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Dietary Fibers-Classification, Properties, Analysis and Function: A Review

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Abstract

Dietary Fiber (DF) is a plant bioactive compound, mainly a mixture of complex organic soluble and non-soluble polysaccharides that is non-digestible and less hydrophobic. This dietary fiber is one of nutritional supplements that demonstrated to have impact on human and animal health. Chemical structures, sources, classification, methods of analysis and therapeutic functions of DF are under investigation by researchers for diseases prevention and enhancing immune response. Dietary Fiber (DF) is diverse organic chemicals with higher molecular weight (HMW) over 10 DP and lower molecular weight of lower under 10 DP and can be classified generally by their solubility, viscosity, and fermentability. Dietary fiber is non-digestible by enteric enzymes and passes through small intestine into the colon intake where is fermented by enteric microbial biomass into beneficial metabolites and short chains fatty acids. Other health benefits from the acceptable daily intake such as adsorption of bile salts, polyphenols, and minerals. In addition to, influence gastrointestinal tract physiology where it has high water holding capacity and viscosity resulted in feeling satiety, alternate digestive enzymes activity, improved gastric emptying, and increase healthy microbial biomass in the colon.

Keywords

DF Definitions, Analysis, Cereals, Prebiotics, Diseases Prevention

1. Introduction

The definition of DFs according to Codex Alimentarius from 2010 is that they are carbohydrate polymers with ten or more monomeric units, not hydrolyzed by the endogenous enzymes in the small intestine and fermentable in the colon. Properties of DF are in the following categories:

- Edible carbohydrate polymers naturally occur in plant sources that are consumed by humans and animals.
- Obtained from natural raw material by physical, enzymatic or chemical methods.
- Have a physiological effect of benefits for both human and animal health.

DFs from plant origins may include phenolic compounds, waxes, saponins, phytates, cutin, phytosterols, etc., and/or compounds associated with celluloses, hemicelluloses, and polysaccharides [1]. The definition of DF also includes oligosaccharides such as inulin, and fructo-oligosaccharides that are three to nine monomeric units [2]. In general, the term of DF refers to any carbohydrate that is not broken down by small intestine enzymes, and passes into the large intestine (colon) where it is partially or fully fermented by enteric microorganisms into short chain fatty acids [3]. These short chain fatty acids as well as enteric microorganisms cell particles and metabolites promote healthy physiological effects for both human and animals [4].

In summary, DF is a mixture of complex polysaccharides with many different functions and activities. This dietary fiber is indigestible by enteric enzymes and passes through the gastrointestinal tract to the colon where it is fermented by enteric microorganisms into beneficial intermediate metabolite for both human and animal health. Many functions and activities of DF depend on its physiochemical properties such as size, bulk volume, surface area characteristics, hydration properties, solubility, viscosity, and adsorption or binding to ions and organic molecules [5]. Previously, there were different multiple definitions for DF before the current Codex definition [6] [7] [8].

2. Classification and Physio-Chemical Properties of DFs

DF is classified based on water solubility into Soluble Dietary Fiber (SDF) and Insoluble Dietary Fiber (IDF). The ratio between soluble and insoluble is important factor on dietary fiber functional properties [9]. Dietary fiber is also, classified based on microbial fermentation in large intestine (colon) into fermentable Dietary Fiber (FDF) and non-fermentable dietary fiber (NFDF). Fermentable dietary fiber is known by the name prebiotic. The prebiotic definition is that indigestible fermentable fibers by enteric bacteria in the colon are converted into physiological active metabolites such as short chain fatty acids and organic acids [10]. The indigestible fermentable fibers by enteric bacteria in the colon include pectin's, beta-glucans, guar gum, inulin and oligofructose. The best sources for these fermentable fibers are beans and legumes [11]. It is important to highlight that plant such as psyllium is indigestible, and non-fermented fiber by enteric bacteria in the colon with only function is stool regularity by retaining water [12] [13] [14] [15]. In addition, dietary fiber influence gastro intestinal tract physiology (**Table 1**) where it has water holding capacity and viscosity that influence satiety resulted in decrease food intake, improve mineral and phytochemical absorption, enhance glycemic response, reduce plasma cholesterol,

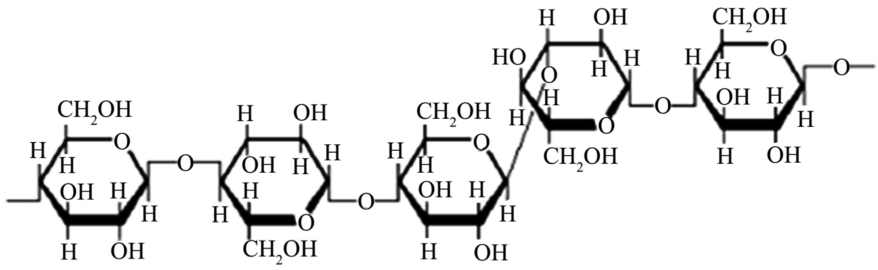
Table 1. Dietary fibers characteristic, gastric effect, and systemic effect [22].

