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PALEO DIET RESEARCH

Prebiotic fiber, and why the "Just Eat Real Food" mantra isn't as good as you think.

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KETOGENIC DIET RESEARCH

Prebiotic fiber, and why the "Just Eat Real Food" mantra isn't as good as you think.

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Abstract

1) Despite the healthful influence prebiotic fiber can have on reducing the risk of chronic disease, the intake remains low in many populations worldwide, in particular in the U.S.A.
2) It is extremely difficult to get 30-50 grams of fiber per day with commonly available, whole foods.
3) Hydrocolloids and food gums represent *healthy*, functional ingredients.
4) Packaged foods containing hydrocolloid stabilizers offer the greatest potential to improving soluble fiber intake in the U.S.A.

KEYWORDS
Prebiotics, Hydrocolloids, Molecular Weight, Polysaccharides, Functional Ingredients, Functional Foods, Resistant Starch, Fiber.

1 | BACKGROUND

Prebiotics are specialized fibers that beneficially nourish the good bacteria already in the large bowel or colon. When prebiotics are used to ncrease commensal bacterial species such as Bifidobacteria or Lactobacilli toward being the numerically predominant genus in the colon, improved colonization resistance results.

These probiotic species are beneficial microorganisms because species within these groups have been reported to exert therapeutic and prophylactic influences on human health [1]. In this way, prebiotic compounds are able to modulate both the luminal and mucosal microbial composition and activities, and beneficially regulate host-microbe interactions.

Moreover, these changes in the gut microbiota composition (especially the number of Bifidobacteria), contribute to the modulation of metabolic processes associated with common metabolic conditions, such as cardiovascular disease, obesity, and type 2 diabetes [2]. Or, in the simplest terms possible, a prebiotic is a "selectively fermented ingredient that allows specific changes, both in the composition and/or activity in the gastrointestinal microflora that confers benefits upon host well-being and health" [3].

The three criteria of prebiotics are that they must be: (a) Resistant to gastric acids, hydrolysis by mammalian enzymes, and gastrointestinal absorption; (b) Fermented by large intestinal microflora, and; (c) Selective stimulation of the growth and/or activity of intestinal bacteria associated with health and well-being.

2 | PREBIOTICS

The concept of prebiotics has attracted much attention, stimulating scientific as well as commercial interest— and for a good reason. However, of note, some prebiotics receive less interest than they deserve, and are often maligned in health communities.

While studies exploring the benefits of dietary fructooligosaccharides (FOS) and galactooligosaccharides (GOS) dominate the scientific literature in the field of prebiotics, a variety of other carbohydrates also show unique promise. These include a wide range of carbohydrate structures from small sugars such as lactulose, as well as various other oligosaccharides, polysaccharides, and resistant starches.

The non-digestible carbohydrates may be broken down into groups, and include Resistant Starch, Non-Digestible Oligosaccharides, and Non-Digestible Polysaccharides.

RESISTANT STARCH

As the name suggests, resistant starch is an insoluble starch that is resistant to hydrolysis. They are lower in molecular weight and are relatively short-chain carbohydrates. Resistant starch is selectively fermented by a wide range of colonic bacterial species including members of the Bacteroides spp., Eubacterium spp. Bifidobacteria, and lactobacilli [4-5].

Types of Resistant starch: There are four main types of resistant starch which vary in structure and source. RS1 refers to starch that is physically encapsulated in food, for example, in a fiber mesh or thick cell wall that is unavailable to enzymes. RS2 is a naturally resistant starch due to its crystallinity or dehydrated nature. RS3 is derived from heating and cooling of gelatinized starch. RS4 has been chemically modified, which may include the formation of cross-linkages and esterification [4-5].

