diets (fat is often displaced by fiber), diets higher in antioxidant factors (fruits, vegetables, whole grains), and are more physically active. Trace levels of chromium significantly affect the course of diabetes, so possibly the higher mineral content of whole foods in a high fiber diet is producing the positive effect. Confounding factors notwithstanding, the positive benefits associated with increasing intake of high fiber foods should be pointed out.

Increased consumption of DF is beneficial for individuals with diabetes. Foods high in fiber modulate the level of glucose in the blood typically decreasing the peak blood glucose concentration and slowing the blood glucose decline after the peak. The slowed decline also indicates a positive effect, namely reduced peak insulin release. Further, high fiber diets increase the insulin sensitivity of the body's extremities, necessitating a lower production of insulin.

Some believe that as many as 35% of cancer deaths in the US are diet related. Increasing DF intake increases fecal softness, fecal bulk, water binding capacity, organic binding capacity and reduces intestinal transit time, all of which enhance removal of stagnant or potentially detrimental materials from the bowels. Increased fermentation in the large intestine also produces an environment healthier for the colonic structure.

Benefits of Soluble Dietary Fiber

While not as effective as IDF in promoting laxation, SDF does exert a positive effect through a different mechanism. IDF, relatively unfermentable in the colon, has a high water holding capacity which promotes bulk and laxation. As SDF is fermented in the colon, a substantial quantity of bacterial mass accumulates which is soft, bulky, and water retaining, the resulting fecal properties being similar to those from IDF. SDF fermentation also generates significant quantities of gases which exercise the colon during transit. (This may be healthy and beneficial, but is not necessarily considered a social benefit of SDF.)

Decreased risk of coronary heart disease is correlated with increases in consumption of DF, typically SDF. Increased risk of coronary heart disease is also correlated with a significant number of other risk factors which are reduced by DF, such as diabetes, high serum cholesterol, high levels of low density lipoprotein (LDL) associated cholesterol, and low levels of high density lipoprotein (HDL) associated cholesterol, obesity, and possibly hyperinsulinemia.

TABLE 2

RELATIVE RISK OF HEART ATTACK vs 10 G INCREASES IN FIBER INTAKE

Fiber Source	**Relative Risk (95% Conf Interval)**
Vegetables	0.88 (0.65-1.21)
Fruits	0.83 (0.62-1.10)
Cereals	0.73 (0.57-0.94)

Increased intake of SDFs such as guar gum, locust bean gum, oat gum and pectin can significantly decrease total and LDL serum cholesterol while maintaining or increasing HDL cholesterol levels. SDFs increase fermentation in the large intestine, increasing the production of short chain fatty acids, helping to remove bile salts from the system and depressing cholesterol production.

Benefits of Insoluble Dietary Fiber

The most obvious benefit of increased intake of IDF (particularly wheat bran) is the feeling of well being resulting from increased laxation. IDF typically has a high water binding capacity which results in the formation of softer stools that pass through the system faster. The softer stools reduce the pressure necessary for elimination, thus, less constipation, and lower incidence of maladies such as divirticular disease, varicose veins, hemorrhoids, hernias, appendicitis, and phlebitis. The more rapid movement of the fecal bulk through the colon (reduced transit time) results in increased "scrubbing action" within the colon reducing the likelihood of stagnation and temporary sepsis setting in at any

TABLE 1

RELATIVE RISK HEART ATTACK vs TDF CONSUMPTION

Quintile	**TDF Grams/Day**	**Relative Risk**
1	12.4	1.00
2	16.6	1.01
3	19.6	0.96
4	23.0	0.92
5	28.9	0.64

TABLE 3
RECOMMENDED LEVELS OF DIETARY FIBER INTAKE

Organization	Year	Level	Comments
USDA and USFDA NLEA Regulations	1993	TDF 25 g/day SDF 0.6 g/serving	2000 calorie diet For cardiovascular health claim
National Cancer Institute	1984 1988	TDF 25-35 g/day TDF 20-30 g/day	Consume whole grains, fruits, vegetables
Federation American Societies of Experimental Biology	1987	TDF 20-35 g/day (10-13 g/1000 kcal) 70-75% IDF 25-30% SDF	Consume wide variety of whole grain products, fruits, and vegetables
American Dietetic Association	1988	TDF 35-50 g/day	General public. Diabetics under medical supervision (Consume as part of low fat diets)
British National Advisory Committee on Dietary Fiber	1986	TDF 30 g/day	
Expert Advisory Committee on DF-Health and Welfare, Canada	1985	TDF-Double intake from current levels	Level in 1985 estimated at 5.8 to 8 g/1000 kcal
Nordisk Ministerrad Standing Nordic Committee on Food	1989	TDF 12 g/1000 kcal	

particular spot.

