

Short Communication

Understanding the Nutritional Needs of the Gut Microbiota

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OPEN ACCESS**Abstract**

Background: Obesity is the second leading cause of preventable death within the United States. Therefore, there is growing interest in elucidating associations between various factors of causation, prevention and treatment. While the genetic predisposition for the development of obesity is well known, researchers have also found that diet type can impart an even greater influence upon disease development through influencing the gut microbiota.

Significance: Since the time of the first nationally published dietary nutrition guidelines, the defining characteristics of a healthy diet has been defined solely in terms of the human being. Understanding the role of the gut microbiota in human health and the fact that the majority of United States residents consume a Westernized diet type, it is beneficial to revitalize national dietary recommendations to specifically include the nutritional needs of the gut microbiota as well as address the over consumption of processed foods.

Aim: We aimed to provide dietitians and primary care physicians with clinically applicable information regarding; (i) the molecular characteristics of dietary fiber and how cooking effects the natural plant structures, (ii) the nutritional needs of the gut microbiota and, (iii) a diet type that is beneficial to both the human host and the gut microbiota.

Conclusion: Here, we provided a dietary guideline based upon the nutrition needs of the residential gut microbiota and the human host. We also provided information to help physicians and patients understand the importance of consuming a diet high in fresh, whole foods and low in processed foods.

Keywords

- Gut microbiome health
- Overweight and obesity
- Dietary fiber
- Human nutrition
- Dietitians
- Primary care physicians

INTRODUCTION

While there are benefits to food processing, it is now understood that methods such as blanching, milling, peeling, juicing, fermentation, genetic alteration, and thermal processing all significantly alter the nutrient content of the once natural food [1]. Within the United States the majority of the residents now consume a Westernized diet type consisting of these energy dense, nutrient poor processed foods that are high in salt, fats, refined sugar, fatty animal proteins, and low in natural fiber [2]. Specifically, the loss of the natural plant fiber poses to be one of most significant factors of food processing contributing to declines in human health as well as that of the gut microbiota with the development of dietary induced gut microbiome dysbiosis. Overall, the consumption of a Westernized diet is also directly associated with many costly diseases including those of overweight, obesity, type 2 diabetes, cardiovascular,

intestinal diseases, some cancers, as well as with food cravings and addiction [3].

The benefits of consuming natural plant fiber was first reported by Hippocrates in (430 B.C.), who reported that coarse wheat imparted a laxative effect. In modern day, regular consumption has also been associated with *decreasing* obesity-induced inflammation as well as the inflammation that is associated inflammatory and autoimmune disorders [4-6]. Understanding the health benefits of fiber imparted upon both human and gut microbiota health, through the following commentary we aim to provide dietitians and primary care physicians with clinically applicable information regarding; (i) the molecular characteristics of dietary fiber and how cooking effects the natural plant structures, (ii) the nutritional needs of the gut microbiota and, (iii) a diet type that is beneficial to both the human host and the gut microbiota.

Characterizing Dietary Fiber

In 2008-2010 researchers and health officials associated with the Codex Committee on Nutrition and Foods for Special Dietary Uses, Codex Alimentarius Commission, International Life Sciences Institute of Europe, and the International Life Sciences Institute of North America Committees on Dietary Carbohydrates, proposed several defining characteristics of dietary fibers. The Committees suggested that dietary fiber is officially defined as; *the plant based carbohydrate polymers that cannot be hydrolyzed by human digestive enzymes*. Fibers are further categorized by their degree of polymerization (DP) capability which ranges from (3-9DP) [7]. Furthermore, the National Institutes of Health recognizes two types of dietary fibers including, *soluble* (e.g., pectin, β -glucans, mucilage, gums) and *insoluble* (e.g., cellulose, hemicellulose, lignin), with the regular intake of insoluble fibers having a greater association with health benefit [8-13]. In terms of nutrient content, fiber is defined as a low-energy, no calorie-fat, micronutrient rich food that increases feelings of satiety and satiation signals [14,15].