Natural Sources of RS: (grams of RS per 100g of food) [6] :

- Oats, Rolled Uncooked 11.3
- Puffed wheat 6.2
- Pumpernickel bread 4.5
- Rice Square Cereal 4.3
- Bananas, Raw 4.0
- Italian bread, toasted 3.8
- Potato Chips 3.5
- Plantain cooked 3.5
- Cornflakes 3.2
- Rye bread, wholemeal 3.2
- Tortillas, corn 3.0
- Pizza dough baked 2.8
- Breadsticks, hard 2.3

Discussion: The top sources of resistant starch in the American diet are breads, cereals, pastas, and non-leguminous vegetables. These contribute to 21%, 19%, and 19% of the total resistant starch intake, respectively. High levels of resistant starch are naturally found in uncooked rolled oats (7-14% of the total content), cooked and cooled potatoes (19% of the total content).

However, more processed forms of resistant starch, like potato starch and corn starch, equate to roughly 66-80% of the material content [6].

Intakes of as little as 6 to 12 grams of resistant starch per meal have been observed to have beneficial effects. These include improving the glycemic control in diabetes, reductions in postprandial glucose and insulin levels, and a potential decrease in the risk for the development of diabetes [7].

However, studies indicate that Americans aged 1 year and older were estimated to consume approximately 4.9 g resistant starch per day when the recommended intake for RS is between 30-50g per day [6]. Americans intakes of RS are considerably low, and efforts should be made to consume more RS-rich foods. Alternatively, scientists have proposed that commercial goods fortified with resistant starch and other forms of prebiotics as a "functional food ingredient" offer a unique solution to help more Americans get the RS they need to see the associated benefits [8].

PREBIOTIC OLIGOSACCHARIDES

Lower molecular weight oligosaccharides are relatively short-chain carbohydrates that occur widely in nature. They are typically found in plants but have also been found in human milk and the colostrum of various animals in smaller quantities.

The main types of non-digestible oligosaccharides are fructooligosaccharides (FOS), galactooligosaccharides (GOS), xylooligosaccharides (XOS), isomaltooligosaccharides (IMO) and lactulose. Culture fermentations with human fecal bacteria have shown that FOS, GOS, XOS, IMO, and lactulose alter the microflora, increasing the level of bifidobacteria and/or lactobacilli, causing harmful clostridia and Bacteroides to decline [8].

These low molecular weight compounds are able to withstand digestive processes before they reach the colon, imparting a prebiotic effect. They have been found to effectively stimulate the growth of a limited number of bacteria, leading to a change in the overall microbial balance in the colon [9].

Oligosaccharide Characteristics and Differences [9] :

- Xylooligosaccharides and lactulose produce the highest number of bifidobacteria.
- Fructooligosaccharides produce the highest populations of lactobacilli.
- Galactooligosaccharides resulted in the greatest decrease in clostridia.
- Short Chain Fatty Acids (SCFAs) were produced the most by lactulose and GOS.
- Gas was produced the most by Inulin.
- Isomaltosaccharides and GOS increased bifidobacteria, producing the least gas

Natural Sources (Percent of oligosaccharides in total fresh content) [10-11] :

- Chicory roots 15-24
- Jerusalem artichoke 16-22
- Dandelion 12-15
- Dahlia 13
- Globe Artichoke 3-10
- Salsify 4-11
- Onions 1.1 – 7.5
- Burdock 3.6
- Garlic 1-16
- Leek 2-10
- Wheat 0.8 – 4.0
- Rye 0.5 – 1.0
- Banana 0.3 – 0.7

Discussion: Results from various studies support the potential of oligosaccharide prebiotics as a means to combat metabolic disorders and intestinal disorders [12]. They also provide evidence that supports the inclusion of supplementation through diet, and commercial products.

Not only are oligosaccharides metabolically beneficial, but the physiochemical properties of oligosaccharides may also have broad applications in commercial products, as they are 0.4 to 0.6 times as sweet as sucrose, have lower caloric value, and have been successfully and healthfully added as fortifications in human and animal experimental diets [13].

NON-DIGESTIBLE POLYSACCHARIDES (NDP)

Nondigestible polysaccharides are long, polymeric carbohydrate chains that contain up to several hundred thousand monomers. Each polysaccharide differs by types of monomeric units linked, types of linkages, the order of monomers in the chains, branch points in the molecular backbone, and presence of acid groups.