Rimm et. al. (1996) reported increased consumption of IDF correlated with reduced coronary heart disease, (an effect usually seen for SDF) after tracking the health habits of some 44,000 US male medical professionals for six years. Self reported food intakes were audited by plasma carotenoid and tocopherol testing. Effectiveness of DF was measured by reduction in heart attacks. Table 1 summarizes the relative risk of heart attack vs TDF consumed per day. Relative risks are adjusted for saturated fat level in the diet, vitamin E intake, age, body mass index and physical activity level of the subjects, smoking, alcohol consumption , hypertension, hypercholesterolemia, family history, and profession. The quintile that consumed the highest level of TDF had 2/3 the risk of those consuming the lowest amount of DF. Looking at the heart health response to the three major sources of fiber, i.e. fruits, vegetables, and cereals, each have an effect, with cereal fiber showing the greatest impact (see table 2).

FOOD LABELING REGULATIONS

Nutrition Facts Label

The Nutrition Labeling and Education Act (NLEA) of 1990 directed the USDA and USFDA to develop regulations for labeling DF. Regulations now require the labeling of TDF, labeling of IDF and SDF is optional. The quantity of IDF can be subtracted from total carbohydrates before calculating calories with a net reduction of 4 calories per serving per gram of IDF.

Health Claims

NLEA regulations do not allow health claims regarding the consumption of DF *per se.* But, there are three specific claims that can be made relating improved health status with increased consumption of high fiber foods.

All claims must use the terms “may” or “might” reduce risk, apply to foods containing grain products, fruits, and vegetables (which contain fiber) and must promote low fat/ high fiber food diets. The claims are:

- Fiber containing grain products, fruits, and vegetables and cancer.
  *Food must qualify as a “good source” (2.5 g/serving) of fiber without fortification
- Fruits, vegetables, and grain products that contain fiber, particularly SDF, and risk of coronary heart disease.
  *Food must contain at least 0.6 g/serving of

TABLE 4
OFFICIAL METHODS OF ANALYSIS-DIETARY FIBER

Method	Title	**Comments**
985.29	Total Dietary Fiber in Foods-Enzymatic-Gravimetric Method	First Official DF method adopted
991.41	Insoluble Dietary Fiber in Food and Food Products-Enzymatic-Gravimetric Method, Phosphate Buffer	Extension of 985.29, quantitating IDF with SDF can be determined by subtraction
993.19	Soluble Dietary Fiber in Food and Food Products Enzymatic-Gravimetric Method, Phosphate Buffer	Measures SDF directly
991.43	Total, Soluble, and Insoluble Dietary Fiber in Foods Enzymatic-Gravimetric Method, MES-TRIS Buffer	Changing buffers to morphlinoethansulfonate (MES)/ tris-hydroxymethylaminomethane (TRIS), uses less digestion solvent and one less pH adjustment step
992.16	Total Dietary Fiber-Enzymatic-Gravimetric Method	IDF and SDF ratios differ substantially from other AOAC methods, therefore this method is only for TDF
993.21	Total Dietary Fiber in Foods and Food Products with ≤ 2% Starch-Non-Enzymatic-Gravimetric Method	Applies primarily to fruits and vegetables where the analyst is sure the sample contains no starch
994.13	Total Dietary Fiber (Determined as Neutral Sugar Residues, Uronic Acid Residues, and Klason Lignin-Gas Chromatographic-Colorimetric-Gravimetric Method)	Breaks DF down to its neutral sugars, uronic acids, and lignin which are summed as TDF

SDF without fortification.

- Fruits and vegetables and cancer (emphasis is on antioxidant vitamins, rather than fiber, but most fruits and vegetables contain significant fiber).
  *Food must be a "good source" of vitamin A, vitamin C, or Dietary Fiber.

DIETARY GUIDELINES

Recommended Levels of Fiber Intake

In 1984, the director, Division of Cancer Prevention and Control, National Cancer Institute recommended: "Research data suggesting that fiber-containing foods provide some protection against colon and rectal cancer have led NCI to make recommendations now, that Americans eat a diet high in fiber from whole grain breads and cereals and fresh fruits and vegetables. If followed, these recommendations may reduce individual risk of these cancers." The recommendations of this and other organizations are listed in table 3.

Good Food Sources of Dietary Fiber

Sources of DF that can be consumed to increase the level of DF are numerous and of a wide variety, sufficient to suit most everyone's taste and caloric intake level. Whole cereal grains and whole grain products, fruits, and vegetables are the primary dietary sources available

OFFICIAL ANALYTICAL METHODS

Numerous researchers including Asp of Sweden, Southgate of the UK, Theander of Norway, VanSoest and Furda of the US, and Schwiezer of Switzerland applied their talents, developing analytical methods suitable for DF. An AOAC workshop in Ottawa Canada (1981) initiated pursuit of a consensus enzymatic-gravimetric method nutrition labeling. The method was finalized by Asp, DeVries and Furda of General Mills, Prosky and Harland of FDA (initiated and conducted collaborative validation) and Schwiezer. Shortly, 43 laboratories in 29 different countries expressed a desire to participate in the collaborative effort. After a successful international collaborative effort, the first Official Method of Analysis (AOAC 985.29) for DF that met the physiological definition was adopted in 1985. There are seven Official Methods for DF (see table 4). The first four are the primary ones used for nutrition labeling and fiber database generation worldwide.