The majority of *insoluble* plant fiber is contained within the walls of the individual parenchyma cells of the plant (e.g., most common cells of cereal grains, fruits, vegetables). *Soluble* fibers are found within the cell walls and inside the plant cell [16]. *Cellulose* (e.g., insoluble) is the major proponent within in cell walls and consists of un-branched linear chains of β -1, 4 glucosidic linked glucose molecules that are bound into micro-fibrils. Cellulose is resistant to biological and enzymatic degradation by human enzymes. *Hemicellulose* (e.g., insoluble), is polysaccharides with the same molecular structure of cellulose but smaller sized particles comprised of branch sugars arabinose, galactose, xylose and mannose. *Pectin* (e.g., soluble) is a D-galacturonic acid based complex polysaccharides, and *lignin* (e.g., insoluble) is an inert complex polymer consisting of 40 oxygenated phenyl-propane

molecules. The amount of fiber content and the size of the micro-fibrils found within a plant cell are dependent upon the specific wall structure of the particular plant, as well as the degree of processing and or cooking of the food before consumption [17]. As shown in (Figure 1), viewing a sample of fresh water algae it is possible to see how plant cells are arranged and unlike human cells, how they are separated by noticeable cell walls. It is also clear to see that the thickness of the cell walls varies depending upon the type of algae.

There are benefits to cooking plant-based foods such as increasing the bioavailability of some vitamins and minerals as the cell walls are lysed allowing human enzymes access to the fiber molecules, and improving palatably as the tough fibrous material of plant is softened. However, processing methods and over cooking ultimately degrade the quality of dietary fibers and nutritional properties of the natural food. Specifically, methods of boiling, blanching, and canning resulted in significant loss of low molecular weight carbohydrates and micronutrients of various conifers. Researchers reported a loss of these properties in carrots ranging from (25-45%), in rutabagas (30-50%) and in Brussels sprouts, peas and green beans (12-23%). Additionally, the processing of micro-fibrils including the milling and grinding of cereal grains and oats requires removal of the fiber-rich outer shell. Peeling, juicing, pureeing, drying, and boiling of produce decreases the overall quality of the insoluble fibers [18,19]. A variety of fruits and vegetable commonly consumed in the United States are in (Tables 1,2) in their natural and cooked states. Viewing the images in (Table 1), in their raw states the individual parenchyma cells are clearly visible as are the cellular contents which in was fruit juice in some such as the pineapple, or starch molecules as shown in the example of a raw new potato. The blueberry pulp is layered with parenchyma cells that are filled with juice and fibers material. As shown in (Table 2), different methods of cooking impart their own effects upon the plant cell

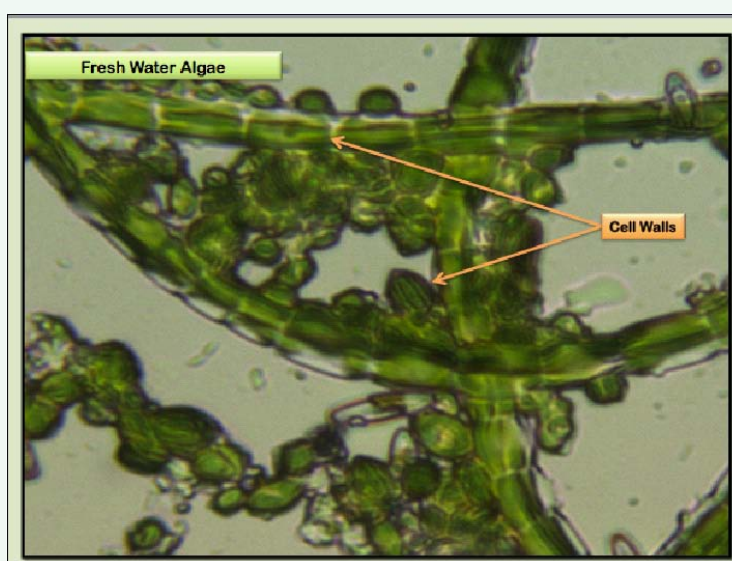


Figure 1 Arrangement of Plant Cells and Depiction of Cell Walls.

Image Source: Shannon C. Davis. While most plant cell walls (illustrated by the arrows) are indigestible by human enzymes, the insoluble fibers the cell wall serve as the primary food source for the gut microbiota and these fibers are fermented to produce short-chain fatty acid energy molecules. Images obtained using OMax 2000 Microscope with (x10 amp) eyepieces and OMax (8mp) digital microscope camera.