DF characteristic	GIT effect	Systemic effect
Water-holding capacity & viscosity	Slows gastric emptying; Changes digesta mixing; Alteration of digestive enzyme activity; Stimulates passage rate;	Slows digestion, especially of protein and lipids; Associated with reduced plasma cholesterol; Blunting of glycemic response;
Bulking	Gastric distension; Changes in mixing & diffusion;	Decrease food intake;
Adsorption of compounds (e.g. bile salts, polyphenols & minerals)	Increases bile acid excretion & other compounds; Retention of polyphenols until large intestine;	Blood cholesterol; fermentation of polyphenols;
Encapsulation	Plant cell walls encapsulate e.g. starch granules;	Transport of starch (resistant) to LI for fermentation;
Fermentability	Increases microbial biomass & fermentation end-products (e.g. SCFA); Induces selection of specific microbes;	Energy for colonocytes; influences satiety; fecal bulking; "colonization resistance" to pathogens;

and is prebiotics colonizing healthy enteric bacteria that inhibit the colonization of enteric pathogenic bacteria via a mechanism known by the name competitive exclusion.

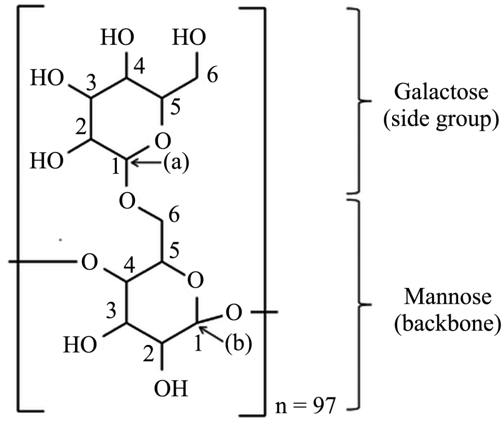
In addition to DF classification based on water solubility, it is also classified on the base of chemical structure into:

- ***β*-Glucan**—Glucose polymers containing various glycosidic bonds of *β*-1,4, *β*-1,3 and *β*-1,6 between glucose units (**Figure 1**).
- **Galactomannan**—Polymers of galactose and mannose consisting of mannose backbone linked together with *β*-1,4 glycosidic bonds and side chains of galactose subunits linked to mannose unit with *α*-1,6 glycosidic bonds (**Figure 2**).
- **Arabinoxylan**—polymers consisting of a *β*-1,4 linked xylose backbone with the xylose monomers bearing a mixture of either 2, or 3, or 2 and 3 substituted *α*-L-arabinose residues (**Figure 3**).
- **Pectin**—diverse polymers of polysaccharides that are found in many fruits and can be subdivided into two broad classes, namely galacturonans consisting of homo-galacturonans, unsubstituted and substituted galacturonans, and rhamnogalacturonans consisting of rhamnogalacturonan-I and rhamnogalacturonan-II (**Figure 4**).
- **Arabinogalactan**—a polymer of polysaccharide consisting of D-galactose and L-arabinose in a ratio 6:1 joint with few units of D-glucuronic acid. The general structure is *β*-1,3 linked linear galactosyl backbone which contain side chains at the C6 position. Most of these side chains are galactose or arabinose *α*-1,6 linkages (**Figure 5**).



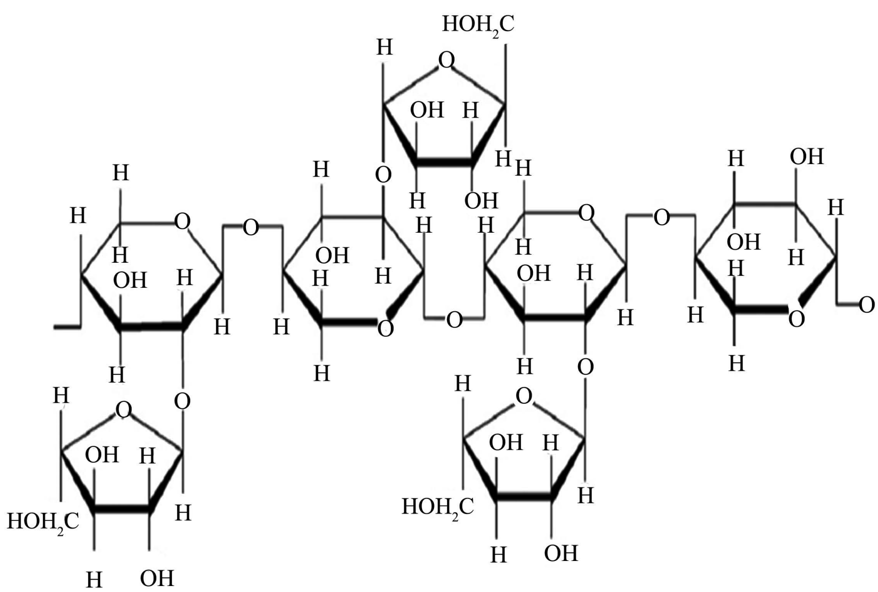
β-Glucans

Figure 1. *β*-glucans are presented as linear polysaccharides, in which glucose units linked by *β*-(1,3) and *β*-(1,4) glycosidic bonds and are mainly found in barley, oats, rye, and wheat.



