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Chris Seal

Kathy Wiemer

Carbohydrate Quality: Exploring the Whole Story

Chris Seal and Kathy Wiemer
Guest Editors

Carbohydrate quality (Carb Q) has sparked lively debate in the nutrition world for several years. Many scientists focus on individual carbohydrate components (e.g., fiber, sugar, starch, whole grain) and their roles in diet and health but do not explore the multifaceted roles of carbohydrates. This issue of *Cereal Foods World* (*CFW*) explores Carb Q from a range of perspectives and tries to clear-up misconceptions about dietary carbohydrates and their varied roles in diet and health. Thought-provoking scientific reviews from leading carbohydrate scientists and communicators examine the complexities and nuances of the carbohydrate story—which are not as simple as some might believe.

On the one hand, carbohydrate foods are maligned as not important nutritionally because they generally require some form of processing to be edible, or in some cases, all carbohydrates are classified by consumers as sugars. These overly simplistic assumptions have led many consumers to believe that low-carbohydrate diets (i.e., high-fat or high-protein/low-carbohydrate diets) are healthier. Additionally, the anti-carbohydrate trend has been fueled by the gluten-free movement, which has also negatively affected consumer perceptions of grain-based foods.

From a scientific perspective, mounting evidence confirms the health benefits of whole grains and dietary fiber and, overall, provides a more complex and nuanced story about the role of carbohydrates in health.

Joanne Slavin's feature article, "Carbohydrate Quality: Who Gets to Decide?," sets the stage for this issue. Joanne provides a framework for defining dietary carbohydrates and their various roles in dietary patterns and human health. This broad, contextual review of various carbohydrate components raises key questions: how can Carb Q be evaluated and who should evaluate Carb Q?

Barbara Schneeman's feature article, "Role of Fiber in Carbohydrate Quality—Meeting Dietary Fiber Recommendations: What Counts?," reviews the evolution of the role of dietary fiber in the context of diet and health and how some countries have shifted the scientific basis for dietary fiber definitions from analytical methodologies to physiological endpoints and/or health benefits.

In their article, "Health Benefits and Recommendations for Daily Whole Grain Intake," Chris Seal and Frank Thielecke explore the value of consuming the "whole of the grain" to boost Carb Q. They show how the scientific evidence related to whole grains has evolved and address the challenges in defining whole grain and whole grain foods, specifically in relation to public policy and intake recommendations.

Luc Tappy's article, "Quality of Sugars and Sugar-Containing Foods," delves into free sugars and their role in diet and health, including an excellent description of how free sugars are metabolized. This article also highlights the difficulties in defining free and added sugars, which impacts how scientific evidence is interpreted and affects both industry and consumers.

Ndegwa Maina and Kati Katina show how manufacturing processes can modify the potential "quality" of carbohydrates in foods in their article, "Effects of Processing on the Functionality of Cereal Polysaccharides." This article illuminates the huge potential for manufacturers and product developers to leverage new technologies to improve Carb Q and potentially to market products based on better knowledge of carbohydrate functionality.

In the article, "Is Everyone Really on a Low-Carbohydrate Diet? Consumer Perceptions of Carbohydrates and Sugars," Allison Dostal Webster and Kris Sollid examine consumer attitudes toward carbohydrates. Consumer perceptions of carbohydrate components vary but are generally negative (except for whole grain and dietary fiber). This article clearly identifies the need for simple, accurate communications to convey critical facts about carbohydrates to improve consumer knowledge and awareness.

As cereal and nutrition scientists grapple with the complexity of distilling carbohydrate science into meaningful consumer messages, glycemic index (GI) sits in the middle of the debate. Upcoming point/counterpoint articles from Effie Viguiliouk et. al. and Julie Miller Jones dive into the controversy surrounding GI and glycemic load (GL) in building healthy diets. The point article argues that GI/GL should be used to build healthy diets, while the counterpoint article argues that there are significant issues with using GI/GL as the (sole) basis for selecting foods to build healthy diets. As a preview, the abstracts for these articles appear in this issue of *CFW*; the full articles will appear in the July-August 201 issue.