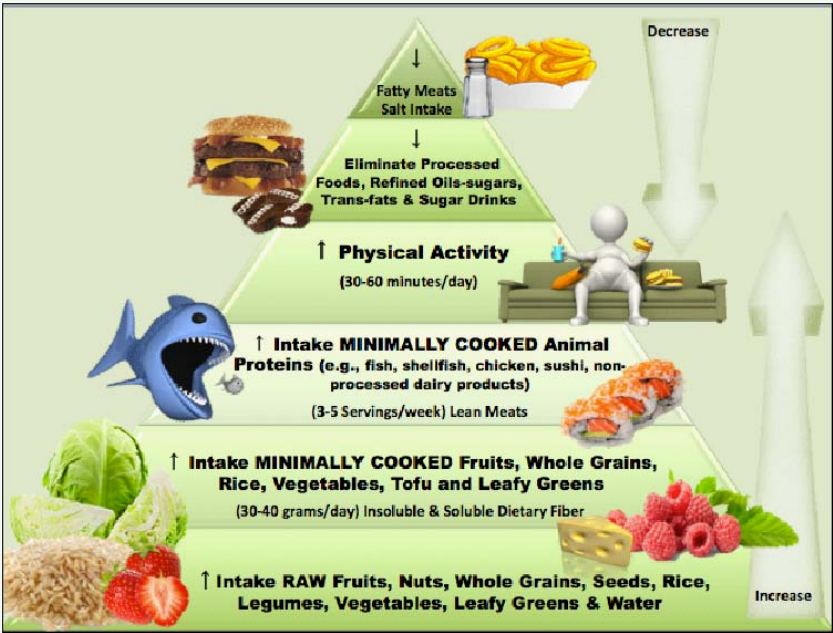


Figure 2 Gut Microbiome Based Food Pyramid.
Gut Microbiome Based Diet: As shown in the food pyramid, the gut microbiota require both insoluble and soluble fiber obtained from raw and minimally cooked vegetables, fruits, whole grains, nuts, seeds, wild rice, and legumes. While proteins can be obtained from non-animal sources, there is benefit to human and possibly the gut microbiota with minimal consumption of lean animal meats no more than 5 times per week. Ultimately, both gut microbiota and human host significantly benefit from decreasing and eventually eliminating consumption of sugared beverages, highly processed meats and foods from daily diet as well as decreasing intake of salt and refined oils, grains and fats. Physical activity is also included as part of a well balanced dietary regime.