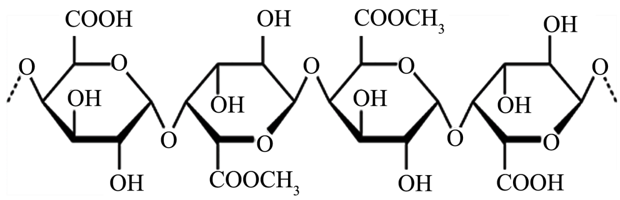
Galactomannan

Figure 2. Polymer of mannose backbone connected together with *β*-1,4 glycosidic bonds and galactose subunits connected to mannose unit with *α*-1,6 glycosidic bonds.



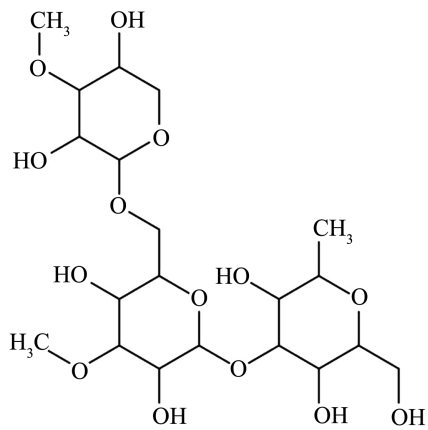
Arabinoxylan

Figure 3. It is consisted of a backbone of *β*-(1,4)-linked xylose residues, which are substituted with arabinose residues on the C(O)-2 and/or C(O)-3 position.



Pectin

Figure 4. Pectin is a complex polysaccharide consisting mainly of esterified D-galacturonic acid resides in an alpha-(1-4) chain.



Arabinogalactan

Figure 5. Highly branched and high molecular weight polysaccharides consisting mainly of arabinose, galactose residues and glucuronic acid

- **Resistant Starch**—any form of starch that is resistant to hydrolysis by the small intestine enzymes. There are four different types of resistant starch. These are RS-1, a physically protected form of a starch found in whole or partly milled grains, RS-2 present in raw granules, RS-3 a retrograded starch, and RS-4 a chemically modified starch (**Figure 6**). These four types of resistant starches (RS) offer a wide array of health benefits [16].
- **Polydextrose**—a synthetic polymer of randomly glucose units with all types of glycosidic linkages, and containing few units or sorbitol and citric acid. Polydextrose is resistant to digestion, and is synthetically manufactures (**Figure 7**).
- **Cutin and Suberin**—a small proportion of dietary fiber made from plant waxes that are generally polymers of long chain aliphatic acid monomers such as 18-hydroxy-oleic acid, or aromatic acid monomers such as hydroxycinnamic acids (**Figure 8**).

3. Food Sources for DF

DF is naturally present in cereals, vegetables, fruits and nuts with chemical structure and concentration that varied in sources and plant varieties [17] [18] [19] [20] [21]. Cereals, vegetables, and fruits are the main sources of DF intake (**Table 2**). The beneficial health effects of DF are not only depended on fiber intake,

Table 2. Dietary fibers form various food sources [1].

Source	Dietary fiber (g/100g edible portion)		
	Total	Insoluble	Soluble
Grains			
Barley	17.3	-	-
Corn	13.4	-	-
Oats	10.3	6.5	3.8
Rice (dry)	1.3	1.0	0.3
Rice (cooked)	0.7	0.7	0.0
Wheat (whole grain)	12.6	10.2	2.3
Wheat germ	14.0	12.9	1.1
Legumes & pulses			
Green beans	1.90	1.40	0.50
Soy	15.0	-	-
Peas, green frozen	3.5	3.2	0.3
Kidney beans, canned	6.3	4.7	1.6
Lentils, raw	11.4	10.3	1.1
Lima beans, canned	4.2	3.8	0.4
White beans, raw	17.7	13.4	4.3
Vegetables			
Potato, no skin	1.30	1.0	0.30
Bitter gourd	16.6	13.5	3.1
Beetroot	7.8	5.4	2.4
Fenugreek leaves	4.9	4.2	0.7
Ladyfinger	4.3	3.0	1.3
Spinach, raw	2.6	2.1	0.5
Turnips	2.0	1.5	0.5
Tomato, raw	1.2	0.8	0.4
Green onions, raw	2.2	2.2	0.0
Eggplant	6.6	5.3	1.3
Cucumbers, peeled	0.6	0.5	0.1
Cauliflower, raw	1.8	1.1	0.7
Celery, raw	1.5	1.0	0.5
Carrot, raw	2.5	2.30	0.20
Broccoli, raw	3.29	3.00	0.29