Both science and controversies influence how nutrition and health policies are formed in many countries. We hope that the articles in this issue of *CFW* will support the application of objective, sound scientific data to develop public policies, educate consumers, and guide industry about carbohydrates and health.

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Carbohydrate Quality: Who Gets to Decide?

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Defining Carbohydrate Quality

We all want quality—whether in our cars, our food, or our footwear. So, why not demand quality carbohydrates? The first question we must ask, however, is quality carbohydrates for whom?

In the United States carbohydrate recommendations are given in the Dietary Reference Intakes (DRIs) (5). The recommended dietary allowance (RDA) for carbohydrate is 130 g/day for adults and children aged 1 year or older. This recommendation is based on the amount of sugar and starches required to provide the brain with an adequate supply of glucose. The DRIs also include an acceptable macronutrient distribution range (AMDR): for carbohydrate the recommended range is 45–65% of total calories.

Sugars and starches provide glucose, the main energy source for the brain, central nervous system, and red blood cells. Glucose also can be stored as glycogen (animal starch) in the liver and muscles or, like all extra calories in the body, can be converted to fat. Dietary fibers are nondigestible forms of carbohydrate. Dietary fibers that are intrinsic and intact in plants help provide satiety and aid in laxation. Diets that are high in dietary fiber protect against several chronic diseases, especially coronary heart disease (CHD). In fact, the DRI for dietary fiber intake (14 g/1,000 kcal) is based on the protection dietary fiber has been shown to provide against CHD in large prospective cohort studies (5).

The energy content of digestible carbohydrates, which include sugars and starches, is 4 kcal/g. Carbohydrates that are not digested and absorbed in the upper gastrointestinal tract and not broken down in the colon (i.e., dietary fiber) are considered to yield no energy to the body. Thus, insoluble fibers are considered to provide no calories. Soluble dietary fibers may be fermented by the gut microbiota and yield short-chain fatty acids (SCFAs) in the gut. Because it yields SCFAs, fermentation of soluble fibers in the gut provides 2 kcal/g to the body.

Dietary guidance is based on the requirements of healthy adults who do not have diseases that require dietary restrictions. Thus, general dietary guidance, by design, must be broad and nonspecific. Conversely, advice can be given on specific foods, food groups, dietary patterns, and nutrients. Each of these approaches has its strengths and limitations. Even if we focus on high-quality carbohydrates for general dietary guidance, we must first determine what metrics to use to define what is a high-quality carbohydrate.

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Carbohydrates can be divided into food groups or chemical entities or by how they function in the body. Over time these divisions have shifted and created confusion in the carbohydrate field.

Certain high-carbohydrate foods are promoted in dietary guidance. For example, consumption of fruits and dairy products that are high in sugar and of grains, vegetables, and pulses that are high in starch and fiber is recommended. These starchy foods also contain protein, fat, vitamins, and minerals, which support their inclusion in dietary patterns.

Another categorical division for carbohydrates is based on chemical structure. Digestible carbohydrates can be divided into sugars and starches.

Sugars. Sugars in the diet are generally disaccharides such as sucrose or lactose (4). These sugars can come from recommended foods, including fruits and dairy products, or they can be added to food products as isolated sugars from sugarcane and sugar beets or as hydrolyzed starches from corn and other grains. Added (extrinsic) sugars are a source of extra calories in the diet, and dietary guidelines around the world recommend consumption of less added or extrinsic sugar (4).

Using these recommendations as a guide, grouping foods based on intrinsic versus extrinsic sugars sounds like a fair system for evaluating carbohydrate or sugar quality. However, other issues may cloud this grouping system. Dairy foods such as milk or yogurt contain intrinsic sugars but may also contain extrinsic sugar (e.g., chocolate milk or flavored yogurt). In addition, many systems for assigning intrinsic sugars do not include fruit juices, while others maintain that fruit juices do not count as added sugars as long as they are not used for sweetening purposes (4). Although fruit juices may contain the same amounts of vitamins and potassium as their whole fruit varieties, they also may be overconsumed in certain population groups. So, should fruit juices be listed as sources of "quality carbohydrate," or should they only be considered sources of "quality carbohydrate" if consumed during appropriate eating occasions and in appropriate amounts?