The consumption of NDP has been associated with fecal bulking, binding to other compounds, and the associated benefits of fermentation. These include attenuating blood glucose, maintaining gastrointestinal health, positively affecting the bioavailability of calcium and magnesium, and improving immune function. All the while, improving the rheological properties and nutritional value of foods [14].

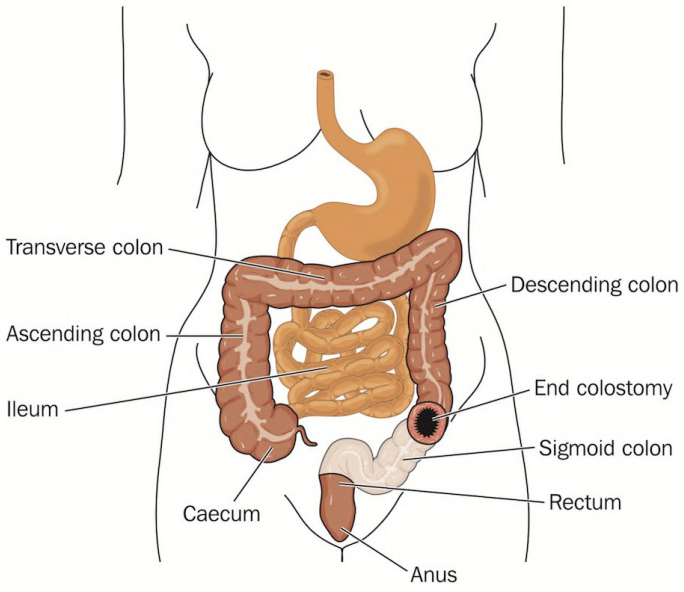
Common Sources of Non-Digestible Polysaccharides [15]:

- Cellulose
- Hemicellulose
- Polydextrose
- Beta-Glucans
- Pectins
- Mucilages
- Galactomannans
- Glucomannans
- Tree Resins
- Leguminous Gums
- Bacterial exopolysaccharides
- Seaweed polysaccharides
- Chitin, chitosan

While these non-digestible polysaccharide fibers do resist hydrolysis and gastrointestinal absorption and are fermented by intestinal flora, it is still essential that the fibers show that they are able to selectively stimulate the growth of commensal bacteria to improve the health and well-being of the host, to be considered as a prebiotic. While it has been found that these non-digestible polysaccharides do have prebiotic effects, the benefits they exert are remarkably different.

3 | ROLE OF MOLECULAR WEIGHT

The adult human gastrointestinal tract (GIT) is 9 meters or 29.5 feet from the esophagus to the anus. [**Figure 1**]. It is important to note that short-chain, low molecular weight monosaccharides and disaccharides are more easily fermented proximally in the gastrointestinal tract than their more resistant and complex, higher molecular weight, oligosaccharide or polysaccharide counterparts [16].