Continued

	Fruits		
Apple, unpeeled	2.0	1.8	0.2
Kiwi	3.39	2.61	0.80
Mango	1.80	1.06	0.74
Pineapple	1.20	1.10	0.10
Pomegranate	0.60	0.49	0.11
Watermelon	0.50	0.30	0.20
Grapes	1.2	0.7	0.5
Oranges	1.8	0.7	1.1
Plums	1.6	0.7	0.9
Strawberry	2.2	1.3	0.9
Bananas	1.7	1.2	0.5
Peach	1.9	1.0	0.9
Pear	3.0	2.0	1.0
	Nuts and seeds		
Almonds	11.20	10.10	1.10
Coconut, raw	9.0	8.5	0.5
Peanut, dry roasted	8.0	7.5	0.5
Cashew, oil roasted	6.0	-	-
Seasame seed	7.79	5.89	1.90
Flaxseed	22.33	10.15	12.18

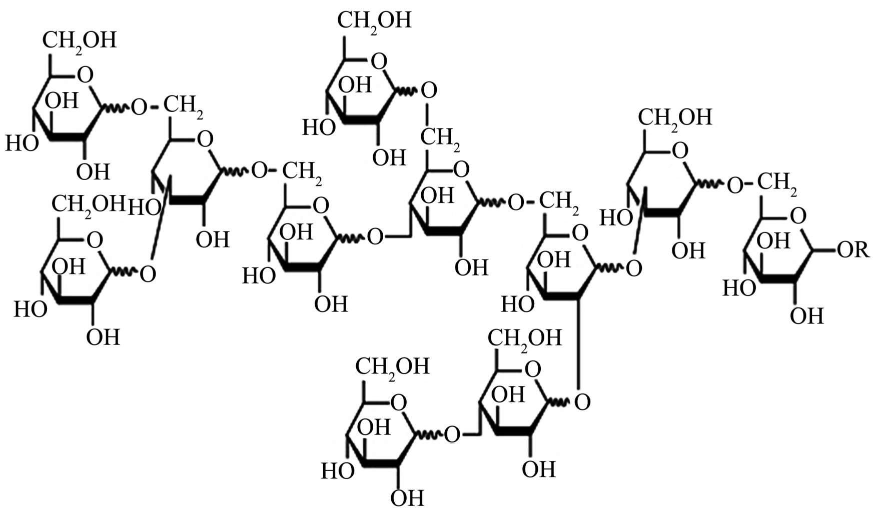
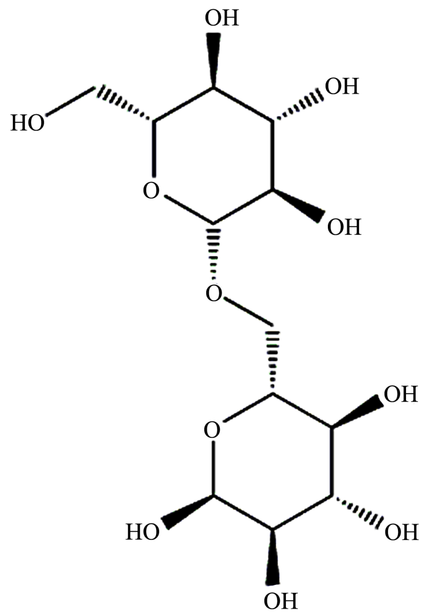
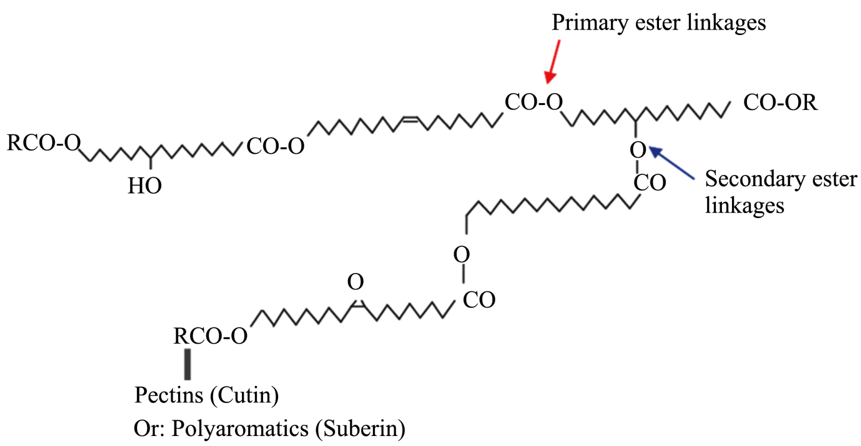


Figure 6. High-molecular carbohydrate composed of linear (amylose) and branched (amylopectin) chains of glucose residues.