Further complicating recommendations, sugars provide properties in food product formulations beyond simply taste (1). As a result, strict rules for sugar removal from product formulations will affect not only flavor, but food safety, storage, and quality as well. Thus, removing added sugars from foods presents many challenges. There is also the question of whether alternatives to added sugars are always higher quality carbohydrates? The answer is not necessarily. Furthermore, many alternative sweeteners are not carbohydrates, so where do they fall on a list of "quality carbohydrates"?

Starches. Starches are long carbohydrate chains of glucose that are readily digested and absorbed. Glycemic response for starches is typically faster than for sugars because glucose is more readily absorbed than fructose from sucrose. Thus, although consumers talk about a "sugar rush," a "starch rush" might be a more appropriate way to think about glycemic response. Of course, not all starches are the same: long-chain amylose is more slowly digested and absorbed than branched-chain amylopectin. Animals, including humans, store glucose in their muscles and liver in the form of glycogen (animal starch). This glucose provides quick energy as needed but is in short supply in the body.

Starches can also be resistant to digestion and absorption in the body. Resistant starches can occur naturally in foods (e.g., raw bananas) or can be produced by chemical or other processing techniques to make a starch resistant to digestion and absorption. Further, certain varieties of corn (e.g., high-amylose corn) are higher in resistant starch than others. Although resistant starch may differ from dietary fiber in some of its properties, it is typically included as dietary fiber on food labels.

Dietary Fiber. Another way to assess carbohydrate quality is digestibility and absorption. Dietary fibers are not digested and absorbed in the gut but may be fermented in the large intestine. This fermentation process produces SCFAs, lowers gut pH, and alters the gut microbiota. All of these changes may have health benefits (7).

Too much fermentation in the gut, however, can cause intestinal gas and other symptoms that are unacceptable to consumers (2). A common challenge in promoting a high-fiber diet is the common consumer perception that it will cause intestinal gas.

Methods to measure the fate of different dietary fibers in the body are quite limited. So, although we can measure the fiber content of a food product, it is not possible to define one biomarker for testing the physiological effect of fiber in the gut. We know that dietary fibers play a role in the prevention of heart disease and diabetes and in bowel health, but because fibers differ widely in their effects in the body, we have no universally accepted biomarker to test for the effects of fiber in the human body.

In the United States, health claims (i.e., disease risk reduction claims) are allowed for oat bran, barley bran, and psyllium based on their ability to lower serum cholesterol levels. There is scientific consensus that these fibers have health benefits. Many fiber supplements are also accepted as laxatives that can be purchased without a prescription, yet we have not identified a biomarker that can be used to document that fibers play a role in bowel health.

In providing recommendations for carbohydrates and carbohydrate quality, we will no doubt continue to use a combination of chemical attributes, including total carbohydrate, sugars, and dietary fiber, while moving toward identifying more attributes based on what happens to the carbohydrate in the digestive tract. This also has applications for low-digestible carbohydrates (carbohydrates that are incompletely or not absorbed in the small intestine but are at least partly fermented by bacteria in the large intestine), such as polyols (2). For example, low-digestible carbohydrates may be quality carbohydrates for consumers who need more fiber in their diet, but may not be quality carbohydrates for patients with irritable bowel syndrome (IBS).

Prebiotics might also be listed as quality carbohydrates (7). A prebiotic is a substrate that is selectively utilized by host microorganisms and confers a health benefit. Most prebiotics are carbohydrates (i.e., dietary fibers) and should be considered candidates for designation as "quality carbohydrate."