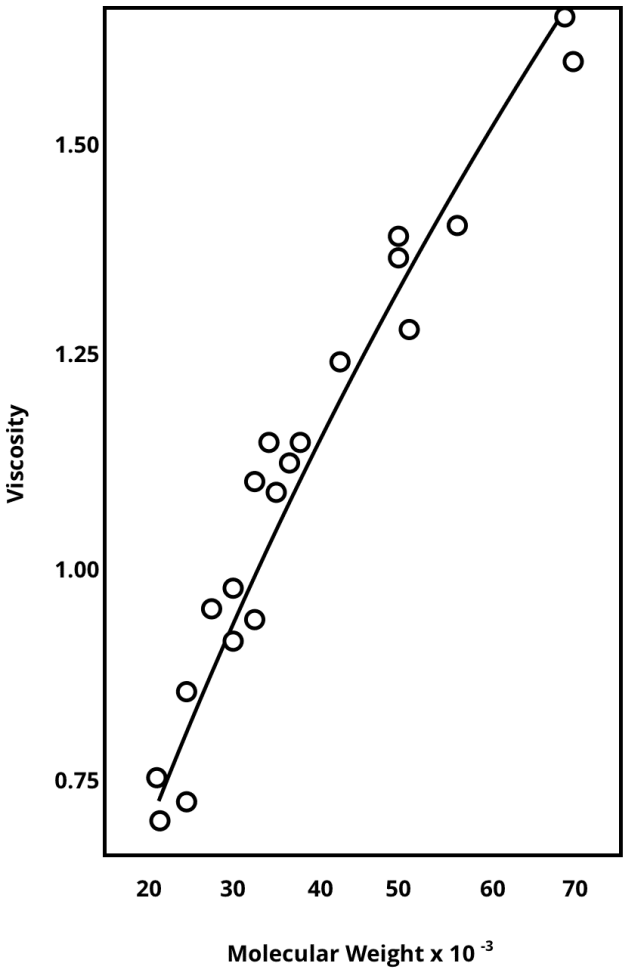


[Figure 1]. Adult Human Gastrointestinal Tract

While short-chain prebiotics have shown to impart benefits, the large, slowly fermented polysaccharides of higher molecular weight may have advantages over small, rapidly fermented sugars such as lactulose, and other non-digestible oligosaccharides. These include the ability to be tolerated at higher doses by consumers with reduced risk of side effects such as intestinal discomfort and flatulence caused by excessive gas formation; mucosal damage from rapid acidification; or the laxative effect of too high concentrations of small sugars in the colon [16].

And perhaps more importantly, high-molecular weight polysaccharides supply a persistent source of fermentable carbohydrate throughout the length of the colon rather than being completely fermented proximally.

This fact may be of particular interest in the prevention of certain types of diseases as well as colon cancer, as the distal colon and rectum are significant sites of inflammation and disease in humans [17].



[Figure 2]. Viscosity and Molecular Weight Correlation. Adapted from Reference 19.

4 | A NOVEL APPROACH TO PREBIOTIC SUPPLEMENTATION

We know that the fermentation of refined, and short-chain carbohydrates and oligosaccharides occur more proximally, whereas the more complex oligosaccharides and polysaccharides can be fermented distally [16]. We also know that a highly refined "Western Diet" high in saturated fat while lacking in complex carbohydrates is associated with several metabolic, and autoimmune diseases [18].

Carbohydrate complexity is associated with molecular weight. The lower the molecular weight, the shorter the chains. The higher the weight, the higher the number of linkages. However, the most complex polysaccharides with the highest molecular weight that are most often found in the diet are food-grade *hydrocolloids*.

The relationship between the molecular weight and complexity of an ingredient is highly correlated with its viscosity [19, Figure 2]. High molecular weight is an attractive feature of commercial hydrocolloids, or substances that form a gel in the presence of water.

High viscosity, high-molecular-weight, non-digestible, complex polysaccharides include pectins, arabinogalactans, b-glucans, inulin, mucilages, as well as bacterial gums like xanthan gum or gellan gum; tree gums, such as gum arabic, gum tragacanth, and gum ghatti; leguminous gums, such as guar gum and locust bean gum; as well as food-grade, water-soluble seaweed extracts, such as carrageenan, sodium alginate, and agar [15]. These ingredients aren't just dietary fibers, they are complex polysaccharides that have shown to impart prebiotic effects when consumed.

5 | AN ARGUMENT FOR PROCESSED, PACKAGED FOODS

Intakes of as little as 6 to 12 grams of prebiotics per meal have been observed to have beneficial effects. These include improving the glycemic control in diabetes, reductions on postprandial glucose and insulin levels, and a potential decrease in the risk for the development of diabetes [20].

A recent meta-analyses pooled data from 185 publications of studies involving just under 135 million person-years, 58 clinical trials, and 4,635 adult participants. Of the randomized trials, pooled, higher intakes of dietary fiber were shown to reduce fat mass, and lower blood cholesterol and systolic blood pressure. These findings were also supported by cohort studies that reported that fiber intake was associated with reduced heart disease incidence, diabetes, and mortality.

Further, the study pointedly described that the effects were apparent in both the prospective studies and clinical trials when examining fiber from different foods described as prebiotic soluble fiber, and insoluble fiber.

Additionally, the data show support for dose-response relationships in significant reductions in all-cause mortality, total cancer deaths, total cardiovascular disease deaths, incidence of cardiovascular disease, stroke, and incidence of colorectal, breast, and esophageal cancers.