Polydextrose

Figure 7. A polysaccharide composed of randomly cross-linked glucose units with all types of glycosidic linkages and containing small amounts of sorbitol and citric acid. Ented that utilise ion exchange and hydrogenation, and provide even broader utility in foods (Borden *et al.* 1997; Guzek *et al.* 1997a, b).



Cutin and Suberin

Figure 8. Cutin is an aliphatic polyester built from C16 and C18 ω-hydroxy fatty acids and their derivatives. Suberin is aliphatic and aromatic components with a higher chain length of C20 to C20, mainly in particular 1-alcanols, ω-hydroxy fatty acids. [R] is a chain of other domains of polyester.

but also depends on fiber chemical composition, as well as on the methods of food preparation [22]. The recommended daily fiber intake is around 14 grams for every 1.00 Kcal ingestion. This average dietary fiber intake recommendation varied according to age, gender, and energy consumption. In Western countries fiber intake is about 50% cereals, 30% vegetables, 16% fruits, and the remaining 4% is from other minor sources such as nuts and seeds [23].

4. Analytical Assay Methods for DF and Its Components

A number of AOAC Official Methods of Analysis have been adopted for the analysis of dietary fiber and its fractions [24]. One of these assay methods for dietary fiber analysis is AOAC 985.29 as well as 991.43 [25]. Both methods quantify only high molecular weight dietary fiber (HMWDF) for soluble and insoluble fiber combined as total dietary fiber (TDF). Lately, soluble and insoluble dietary fiber fractions were distinguished and quantified separately in the analyses [26]. Low molecular weight dietary fiber (LMWDF) such as inulin, fructo-oligosaccharides, galacto-oligosaccharides, and polydextrose were incorporated in dietary fiber definition by Codex Alimentarius in the year 2008 and were incorporated in analytical methods for quantifying the total dietary fiber (TDF) [27]. In addition, a number of AOAC analytical methods were developed to measure different dietary fiber components separately [28].

In general, based on dietary fibers recent definitions, three analytical methods were used. The three assay analytical methods for dietary fiber measurement are Weighing after removal of non-fiber components for measuring high molecular weight dietary fiber (HMWDF), Colorimetric carbohydrates assay, and Specific assay of monomeric constituents using gas-liquid chromatography (GLC) or high-performance liquid chromatography (HPLC) for measuring low molecular weight dietary fiber (LMWDF). Weighing after removal of non-fiber components method is based on enzymatic-gravimetric approach as an attempt to simulate human digestion. This enzymatic-gravimetric approach uses the three digestive enzymes α-amylase, protease, and amylglucosidase at their optimum temperature and PH. After enzymatic digestion and alcohol precipitation both proteins and ashes are measured and subtracted from the calculation for measuring High molecular weight dietary fiber (HMWDF) for both soluble and insoluble dietary fiber. The second method is the assay of low molecular weight dietary fiber (LMWDF) using colorimetric or high-performance liquid chromatography (HPLC). HPLC is commonly used for this assay method. The definition of total dietary fiber (TDF) is HMWDF and LMWDF combined. It is important to highlight that these assay methods require multiple steps that could generate systematic errors that can be avoided by applying good laboratory practice (GLP).

Currently, there are three available commonly-used methods for total dietary fiber measurement. These methods are:

1) Prosky/Lee method, **AOAC** 985.29/991.43 method being introduced in the year 1985 using thermostable bacterial α-amylase at optimum incubation conditions of 100˚C and pH 8.2. In this method most of resistant starch and all of non-digestible oligosaccharides are not included in the result. This method is giving measurement less than all dietary fiber components as defined by CODEX Alimentarius for the international regulatory body for food ingredients.

2) McCleary method, AOAC 2009.01/2011.25 method that was introduced in the year 2009. This method uses pancreatic α-amylase at optimum incubation

conditions of 37˚C and pH 6 as well as protease and amylglucosidase to measure all components of dietary fiber as defined by CODEX Alimentarius for the international regulatory body for food ingredients (**Figure 9**).

3) Rapid Integrated Total Dietary Fiber (RINTDF) method, (AOAC 2017.16) method that was introduced in the 2015 and closely resembles to AOAC 2009.01 (McCleary method). The RINTDF is the only method that accurately measures all components of total dietary fiber including all forms of resistant starch (**Figure 10**).

It is important to highlight that both McCleary's and Rapid integrated total dietary fiber (RINTDF) methods are available in the market as test kits from Neogen Company—Megazyme products.