Ways to Help Consumers Select Quality Carbohydrates

One role of dietitians is to design diets that provide specific information about the carbohydrate load of a diet. Useful tools exist, including the carbohydrate exchange system, that provide information on the digestible carbohydrate, from sugar or starch, that is provided by the exchange of a food. This system is known as carbohydrate counting and is an essential tool used by diabetics to control their blood sugar by monitoring their intake of digestible carbohydrates. Using carbohydrate exchanges to control digestible carbohydrate intake works well because different food groups provide different amounts of digestible carbohydrate. For example, each starch serving (e.g., 1/2 cup of pasta, 1/2 cup of potatoes, 1 slice of bread) provides 15 g of carbohydrate. Each fruit serving (e.g., 1 small apple, peach, or pear or 1/2 banana) provides 15 g of carbohydrate. Each milk serving (e.g., 1 cup of milk or yogurt) provides 12 g of carbohydrate. Vegetables, except for starchy vegetables, are low in carbohydrate, with a 1/2 cup of cooked vegetables or 1 cup of raw vegetables containing 5 g of carbohydrate. It might be argued that this system only provides information on carbohydrate quantity, not quality, but it is noteworthy that all of these foods are included in dietary guidance.

Perhaps the first way to insert quality into the equation is to select foods that are higher in dietary fiber. Fiber recommendations on the revised Nutrition Facts panel list 28 g of fiber as the recommended amount in the U.S. diet, based on fiber recommendations for 2,000 kcal/day (14 g/1,000 kcal). Fiber intake in the United States currently is only about half the recommended levels, so to support carbohydrate quality, we should support choosing recommended foods with the highest fiber contents. Recommendations for grains (6), pulses (3), and vegetables and whole fruits (8) would increase both the fiber content of the diet and its carbohydrate quality.

Carbohydrate-rich foods are also the most sustainable foods in our diets and the least expensive. In addition to fiber, recommended carbohydrate-rich foods supply other nutrients. Dairy foods provide calcium, vitamin D, and high-quality protein—nutrients that are lacking in many U.S. diets. Fruits and vegetables provide potassium, which is another nutrient of concern in U.S. diets. Whole grains provide minerals and vitamins.

Because grains are relatively inexpensive, widely consumed, and stable when nutrients are added, they were a logical choice for nutrient additions in the U.S. diet. Enriched grains provide iron, thiamin, riboflavin, and niacin, and since 1998, refined grains are also fortified with folic acid, which is well absorbed and important for the prevention of neural tube defects.

Societies around the globe have incorporated carbohydrate staples as the foundations of their diets. Whether it is potatoes in Ireland, pasta in Italy, corn tortillas in Mexico, rice in Asia, or bread in France, we have all long-appreciated that carbohydrate-based staple foods are the foundation of our diet and should be promoted in dietary guidance for the masses.

Many clinical conditions require that individuals restrict carbohydrate intake to promote beneficial health outcomes. For example, lactose intake must be restricted for those with lactose intolerance, while diabetics must use carbohydrate exchange lists to monitor their digestible carbohydrate intake. Carbohydrates are often restricted in weight-loss diets—both as a means of cutting calories and to assist in more rapid weight loss. On the flip side, athletes consume large quantities of digestible carbohydrates to fuel their activities. Thus, carbohydrate recommendations must be tailored for the person and lifestyle and to address individual nutrition needs.

For healthy individuals, other proposed methods for rating "carbohydrate quality" provide more challenges than opportunities. For example, "net carbs" are often promoted in diabetes education. In this exercise consumers are instructed to subtract fiber amounts from total carbohydrate amounts to yield a net carb amount. Despite all efforts to provide factual information on the Nutrition Facts panel, total carbohydrate is determined "by difference," so this calculation for net carbs is likely not a good predictor of carbohydrate response.

Another example is glycemic index (GI) and glycemic load (GL), which have been used to predict health outcomes in epidemiological studies. Because fructose is more slowly absorbed than glucose, foods that are high in sugar have a lower GI, but they are not promoted in dietary guidance. Additionally, GI measurements are performed on individual foods. Because foods are generally eaten as mixtures, an individual GI may not be helpful. Thus, GI may be helpful in defining blood glucose response for diabetics but may not be helpful for delivering high-quality carbohydrates for other consumers.

Bottom Line on Carbohydrate Quality

We all want to be quality individuals and to consume quality carbohydrates. At the end of the day, however, our best measures for carbohydrate quality must be based on consuming an optimal quantity of digestible carbohydrates and making selections from the recommended food groups—whole grains, pulses, vegetables, nuts, fruits, and dairy. Within each of these food groups, high-fiber foods should be chosen often. Despite efforts to improve carbohydrate quality by promoting high-fiber foods, fiber intakes continue to be lower than recommended levels. Thus, different strategies to increase fiber consumption without increasing calorie consumption must be devised and delivered to consumers.