Given the consistency in findings between the trials and the dose-response relationships reported and the final results from the meta-analysis, there is ample support for the causal relationship of fiber intake on metabolic disease and not a consequence of confounding variables. [21]

While it is always preferred to provide the nutrients your body needs through whole, minimally processed, clean foods, this remains challenging to the average person.

Consider the following table, showing the amount of whole foods needed to meet 30-50 grams suggested prebiotic intake per day [**Table 1**] [22-23].

Food	Percent of Total Prebiotic Fiber	Daily Recommended Intake grams / ounces	Daily Recommended Intake Metric Cup conversion
Raw Chicory Root	65%	55.8 - 93.0 g 1.97 - 3.28 oz	½ cup - 1 cup
Raw Jerusalem Artichoke	31.5%	114 - 190 g 4.02 - 6.70 oz	¾ cup - 1 ¼ cups
Raw Dandelion Greens	24.3%	148.2 - 247.0 g 5.23 - 8.71 oz	2 ¾ cup, 4 ¾ cups
Raw Garlic	17.5%	205.8 - 343.0 g 7.23 - 12.10 oz	1 ½ cup - 2 ½ cups
Raw Leeks	11.7.%	307.8 - 513.0 g 10.86 - 18.10 oz	2 ½ cup - 2 ¾ cups
Raw Onion	8.6%	418.8 - 698.0 g 14.77- 24.62 oz	2 ¾ cup - 4 ¼ cups
Cooked Onions	5%	720-1200 g 25.4 - 43.33 oz	3 ½ cup - 5 ¾ cups
Raw Asparagus	5%	720-1200 g 25.4 - 43.33 oz	5 ½ cup - 9 cups
Raw Wheat Bran	5%	720-1200 g 25.4 - 43.33 oz	12 ¼ cup - 20 ½ cups
Baked Wheat Flour	4.8%	750 - 1250 g 26.46- 44.09 oz	6 ½ cup - 10 ½ cups

Table 1. Percent of total prebiotic content in various foods, and the amount of whole foods needed to meet 30-50 grams suggested prebiotic intake per day

While it would not be difficult to meet the daily recommended amount of prebiotic fiber by eating foods like chicory root or raw jerusalem artichoke regularly, most of these foods are either not largely available, or not eaten in quantities sufficient to meet prebiotic fiber targets in the American Diet.

In fact, the top sources of prebiotics in the average American diet are breads, cereals, pasta, and non-leguminous vegetables, respectively. [21, 24] From Table 1, it is evident that relatively large amounts of grains are necessary to meet daily prebiotic requirements, and the CDC reports huge gaps on the consumption of vegetables relative to the U.S. Dietary Guidelines. Further, initiatives aimed at increasing the consumption of vegetables by changing behaviors have been largely unsuccessful. [25]

Having such well-documented beneficial effects, how then, could the Average American increase their total prebiotic consumption sufficiently while eating highly recognizable and available food items?

Many scientists now propose that commercial goods fortified with resistant starches and hydrocolloids are may offer a unique solution to help more Americans get the prebiotic fiber they need in the diet to get the associated benefits. [26]

Table 2 shows the total amounts of prebiotic fiber from hydrocolloids and common starches that would be necessary to fulfill the daily requirements. As evidenced by Table 2, the amounts necessary are significantly less than required by the whole foods addressed in table 1.

Thus, in a 21st century food setting, adding "functional ingredients" such as those provided in Table 2 to shelf-stable, packaged, and *processed* foods have the potential to provide significantly more prebiotic fiber to the average individual than whole foods are currently able to.