5. Health Benefits of DF

The health benefits of DF are numerous. They have been established for over 30 years and were associated with both adult and children health [29] [30]. The intake of diets containing higher fiber content resulted in the prevention of gastro-intestinal diseases, and improves insulin sensitivity. The interest in dietary fibers intake is increasing especially after the discovery of its impact on obesity control by reducing food appetite. In addition, researchers demonstrated that the intake diets rich in fibers has multiple health benefits such as, lower cholesterol that might reduce the risk of heart disease, regulate blood sugar level for diabetes, prevent constipation by regulating bowel movements, softening stools

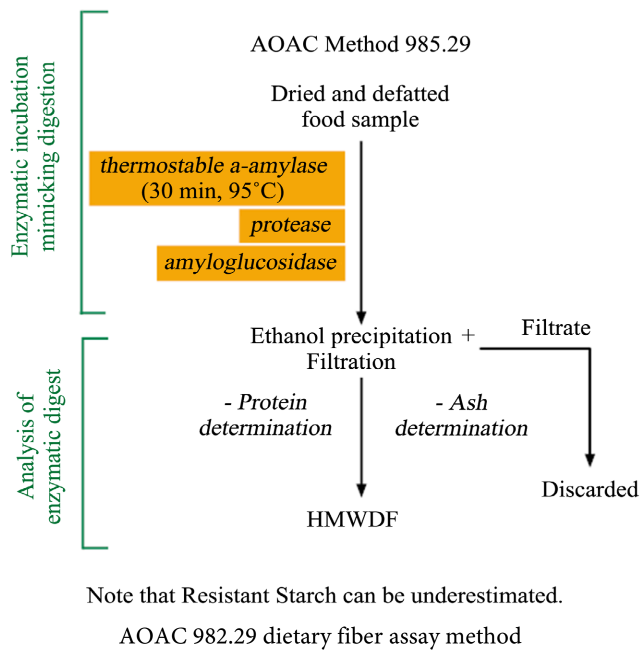
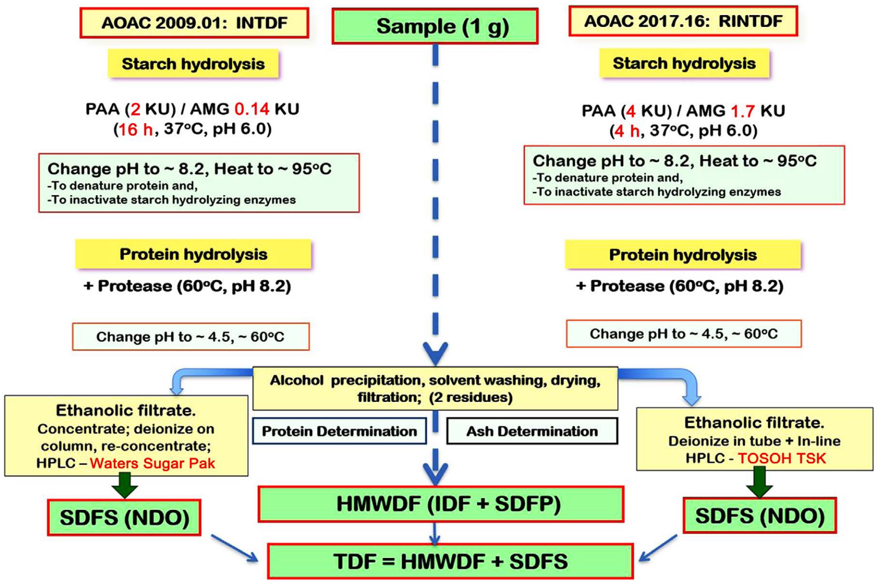


Figure 9. Assay method for High molecular weight dietary fiber (TDF) is based on simulate digestion system by subjecting the sample to the three digestive enzymes of α-amylase, protease, and amyloglucosidase at optimum PH and temperature of each, after digestion protein, and ash are subtracted from the calculation. (Source: https://www.neogen.com/categories/nutritional-analysis/rapid-integrated-total-dietary-fiber-assay-kit/).

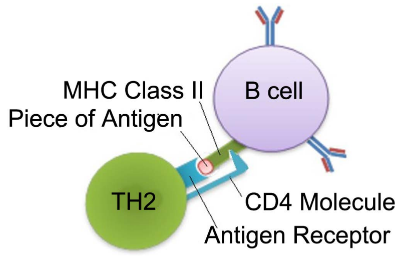


McCleary Method AOAC 2009.01/2011.25 Vs. Rapid Integrated Total Dietary Fiber AOAC 2017.16

Figure 10. McCleary method measures all components of dietary fiber as defined by CODEX Alimentarius, and RINTDF method address miner limitations identified in McCleary method and measure all components of total dietary fiber (TDF) including all forms of resistant starch (RS) (Source: https://www.megazyme.com/documents/Assay_Protocol/K-RINTDF_DATA.pdf).