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Role of Fiber in Carbohydrate Quality—Meeting Dietary Fiber Recommendations: What Counts?

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To understand the contribution of dietary fiber to carbohydrate quality, it is useful to examine the definition of dietary fiber, how that definition has evolved, and what is currently accepted in recommendations for fiber intake by humans. Two aspects of dietary fiber have consistently emerged to define its quality and to provide a basis for recommendations for intake: fiber as a component of plant foods in the diet and fibers that have physiological effects that provide a health benefit.


Photo: Public Domain – National Institutes of Health

Early Definitions of Dietary Fiber

In early literature from the late 1800s and early 1900s fiber was identified as a component of carbohydrates in the diet and was characterized as cellulose or woody fibers (1). In these early evaluations of diet and nutrition, carbohydrates were primarily viewed as a source of energy and often regarded as less important in the diet than proteins or fats. However, in a 1917 guide on "How to Select Foods," Hunt and Atwater (8) state that fiber (cellulose) "gives bulk to the diet and may tend to prevent constipation… [and be] more satisfying to the appetite." The early characterization of fiber as cellulose was likely due to the use of a crude fiber method, which primarily measures cellulose, in food analysis. Cummings and Engineer (4) have published a review on the origins of the dietary fiber hypothesis in which they characterize the key steps in broadening our understanding of the complexity of dietary fiber and its contribution to health. The steps they characterize in this evolution include the work of McCance and Lawrence to identify the various carbohydrates, in addition to cellulose, that are associated with the plant cell wall and should be included as a component of fiber in the diet. In addition, the analytical work conducted by David Southgate to determine available carbohydrates (i.e., starches and sugars that are digested by enzymes in the human digestive tract) and unavailable carbohydrates (i.e., carbohydrates that are not digested by enzymes secreted in the human small intestine) created a framework to examine the carbohydrates associated with dietary fiber that are meaningful in human nutrition. The concept of the digestibility of carbohydrates in the small intestine of humans became integral to the definition of dietary fiber and was central to the dietary hypothesis presented by Burkitt and Trowell in 1975 (2). Their definition states that "Dietary fibre has been defined as the remnants of the plant cell-wall that are not hydrolysed by the alimentary enzymes of man…. It is composed largely of celluloses, hemicelluloses, and lignin…. Dietary fibre is not the same as crude fibre…" (2).

This early work in defining dietary fiber resulted in the establishment of two elements of quality for dietary fibers: the association with plant cell walls and lack of digestibility in the human small intestine. In addition, the early definition of dietary fiber and the development of the dietary fiber hypothesis related to disease established a link between plant foods and dietary fiber consumption. As a consequence, most recommendations on fiber intake have emphasized the importance of consuming fiber from plant foods.

Updating the Definition of Dietary Fiber

The dietary fiber hypothesis put forward by Burkitt and Trowell (2) stimulated research to understand the impact of dietary fiber on health promotion and disease prevention and to determine whether dietary fibers have unique properties that affect human physiology and metabolism or whether they primarily serve as markers of a diet rich in plant foods. During this phase of research activity, several scientists observed that solubility was a potential way to characterize differences in various types of fibers. Fibers that were classified as soluble were characterized as swelling or dispersing in water, more likely to contribute to plasma cholesterol reduction and improved glycemic

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control, and highly fermentable in the large intestine. In contrast, insoluble fibers were characterized as not taking up water in the gastrointestinal tract, not readily degraded in the large intestine by microbial action, and more likely to improve laxation by increasing stool output. However, this categorization of fibers proved to be too simplistic for predicting the physiological effects of fibers, in part because various factors contribute to whether a fiber can be classified as soluble or insoluble, and most food sources contain a variety of fiber types (12).