Prebiotic Fiber	Percent of Total Prebiotic Fiber	Daily Recommended Intake grams / ounces	Daily Recommended Intake Metric Tablespoon (tbsp) Conversion
Glucommanan	100	30-50 grams/ day 1.05 – 1.07 oz/ day	1½ tbsp - 2 ¼ tbsp
Xanthan Gum	100	30-50 grams/ day 1.05 – 1.07 oz/ day	1½ tbsp - 2 ¼ tbsp
Isolated Inulin	100	30-50 grams/ day 1.05 – 1.07 oz/ day	1½ tbsp - 2 ¼ tbsp
Guar Gum	100	30-50 grams/ day 1.05 – 1.07 oz/ day	1½ tbsp - 2 ¼ tbsp
Gum Arabic	98.5	31-51 grams/ day 1.09 – 1.8oz/day	1½ tbsp - 2 ¼ tbsp
Resistant Maltodextrin	85	35-55 grams/ day 2.1 – 2.2 oz/day	1½ tbsp- 2 ½ tbsp
Potato Starch	75	40-67 grams/ day 1.41 – 2.36 oz/ day	1 ¾ tbsp - 3 tbsp

Table 2. Percent of total prebiotic content in various starches and hydrocolloids, and the amount of needed to meet 30-50 grams suggested prebiotic intake per day

FUNCTIONAL INGREDIENTS

According to the European Commission's Concerted Action on Functional Food Science in Europe (FUFOSE) , a food can be regarded as a "functional food" if it is satisfactorily demonstrated to beneficially affect one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either improved stage of health and well-being and/or reduction of risk of disease [27].

A functional food must remain food and it must demonstrate its effects in amounts that can normally be expected to be consumed in the diet. A functional food cannot be a pill or a capsule, but part of the normal food pattern.

The unique features of functional food are:

- being a conventional or everyday food;
- to be consumed as part of the normal diet;
- composed of naturally occurring components that may be in unnatural concentration or present in foods that would not normally supply them;
- having a positive effect on target function(s) beyond nutritive value/basic nutrition;
- and enhance well-being and health and/or reduce the risk of disease or provide health benefits so as to improve the quality of life including physical, psychological and behavioural performances and have authorised and scientifically validated claims.

Resistant starches, as well as the high viscosity hydrocolloids such as those mentioned in Table 2 have shown to elicit therapeutic, functional effects. Or, specifically, these prebiotic ingredients have shown to selectively ferment in a way that allows specific changes, both in the composition and/or activity in the gastrointestinal microflora that confers benefits upon host well-being and health [Table 3]

Further, the higher-viscosity hydrocolloids and starches are used in commercial foods as a means to improve shelf-life, taste, mouth-feel, consistency, and overall quality of everyday products. [28]

Thus, these attributes combined make resistant starches and hydrocolloids high-quality candidates for "functional foods" according to the FUFOSE definition, and should be considered a welcomed addition in the production of processed foods.

Prebiotic Fiber	Benefits
Glucommanan	Blunts postprandial glucose [29] Blunts insulin response to a meal [29] Reduces adiposity [29] Anti-tumor [30] Anti-viral [30]
Xanthan Gum	Lowers cholesterol [31] Improves Satiety [32, 33] Anti-cancer [34] Decrease blood sugar [33, 35, 36]. Improves Bowel Regularity [37]. Improves Dry Mouth [38, 39] Improves food safety in Dysphagia patients [40, 41] Improves Tooth Decay [42]* Immunostimulatory [43 , 44]
Isolated Inulin	Improves bowel regularity [45] Increases SCFA production [45] Immunomodulatory [46] Antiviral [46] Bifidogenic [47, 45] Increases Lactobacilli [47] Antioxidant and anti-inflammatory activity [47] Reduces tumor risk [47]
Guar Gum	Reduces Cholesterol [48] Reduces Appetite [48] Inhibits Glucose absorption [48] Aids in weight loss [49] ** Acutely reduces postprandial blood glucose [49] ** Reduces educing total serum cholesterol and triglycerides [49] ** Reduces diabetes risk [49] ** Antiobesigenic [49] **
Gum Arabic	Bifidogenic: [50-53] Selective, Distal fermentation [54] Increases SCFAs [55] Anti-diabetic [56, 57] Anti-obesigenic [57, 58] Nephroprotective [57, 59] Anti-cancer [59] Lower Cholesterol [60] Ulcerative Colitis Treatment [61]
Resistant Maltodextrin	Reduces Cholesterol [62] Maintains healthy intestinal regularity [63] Improves blood glucose levels [63] Improves serum lipids [63] Increases weight loss [64] Improves metabolic syndrome [65-68] Significantly improves glucose and lipid metabolism [69-71] Potential treatment for obesity [69-71]
Potato Starch	Enhances Intestinal Barrier protection [72] Reduced plasma tumor necrosis factor (TNF)-α, [72] Reduces interleukin (IL)-1β [72] Reduces endotoxin concentrations [72] Anti-inflammatory [72] Increases SCFA production [72] Modulaties microbiota composition [72] Reduce post-prandial glucose [73,74] Reduce post-prandial insulin [73,74]