FUTURE EFFORTS

What is the future for DF research and method development? Will scientists be looking for further physiological fractionation of TDF beyond the physiological effects associated with SDF and IDF? Will additional physiological effects be discovered? Physicochemical characteristics, such as molecular structure, types of bonding, chain length, ion exchange capacity, water holding capacity, and fermentability critically affect the physiological behaviors of DF. In future research efforts, it will be important to characterize these physicochemical/physiological relationships. This will further help the food industry and the public choose DF sources of maximum potential health benefit for food formulation and consumption.

BEYOND DIETARY FIBER-COMPLEX CARBOHYDRATES

Cereals provide a significant level of digestible complex carbohydrates in addition to DF. Fruits and vegetables are high fiber foods having low levels of digestible complex carbohydrates. Digestible complex carbohydrates affect the rate of digestion, and some reach the large intestine where they provide energy for fermentation, possibly explaining this phenomenon. Numerous dietary recommendations have been made to increase complex carbohydrate consumption. Complex carbohydrates quantities were proposed as part of the Nutrition Facts label in 1991, but excluded in the final NLEA regulations issued in 1993. Therefore, label information does not reconcile with recommendations to increase complex carbohydrate consumption. Currently efforts are underway to clearly define complex carbohydrates and set up standard methodology for this nutritional entity.

REFERENCES

Anonymous, 1996, Food Labeling: Health Claims; Oats and Coronary Heart Disease, in *Federal Register*, **61,** no 3, January 4, 1996, pp 296-337.

Burkitt, D.P., Walker, A.R.P., and Painter, N.S., 1972, Effect of dietary fibre on stools and transit times, and its role in the causation of disease. *Lancet,* ii:1408-1412.

Butrum, R.R., Clifford, C.K. and Lanza, E. 1988 NCI dietary guidelines:rationale. *American Journal of Clinical Nutrition* 48:888-895.

Deas, A.H. and Holloway, P.J. 1977. The Intermolecular structure of some plant cutins in *Lipids and Lipid Polymers in Higher Plants.* ed. M. Tevini, H.K. Lichtenhaler, 293-300.

DeVries, J.A., Rombouts, F.M., Voragen, A.G.J., and Pilnik, W., 1982, Enzymatic degradation of apple pectins, *Carbohydr. Polym.,* **2,** 25.

DeVries, J.A., den Vijl, C.H., Voragen, A.G.J., Rombouts, F.M., and Pilnik, W., 1983, Structural features of the neutral sugar side chains of apple pectic substances, *Carbohydr. Polym.,* **3,** 193.

Hipsley, E.H. 1985. Dietary "fibre" and pregnancy toxaemia. *British Medical Journal* 2:420-422.

Kolattukudy, P.E. 1981. Structure, biosynthesis, and biodegradation of cutin and suberin. *Ann. Rev. Plant Physiol.* **32**:539-67.

Lee, S.C., and Prosky, L. 1995. International Survey on Dietary Fiber Definition, Analysis, and Reference Materials. *J.AOAC Int.* 79(1) 22-36.

Prosky, L., and DeVries, J.W. 1992. *Controlling Dietary Fiber in Food Products.* New York: Van Nostrand Reinhold

Rimm, E.B., Ascherio, A., Giovannucci, E., Spielgelman, D., Stampfer, M.J., and Willett, W.C., 1996. Vegetable, Fruit, and Cereal Fiber Intake and Risk of Coronary Heart Disease Among Men. *JAMA* 275.6:447-451.

Ripsin, C.M., Keenan, J.M., Jacobs, D.R., Elmer, P.J., Welch, R.R., Van Horn, L., Liu, K., Turnbull, W.H., Thye, F.W., Kestin, M., Hegstad, M., Davidson, D.M., Davidson, M.H., Dugan, L.D., Demark-Wahnefried, W., and Beling, S., 1992, Oat Products and Lipid Lowering-A Metaanalysis, *Journal of the American Medical Association,* 267:3317-3325.

Stuart, et. al. 1987.

Trowell, H.C. 1972. Crude fiber, dietary fiber and atherosclerosis. *Atherosclerosis* 16:138.

Trowell, H.C. 1974. Diabetes mellitus death rates in England and Wales, 1920-70, and food supplies. *The Lancet* 2:998-1001.

Trowell, H.C., Southgate, D.A.T., Wolever, T.M.S., Leeds, A.R., Gassull, M.A., and Jenkins, D.J.A. 1976. Dietary fiber redefined. *Lancet* a:967.

Trowell, H.C., Godding, E., Spiller, G., and Heaton, K., 1978 Fiber bibliographies and terminology. *The American Journal of Clinical Nutrition* 31:1489-1490.

Williams, R.D., and Olmstead, W.D. 1935. A biochemical method for determining indigestible residue (crude fiber) in feces: Lignin, cellulose, and non-water soluble hemicellulose. *J. Biol. Chem.* 108:653-66

A publication of Medallion Labs
Dr. Jonathan DeVries, Editor