In the Dietary Reference Intake (DRI) report for macronutrients, the Institute of Medicine (IOM) identifies viscosity and fermentability as two characteristics of fibers that are more likely to predict physiological effects associated with consuming dietary fiber that would result in health benefits (9). A review by McRorie and McKeown (12) summarizes the evidence that illustrates how these two characteristics (viscosity and fermentability) are associated with lowering blood lipids, improving glycemic control, and improving laxation. As outlined in their review, viscous soluble fibers, such as psyllium and β-glucan, are more likely to lower cholesterol concentrations and improve glycemic control, whereas low-viscosity or nonviscous, soluble fibers, such as methylcellulose or inulin, do not have this beneficial physiological effect. Likewise, insoluble fibers, such as those found in wheat bran, that are not extensively degraded by microbial action in the large bowel are more effective in improving laxation than fibers that are more completely fermented by microbes. McRorie and McKeown's analysis suggests that these characteristics of fibers are potentially useful indicators of quality; however, the fact that an analytical approach for accurately measuring these fiber properties has not been developed and standardized is a major limitation in using these characteristics (12).

The IOM approach, which influenced the regulatory process for defining dietary fiber in the United States, as well as the approaches taken by the Codex Alimentarious Commission and the European Union, have resulted in new definitions of fiber that extend beyond the association of fiber as a marker of a diet containing plant foods to include isolated and synthetic fibers that are ingredients in formulated foods or used as dietary supplements (3,6). These definitions, as summarized in Table I, introduce additional factors for understanding quality associated with dietary fiber. In this context, fibers that are intrinsic and intact in foods are considered, by their nature, to be dietary fiber and predominately include the fibers associated with the plant cell wall matrix. In addition, isolated or synthetic polysaccharides or oligosaccharides can be considered dietary fibers if they have been demonstrated to have a physiological effect that is of benefit to human health. These regulatory and standard-setting approaches to defining dietary fiber do not rely on the physical properties of fiber (i.e., viscosity or degree of fermentation) to define isolated and synthetic polysaccharides and oligosaccharides as dietary fibers, but instead rely on the part of the definition that focuses on a physiological effect that is beneficial to health. Examples of such benefits identified by the U.S. Food

Table I. Definitions of dietary fiber established by the Codex Alimentarious Commission, the European Union, and the U.S. Food and Drug Administration

Organization **Publication**	**Definition**
Codex Alimentarius Commission *Codex Guidelines on Nutrition Labelling, Section 2.8.* (CAC, 1985)	Dietary fibre means carbohydrate polymers[1] with ten or more monomeric units[2], which are not hydrolysed by the endogenous enzymes in the small intestine of humans and belong to the following categories: • Edible carbohydrate polymers naturally occurring in the food as consumed, • carbohydrate polymers, which have been obtained from food raw material by physical, enzymatic or chemical means and which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities, • synthetic carbohydrate polymers which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities [1] When derived from a plant origin, dietary fibre may include fractions of lignin and/or other compounds associated with polysaccharides in the plant cell walls. These compounds also may be measured by certain analytical method(s) for dietary fibre. However, such compounds are not included in the definition of dietary fibre if extracted and re-introduced into a food. [2] Decision on whether to include carbohydrates from 3 to 9 monomeric units should be left to national authorities.
European Union *Commission Directive 2008/100/EC of 28 October 2008 amending Council Directive 90/496/EEC on nutrition labelling for foodstuffs as regards recommended daily allowances, energy conversion factors and definitions.* (Off. J. EU 285(29.10.2008), pp. 9-12)	For the purposes of this Directive 'fibre' means 'carbohydrate polymers with three or more monomeric units, which are neither digested nor absorbed in the human small intestine and belong to the following categories: – edible carbohydrate polymers naturally occurring in the food as consumed; – edible carbohydrate polymers which have been obtained from food raw material by physical, enzymatic or chemical means and which have a beneficial physiological effect demonstrated by generally accepted scientific evidence; – edible synthetic carbohydrate polymers which have a beneficial physiological effect demonstrated by generally accepted scientific evidence.'
U.S. Food and Drug Administration *Code of Federal Regulations. 21 CFR 101.9 (c)(6)(i), Nutrition labeling of food.* (22)	Dietary fiber is defined as non-digestible soluble and insoluble carbohydrates (with 3 or more monomeric units), and lignin that are intrinsic and intact in plants; isolated or synthetic non-digestible carbohydrates (with 3 or more monomeric units) determined by FDA to have physiological effects that are beneficial to human health.