Table 3. Health benefits associated with specific resistant starches and hydrocolloids.
* Examined benefits of fortification with hydrocolloid. ***Explicity supports fortification initiatives.*

While measurements of morbidity and mortality are key considerations for estimating the burden of disease in populations, they provide an incomplete picture of the total adverse impact of diet-related disease on human welfare, and economic burden.

It is estimated that the economic cost of the top five diet-related chronic diseases in the U.S.is over one *trillion* dollars per year [**Table 4**]. However, this estimation does not factor in the costs of the other diseases, or decline in gross domestic product (GDP).

Disease	Cost
Cardiovascular disease and stroke	$320.1 Billion [75]
Cancer	$173 Billion [76]
Diabetes	$327 Billion [77]
Obesity	$342.2 Billion [78]
Osteoporosis	$25 Billion [79]
Total	**$1187.3 (~ $1.2 Trillion)**

Table 4. Total estimated cost per year of cardiovascular disease, stroke, cancer, diabetes, obesity, and osteoporosis in the United States.

Even though a whole-foods based, balanced diet remains a key objective to prevent or reduce the risk of disease, the goal of optimizing nutrition aims at establishing optimized intake of food components which promote well-being and health, and reducing diet-related disease.

In that sense, the argument could be made that commercial foods offer one of the greatest, and largely untapped potential for optimizing nutrition.

It is clear that food-grade hydrocolloids and resistant starches encompass all main features of functional foods defined above, and have therapeutic potential for the top diet-related chronic diseases.

Further, because commercial foods offer a vehicle for the enhanced delivery of prebiotic fibers, it would be antithetical to the purpose of optimizing nutrition to dismiss them outright in the name of 'whole foods.'

Because diet-related diseases are costly and preventable, and because hydrocolloids and resistant starches are functional ingredients that show great potential in reducing all-cause mortality, food foritification in processed and packaged foods should be widely considered.

PREBIOTIC FORTIFICATION

Probably more than any other nutrient/food ingredient, prebiotics are essential to human (and mammalian) nutrition and, in the context of dietary guidelines, it should be considered to include a recommended daily intake.

The use of diet to fortify certain gut flora components is a popular current aspect of functional food sciences and prebiotics have a significant role. Some processed foods currently employ the use of certain prebiotics as a means to provide function to a product [**Table 5**].

However, it is likely possible to fortify almost all of the processed foods in the industry. Despite the inherent issues with highly processed foods, prebiotic fortification may impart significant benefits.

5 | DISCUSSION

Application	Functional Property
Yogurts and Desserts	Sugar replacement, texture and mouthfeel, fiber
Beverages	Sugar replacement, mouthfeel, foam stabilization
Breads	Fat or sugar replacement, improves texture, added fiber
Meat Products	Fat replacement, improves texture, increases product stability.
Cakes	Sugar replacement, increases moisture retention, enhances mouthfeel, gluten replacer, binding agent, source of fiber
Chocolate	Sugar replacement, enhances heat resistance
Ice cream	Sugar substitute, prevents crystal formation, improves texture and mouthfeel
Soups and sauces	Thickeners, sugar substitute
Confectionaries, and fillings	Used for gelling properties

Table 5. Common applications and functional properties of prebiotics in food.

SHINING A LIGHT ON PROCESSED FOODS

In the health food industry, it is widely recognized that highly refined foods are a major contributor to metabolic disease and as such, processed and refined foods are stigmatized. However, while this stigma may be deserved in a sense, it may be short-sighted if optimal health is the goal of the health food industry.