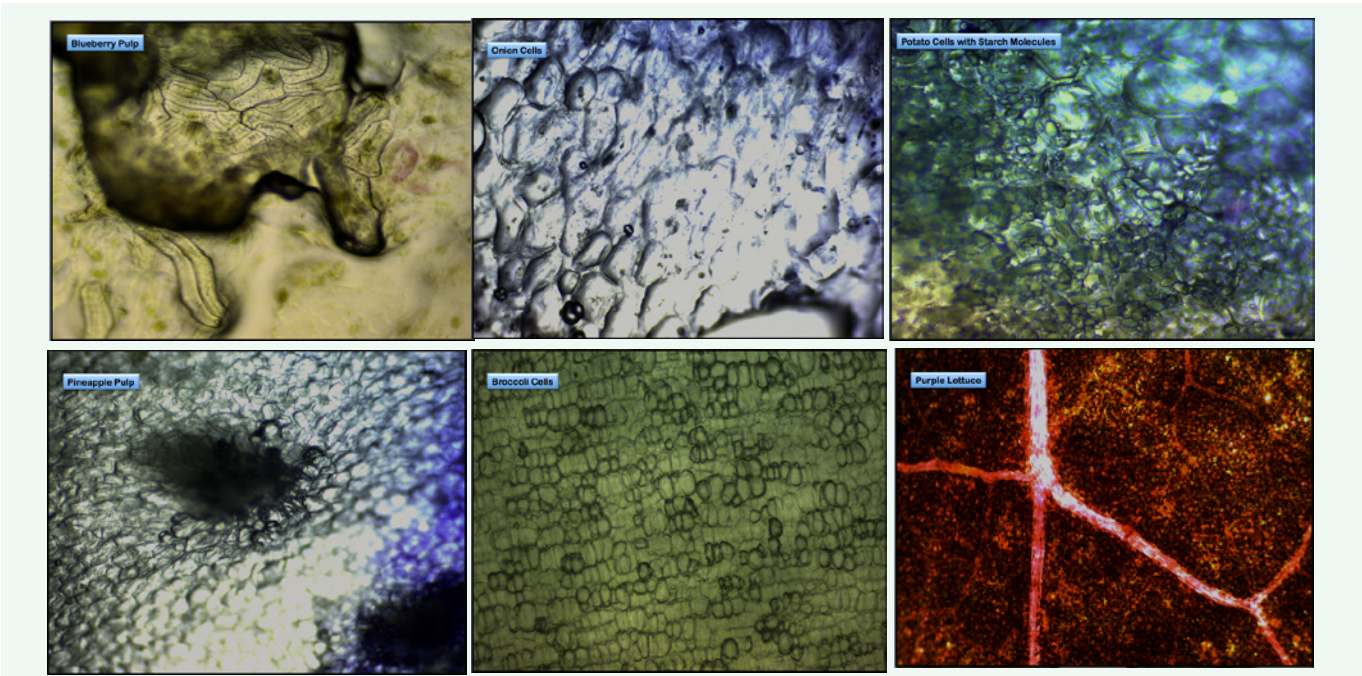


Table 1 Parenchyma Cells of Raw Fruits and Vegetables.
Image Source: Shannon C. Davis. Raw Food Plants: (Top Left-Bottom) fresh blueberry pulp, new potato cells with starch molecules and fresh broccoli cells. (Top Right-Bottom); fresh onion, pineapple and purple leaf lettuce showing cell lined leaf veins in lighter pink. As indicated, the parenchyma cells of these fruits and vegetables in their natural state have observable cell wall structures and or nutrient molecules. Some are very tightly packed together, while others (e.g., pineapple, onion) are somewhat loosely packed and full of juice. Specimens were viewed using an OMax® 2000 Microscope with (x10) magnification eyepiece inserts. Images were obtained using OMax® (8mp) digital microscope camera and accompanying software.

and the contents. In some cases such as in dried fruit (e.g., cherry) the cell walls are no longer recognizable. As shown in the example of the potato, after frying the cell walls are clearly degraded, the starch molecules are no longer contained within the cell and it appears the cells fill with oil as suggested by the cells that took up the crystal violet stain (e.g., purple cells). The stewed carrot has also lost cell wall components noticeable as the orange beta-carotene pigments are scattered within the mix. In the stewed onion, it is clear to see the broken spiral fibrils and lacking cell walls. Specimens were viewed using an OMax® 2000 Microscope with (x10) magnification eyepiece inserts and then images were obtained using OMax® (8mp) digital microscope camera and accompanying software for use with PC and Mac computers.

Nutritional Needs of the Gut Microbiota

Archeological findings of widened molars and pronounced mandibles suggest that prehistoric humans consumed a diet of comprised mostly rugged plants, grains, seeds, tubers, roots and berries. However, as humans lack the natural enzymes to breakdown and extract the energy from the plant cells, the cornerstone of the human host-gut microbiota relationship, was and still is founded upon the ability of the gut microbiota to extract the energy from plant-based foods [20]. It is presently understood that insoluble plant fibers serve as the primary energy source for the gut microbiota, however other researchers proposed that each type of dietary fiber possess its own particular chemical profile, referred to as a *discrete structure* which is utilized by the gut microbiota for various metabolic functions. Ultimately, through Embden-Meyerhof-Parnas pathway and using a variety of carbohydrate hydrolyzing enzymes (CAZymes),

the gut microbiota ferment the plant fibers to produce pyruvate and end products of gaseous byproducts, lactate, as well as short-chain fatty acids (*butyrate, acetate and propionate*). These fatty acids are key cellular energy molecules used by both the gut microbiota and human cells [21].