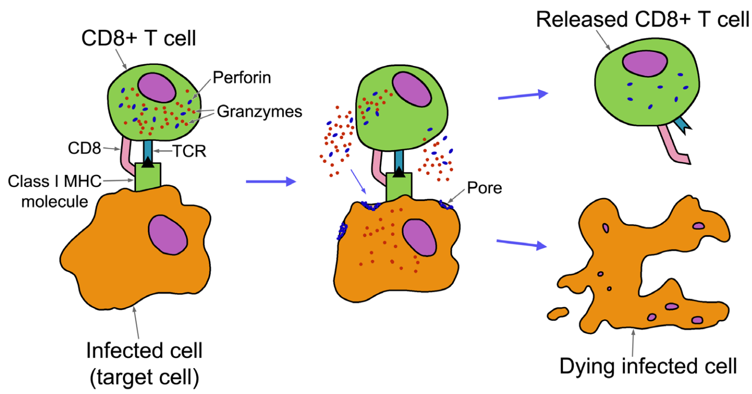
by increasing water retention capacity in the colon, and the claim in preventing intestinal cancer by speeding food movement in intestinal tract reducing residence time of harmful microbial metabolite causing cancer [31]. One healthy function of low molecular weight dietary fiber (LMWDF) such as fructo-oligosaccharides, galacto-oligosaccharides, inulin, etc. is the prebiotic property for enhancing the growth of beneficial bacteria such as lactic acid bacteria, and *Bifidobacterium* in the colon [32]. These beneficial enteric bacteria ferment dietary fibers into short chain fatty acids and secrete metabolites for healthy colon. In addition, it was claimed that enteric bacteria cell wall debrides enhance host immune response by activating cell immunity system of lymphocytes including the enhancement of monocytes, macrophages, dendritic cells, natural killer and neutrophils cells [33]. There are two types of lymphocytes, B-lymphocytes that make antibodies, and T-lymphocytes that is divided into $CD4^+$ T helper (T_H) cells in gut-associated lymphoid tissue (GALT) to help in triggering a controlled immune response (**Figure 11**), and cytotoxic $CD8^+$ cytotoxic T (Tc) cells to kill any developed tumor cells (**Figure 12**). The T cells regulate antibodies and cytokines.

DF immunomodulation function of lymphocytes is by stimulating membrane receptors on the surfaces on these lymphocytes, to trigger the secretion of cytokines such as tumor necrosis factor (TNF-α) and interleukins (ILs) [34]. These cytokines are small proteins secreted by immune cells as a signal for triggering immune response [35]. It is important to highlight that immune stimulation



B cells is activated in presence of helper CD4+ T helper cells

Figure 11. B cells function is antigen presenting cell (APC). It binds and engulfs foreign antigens via B cell receptors (BCRs), then display processed antigens on Major histocompatibility class II (MHC II) expressed on B cell surface to T helper cell (CD4+ TH2). When a T helper cell detects APC (B cell) it secretes specific cytokines that induce the B cell to proliferate and differentiate into antibody-secreting plasma cells.



CD8+ cytotoxic T cells (CTLs) are activated by the presence of tumor antigen coupled to an Major histocompatibility class I (MHC I).

Figure 12. Cytotoxic T-cells (CTLs), also known by the name CD8+ T-cells, express T-cell receptors (TCRs) accompanied by the CD8+. The tight binding of CTLs and tumor cells through the CD8/TCR complex and Tumor cells antigen presented by major histocompatibility complex (MHC), class I causing T-cells to proliferate and secrete enzymes that lyse tumor cells (Source: Westburg).

functions for DF claims to trigger both innate immune response and adaptive immune response [36] as well as they have direct anticancer effect [37].

It was demonstrated that fiber is essential for the health and that it delivers a lot of health benefits: supports weight loss, reduces cholesterol, lowers the risk of cardiovascular diseases such as stroke, heart disease, reduces blood sugar levels, lowers the risk of diabetes, enhances the growth of healthy enteric bacteria, improves digestive system, improves bowel movement, reduces the risk of constipation, and lowers the risk of colorectal and breast cancer. Because of these health benefits it is important to intake the right amount of fiber in the daily diet. The United State Food and Drug Administration (FDA) recommended the average value of 28 grams of fiber per day for adults on a 2000-calorie diet. The recommended daily intake varies based on age and gender [38]. The United State Department of Agriculture (USDA) suggested the daily fiber intake for women under age 50 to be 25 - 28 grams per day, for women over 50 to 22 grams per day, for men under 50 to 30 - 31 grams per day, and for men over 50 to 28 grams per day. The USDA also, recommended children at the ages from 1 to 18 years to intake fiber in the range of 14 grams per day. It is important to highlight that dietary fiber does not provide the body with other nutrients such as vitamin D, and calcium. So, these nutrients must be supplied from foods or from dietary supplements.

6. Discussion

Dietary fibers diverse in organic chemical compounds that can be classified generally by their solubility, viscosity, and fermentability. Dietary fibers of plant foods are legumes, whole grains, cereals, vegetables, fruits, and nuts or seeds. There are two types of dietary fiber: soluble and insoluble. Soluble fiber can easily dissolve in water and breaks down into viscous particles in the colon. It is a source of few calories. Insoluble fiber does not dissolve in water and reaches intake to the colon not digested and is not a source of calories. Plant foods contain both types of fiber in varying amounts. Both types of DF have health benefits as total dietary fiber (TDF). The term fiber refers to a complex carbohydrate in all plant parts or plant-based foods that cannot be digested or absorbed by the body and does not raise blood sugar levels. Fiber is essential nutrient and generally is associated with health supporting and lowering the risk of several diseases. The benefits from fiber consuming depend on the type of fiber consumed and of the result in the gastrointestinal system.