A recent landmark systematic reviews and meta-analyses that employed the data from 185 prospective studies, 58 clinical trials, 4,653 adult participants totaling to roughly 135 million person-years of data conclude that fiber, or lack thereof, plays the most significant role in non-communicable disease and all-cause mortality than any other factor.

While the findings of this study and numerous others are remarkable, these findings are not reflected by the trends of the health food industry that exceedingly promote low-carbohydrate, low-fat, or low-sugar products as opposed to foods that are high in fiber, or fortified with fiber.

While fiber fortification can occur with processed foods relatively easily in the form of functional ingredients and have the potential to be distributed to impoverished areas that are disproportionately suffering from metabolic disease, there are still many obstacles to the concept of processed foods benefitting health.

OBSTACLES TO ACCEPTANCE

The communication of health benefits and other physiological effects of hydrocolloids and resistant starches as functional foods remains a major challenge to the adoption of food fortification initiatives. This is likely because communication in nutrition generally comes from multiple sources with that are often contradictory or misleading. Or, there are deep-seated ideologies that serve as barriers to progress.

For example, the stigma against processed foods in the health food industry also includes negative beliefs about sugar and carbohydrates as the culprit of obesity. Although sugar and carbohydrate intake has decreased precipitously since the late 1990's, obesity is still on the rise [**Figure 3, 4**] [80]. This evidence suggests that sugar and carbohydrates may simply be the scapegoat of the health food industry, which grossly oversimplifies the true and complex nature of the obesity epidemic.

However, with rising healthcare costs and the socio-economic burden associated with preventable diet-related disease, the 'just eat real food' messaging that is most often driven by the health food industry may be the greatest obstacle of all.

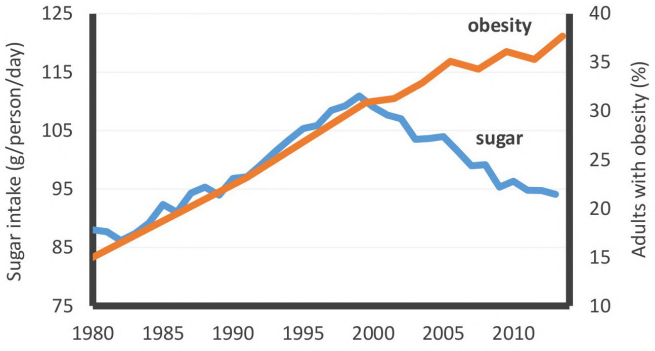


Figure 3. US Sugar Intake vs. Obesity Prevalence, 1980-2013. Source: USDA Economic Research Service, CDC NHANES surveys. Prepared by Stephan J. Guyenet.

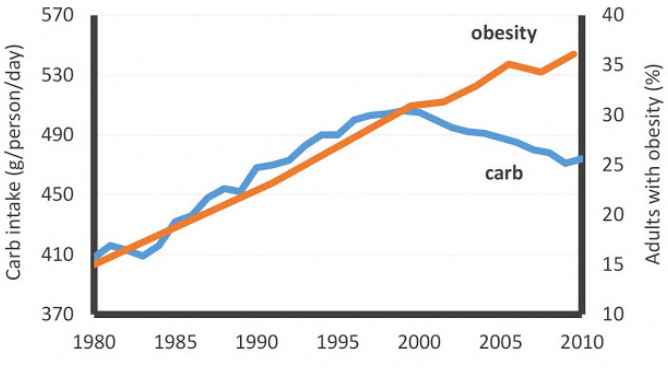


Figure 4. US Carbohydrate Intake vs. Obesity Prevalence, 1980-2010. Source: USDA Economic Research Service, CDC NHANES surveys. Prepared by Stephan J. Guyenet.

Despite the rigorous data that exist in favor of fortification initiatives, naturalistic and dogmatic sentiments regarding processed foods, sugar, and carbohydrates are deep-seated. These beliefs serve to obfuscate at best, and hinder at worst, the real opportunity that functional foods— processed or not— offer to achieving optimal health.

6 | CONFLICT OF INTEREST

The author reports no conflicts of interest.

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