and Drug Administration (FDA) include lowering blood glucose or cholesterol levels, lowering blood pressure, increasing feelings of fullness (satiety) resulting in reduced calorie intake, increased mineral absorption in the intestinal tract, and improved laxation and bowel function (21). The FDA guidance indicates that only one benefit must be demonstrated to make a carbohydrate eligible to be considered as dietary fiber in a food. If scientific evidence is available, additional physiological endpoints that provide a health benefit can be added to the list. The FDA has provided draft guidance on scientific evaluation of the evidence that, outlining an approach that is consistent with how the FDA has evaluated scientific evidence for substantiating nutrition-related claims on packaged foods (20).

Recommendations for Dietary Fiber Intake

As our understanding of the contribution that fiber makes in a health-promoting diet has evolved, what is counted as contributing to fiber intake has been updated, and recommendations for fiber intake have progressed from qualitative recommendations concerning plant foods to quantitative recommendations based on the quality of the fiber sources related to physiological function and on reduced risk of certain chronic diseases.

In the early 1900s crude fiber was recognized as a component of plant foods that might have a benefit for gastrointestinal regularity but was not viewed as essential in the diet. The dietary fiber hypothesis put forward by Burkitt and Trowell (2) indicated that more research was needed to understand the metabolic effects of dietary fibers beyond simply providing roughage in the diet. In the United States the recommendations for fiber intake, which were established as a part of the development of Recommended Dietary Allowances (RDAs), now referred to as DRIs by the National Academies of Science, Engineering, and Medicine, reflect this evolution of the scientific basis for the importance of fiber intake. The RDA reports published between 1968 and 1980 included fiber in the category of complex carbohydrates (cellulose and hemicelluloses), which were not considered as an essential nutrient but as a preferred source of carbohydrate in the diet relative to sugars and refined starches (13–15, 17). The 1989 RDA report recognized the need to increase fiber intake, with an emphasis on dietary fiber from foods not fiber concentrates (17). The 1989 report was informed by diet and health reports published by the National Research Council (16) and the surgeon general (19), both of which highlighted the association of risk for chronic diseases with diets lacking in dietary fiber. The 2005 DRI report on macronutrients published by the IOM (9) reaffirmed that fiber is not considered an essential nutrient for which inadequate intake can be assessed based on biochemical or clinical symptoms but did recognize that a lack of fiber intake detracts from optimal health and examined scientific evidence to establish an adequate intake (AI) level (as defined in the report, an AI is an estimated intake needed to sustain a defined nutritional state used when it is not feasible to establish an RDA). By evaluating the scientific evidence on the effects of fiber on laxation and gastrointestinal function, normalizing blood cholesterol, or attenuating blood glucose responses, the IOM determined that an AI of 14 g/1,000 kcal could be recommended for fiber intake to reduce the risk of coronary heart disease (9). The European Food Safety Authority (EFSA) concluded that an adequate intake for dietary fiber could be established based on bowel function and recommended that 25 g/day in adults (or 2–3 g/MJ) is adequate for laxation (6). On a more global level, in 2003 the Food and Agriculture Organization of the United Nations and the World Health Organization (FAO/WHO) (24) established population goals for carbohydrates, including dietary fiber, of 55–75% of energy intake. Although FAO/WHO did not establish a population goal for dietary fiber, a food-based recommendation to consume 25 g of fiber/day from plant foods such as fruits, vegetables, and whole grains was established, and these recommendations were reaffirmed in the 2007 update on carbohydrate intake recommendations (10).