Human studies have shown that consumption of a diet high in fresh fruits, vegetables, and legume type fiber is associated with a greater diversity of species constituting the gut microbiota populations and increased gut microbiota diversity is in turn associated with population and human health. Alternately, the consumption of a Westernized diet type imparts the opposite effect [22]. Within the past decade, researchers have reported that diet type, especially one high in processed foods, more so than the genotype of the individual influences the selection for specific species of the gut microbiota. As an individual continues to consume processed foods, a disorder known as *gut microbiome dysbiosis* occurring as result of the dietary induced changes upon of the microbial species [23,24]. Therefore, it is apparent that increasing the amount of natural plant fiber and decreasing the intake of processed and over cooked plant foods, is beneficial to the human host and gut microbiota [25,26].

Healthy Diet for Gut Microbiota and Human Host

The National Institutes of Health recommends consumption of (20-35 grams) of dietary fiber daily based upon an adult diet of 2000 calories. Currently Americans consume only about (15 g/day). As their main fiber source, Americans consume mainly potatoes, refined flours and refined grains, compared to fresh fruits, nuts, legumes and leafy vegetables mainly consumed

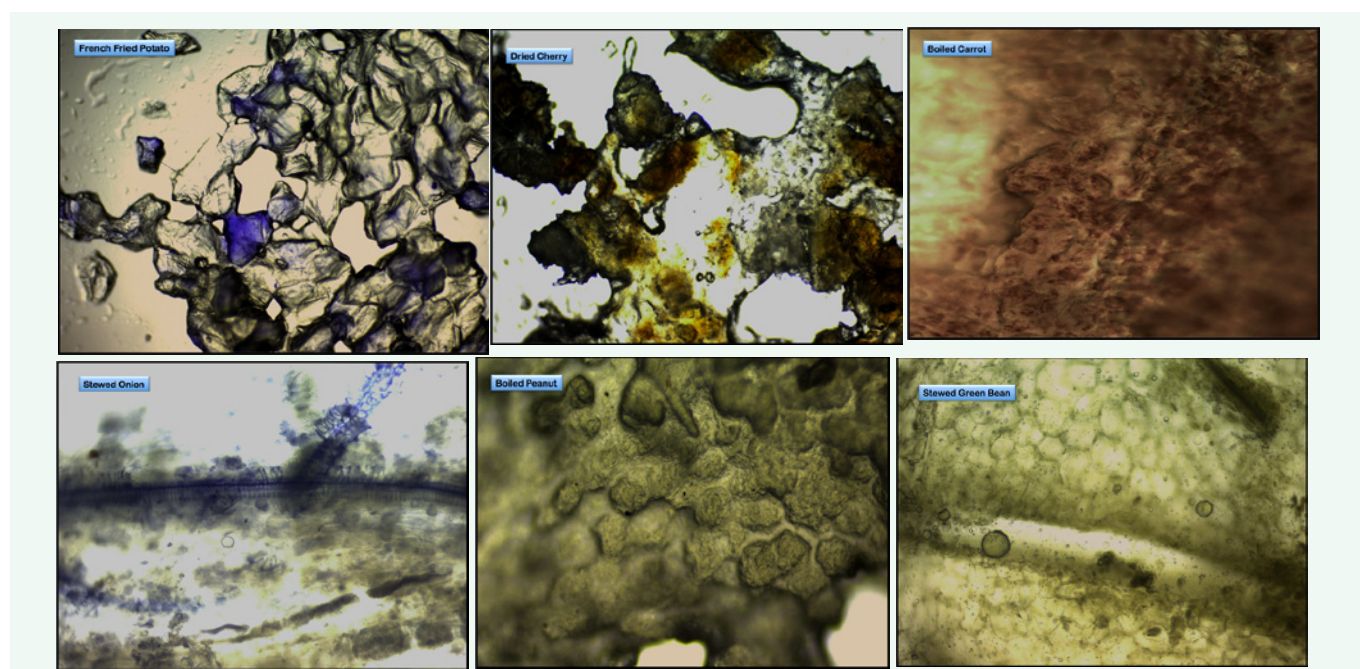


Table 2 Parenchyma Cells of Cooked Fruits and Vegetables.