Soluble dietary fibers (SDF) include compounds such as β-glucan, inulin, fructo-oligosaccharides, xyloglucans, pectin, gums and psyllium. SDF dissolves in water and is generally fermented in the colon into physiologically active metabolites of short-chain fatty acids by beneficial enteric bacteria. SDF also extends the feeling of fullness due to its property in delaying gastric emptying causing the feeling of fullness, and it can improve digestion and also lowers blood glucose [32] [33]. On other hand, add Insoluble dietary fibers (IDF) such as cellulose, hemicellulose, lignin, and resistant starch, are found in whole-wheat bread, brown rice, seeds and skin of fruits and are not soluble in water or gastrointestinal fluids, remaining more or less unchanged as it moves through the digestive tract [34]. Insoluble dietary fibers (IDFs) play important role in controlling weight, also improve bowl health by preventing constipation, and colon cancer.

The chemical structure of soluble and insoluble dietary fibers includes oligosaccharides that differ in monosaccharide components and in the glycosidic bonds that connect these monosaccharides units together. These nondigestible fibers are present naturally in plants such as vegetable, fruits, and whole grains. They can also be synthetized enzymatically from carbohydrates as a substrate into functional oligosaccharides such as fructo-oligosaccharides that are manufactured enzymatically from lactose as a substrate, and galacto-oligosaccharides that are manufactured enzymatically from milk sugar lactose. These functional oligosaccharides are defined as dietary fiber resistant to enzymatic hydrolysis in digestive system and are partially or complete fermented by beneficial enteric bacteria in the colon [34].

Association of the Official Agricultural Chemists (AOAC) has responsibility to identify and develop standard methods for measuring the quantity of DF. AOAC developed in the year 2005 the standard AOAC 985.29 method, and AOAC 991.43 method for measuring dietary fiber in foods. These two methods measure only the high molecular weight dietary fiber (HMWDF) soluble and insoluble fiber as total dietary fiber (TDF). In the year 2008 the distinguish soluble and insoluble fraction measurement was added in the dietary fiber measurements. In addition, Codex Alimentarius added the low molecular weight dietary fiber (LMWDF) such as inulin, fructo-oligosaccharides, galacto-oligosaccharides and polydextrose into dietary fiber definition. This new addition to dietary fiber definition was accepted by AOAC and was incorporated in the both AOAC 985.29, and AOAC 991.43 methods for measuring the TDF in foods. The drew back from these two AOAC methods are only the measure of resistant starch type RS-3. Resistant starch RS-3 is gelatinized starch that occurred during food processing. The other three types of resistant starch, RS-1 is presented in whole or partly milled grains, RS-2 is present as raw granules, and RS-4 is the chemically modified starch that cannot be measured in the TDF by these two AOAC methods (AOAC 985.29, and AOAC 991.43). In the year 2007, new integrated method was developed [39] for measuring the TDF. This developed method is now known by the name of AOAC 2009.01 method for measuring TDF, HMWF, and LMWDF. HMWDF fraction was measured by enzymatic-gravimetric method, and LMWDF was measured by high performance liquid chromatography (HPLC). The AOAC l2009.01 method demonstrated to be also an easy method for measuring inulin and fructo-oligosaccharides, as well as other functional-oligosaccharides as prebiotics in dietary fiber.

In summary, the developed rapid integrated AOAC official assay method is based on the simulated digestion system by subjecting the sample to the three digestive enzymes of α-amylase, protease, and amyloglucosidase at optimum PH and temperature of each. After digestion of protein, and ash they are subtracted from the calculation for measuring TDF in food [40].

Finally, consumers are growing their awareness about dietary fiber health benefits such as cardiovascular diseases, obesity, control of blood sugar and cholesterol levels, as well as the desire to live healthy life style, that are the key factors influencing global dietary fiber market. In addition, there is a claim to increase immune defense by activating host cell immunity system [41].

The global dietary fiber market reached about $ 7.8 Billion (USD) in the year 2021 and it is expected to reach about $ 21.7 billion (USD) by the year 2030 at 11.1% CAGR (Compound Annual Growth Rate).

7. Conclusion

DFs represent a plant bioactive non-digestible soluble and insoluble polysaccharides that are naturally present in cereals, fruits, vegetables and nuts. DFs are important for both adult and children's health, preventing numerous diseases and improving the immunity. Numerous analytical methods were established in the world through the years and were improved for measuring and accurate determination of the TDF and their fractions. At the same time, investigations on DFs impact on the health were undertaken and the awareness of the population is rising for including the DFs in contemporary daily meal. In addition, the biomanufactured oligosaccharides have been reported to have a positive effect on both humans and animals. Therefore, food industry should have an important role in producing food supplements that contain DFs. Plus, highlight DFs function, and daily intake.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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