Image Source: Shannon C. Davis. Cooked Food Plants: (Top Left-Bottom); French fried potato, boiled carrot, and boiled peanut. (Top Right-Bottom); dried cherry, stewed onion showing broken fibrous coils, and stewed green bean with fragile cell walls. In comparison with plant examples in (Table 1), these show marked differences in cell wall structures, such as the dried cherry where intact cells were not detectable. In the example of the carrot it is easy to see how cooking releases the internal cellular nutrients (e.g., beta carotenes) as the cell lyses. Specimens were viewed using an OMax® 2000 Microscope with (x10) magnification eyepiece inserts; images were obtained using OMax® (8mp) digital microscope camera.

in European countries [27]. For every (100g) of fermented dietary fiber, (~30g) of gut microbiota bacteria are produced leading to increased population diversity. Increasing the intake of natural (raw or minimally cooked) insoluble dietary fiber increases the gut transit time, the fermentation rate of the gut microbiota and ultimately the concentration of short-chain fatty acid production [28]. Depending upon the species dynamics of the gut microbiota, diet type and substrate availability, the gut microbiota can ferment (100%) oligosaccharides, inulin, pectin, gums and resistant starch, (>50%) of insoluble wheat brans, (60-90%) hemicelluloses and (20-80%) of cellulose fibers [29]. The dynamics of insoluble and soluble fiber fermentation were recently investigated, providing evidence that gut microbiota are highly efficient at extracting energy from insoluble fibers using (51.0%) of all chicory root pulp carbohydrate after 24 hours of fermentation. However, the population will utilize the more easily obtainable soluble dietary first. These are important considerations for those consuming a Westernized diet as it is reported that such diet type, in conjunction with an intake of soluble fiber results in an excess of dietary energy for the gut microbiota and ultimately chronic weight gain for the human host [30].

National nutritional guidelines provided by the Centers for Disease Control suggest increasing the intake of dark-green vegetables, fruits, other vegetables, beans, grains, nuts and variety of proteins including more seafood. Furthermore, the organization suggests reducing the intake of sodium, fats, and trans-fats [31]. Since the time of the first official dietary guidelines, the defining characteristics of a healthy diet have been defined solely in terms of the human being. Therefore, considering that gut microbiota utilize insoluble and soluble dietary fibers in different ways and the fact that the majority of United States residents consume a Westernized diet type, it is beneficial to revitalize national dietary recommendations to specifically include the nutritional needs of the gut microbiota as well as address the over consumption of processed foods. While national guidelines have changed from the food pyramid to a portion control model to represent daily nutritional needs, it is the opinion of the authors that the pyramid model is one more conducive to representing the nutritional needs of both the human host and gut microbiota.

As depicted in (Figure 2), we propose an example of such food pyramid based on current national guidelines. As shown, the base of the pyramid constitutes the foods that should constitute the largest proportion of the diet. Moving up the pyramid, the consumption of the foods included at each level decreases. At the top of lies fatty, meats, processed foods and refined sugar. Because physical activity is as important as consuming a fresh diet in terms of human health, it is also included within the pyramid as part of a daily nutrition regime.

CONCLUSION

It is well known that more Americans are consuming a Westernized diet type and many consume less than the recommended daily amount of dietary fiber. As such, there is a need for redefining what is meant by a *healthy diet* in terms of fresh foods compared to processed foods. Additionally, as the global demand for food increases it is inevitable that large-scale

food processing technologies will be in demand. Therefore, it is important for physicians and dietitians to consider the effects of food processing and to help patients understand that in terms of their health and that of the gut microbiota, a diet consisting of fresh, raw fruits and vegetable or those that are minimally cooked (e.g., grilled, roasted) is more beneficial than a diet consisting of canned fruits and vegetables as these products generally contain added salt, sugar, chemical preservatives, and are lower in vitamin and natural fiber content. Additionally, it is important for patients to understand the different types of fiber (*soluble* compared to *insoluble*) and that increasing their intake of soluble fiber along with the continued consumption of a Westernized diet, has the propensity to cause dietary induced *gut microbiome dysbiosis*, which manifests as chronic weight gain [32]. Through this commentary, we have provided dietitians and primary care physicians with a food pyramid guide based upon the nutritional needs of humans as well as their residential gut microbiota. It is our hope such guide and information will assist physicians in their understandings of the Westernized diet as well as those of regarding the health of the gut microbiota.

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