Conclusions

Two primary factors determine the quality of dietary fiber as a component of carbohydrate. One aspect of quality is based on dietary fiber as a component of plant foods. The importance of consuming plant foods for adequate fiber intake is typically a component of food-based dietary guidelines (FBDG), such as the *Dietary Guidelines for Americans* (18). FBDG from many different countries consistently recommend fruits, vegetables, legumes, and whole grains, and the justifications for such recommendations include their contribution to dietary fiber intake, as well as essential nutrients, and to dietary patterns associated with disease risk reduction and health promotion (7). Epidemiological studies have associated the intake of plant foods with lower risk of chronic diseases. However, based on observational data it is not feasible to establish a cause-and-effect relationship for fiber and specific chronic diseases. In the context of FBDG, the contribution of fiber to carbohydrate quality is based on the foods that are included in dietary patterns to meet fiber recommendations.

Several analytical approaches are possible to determine the fiber content that is intrinsic and intact in foods, as required for food composition databases and food labeling (5,11). However, the updated definition of dietary fiber has allowed a second approach for determining dietary fiber quality, which is to evaluate the physiological effects related to health benefits. As implemented, this second approach for defining dietary fiber requires a regulatory approach to evaluate the scientific evidence supporting the health benefits of a fiber source rather than an analytical methodology. As recognized in the final rule for updating Nutrition Facts labels in the United States, fibers for which a health claim has been approved (β-glucan soluble fiber and psyllium husk) can be included in the total fiber content of a food (23). In addition the FDA has stated that adequate scientific justification exists to consider cellulose, guar gum, pectin, locust bean gum, and hydroxypropylmethylcellulose as meeting the dietary fiber definition and is in the process of considering evidence for an additional 26 isolated and synthetic nondigestible carbohydrates (20). If an isolated or synthetic nondigestible carbohydrate is considered as a dietary fiber, then AOAC methodology can be used to estimate the total fiber content of foods that contain the fiber (11). However, any analysis of the total fiber content of foods will need to be corrected for any isolated or synthetic nondigestible carbohydrates used as ingredients that are not considered dietary fiber because they have not been demonstrated to have a physiological effect beneficial to human health.

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Health Benefits and Recommendations for Daily Whole Grain Intake

Chris J. Seal[1,2] *and Frank Thielecke*[3]

ABSTRACT

Cereals are staple foods in the diet of many populations, and they are essential sources of carbohydrate energy, protein, dietary fiber, and numerous phytochemicals and micronutrients. Retaining all of these components in the form of whole grains and whole grain foods improves the quality of the diet, and there is strong evidence, especially from observational studies, that consumption of whole grains results in health benefits. Increasing whole grain consumption is, therefore, a target for health organizations, with recommendations for intake proposed in many countries. However, intake remains universally low, except in some Northern European countries, and so new strategies and partnerships between industry and health agencies are needed to promote whole grain consumption. Consolidating definitions for whole grain and whole grain foods is an important initial step to better inform consumers and encourage the development of new whole grain foods by industry.

Whole grains, and foods made from them, are recommended for consumption as replacements for foods made from refined grains, because they provide greater carbohydrate quality. In particular, whole grains have a higher fiber content compared with refined grains, as well as delivering a multitude of micronutrients and phytochemicals associated with the bran and germ into the diet. There is considerable evidence showing that people who consume more whole grains have a lower risk of some chronic diseases, and they are less likely to be overweight than people who consume the least amount of whole grains. Some, but not all, health agencies encourage whole grain consumption; the benefits of whole grains should be broadcast more widely to encourage their consumption and improve diet quality and health.

The invention of the roller mill during the industrial revolution contributed to many advances in food manufacturing processes. Roller milling was cheaper and faster than stone grinding of cereals, and the market for white (refined) flours rapidly outgrew that of wholemeal flours. White flour was thought to be purer and was more popular with consumers than wholemeal flour. White flour also had a longer shelf life because of its lower oil content and was easier to use in large-scale bakeries. The result was a complete transformation in the food supply chain, where refined white flours became the dominant staple cereal product at the expense of wholemeal flours. The nutritional consequences of using refined rather than wholemeal flours were not immediately obvious, and it took some time before fortification of white flour was mandated in some countries to replace some of the minerals and vitamins lost during the refining process. In general, wholemeal flours are richer in dietary fiber, protein, micro- and macronutrients, and phytochemicals but are lower in total carbohydrate. The debate continues today, with international panels debating the merits of folate and vitamin D supplementation of refined flour, for example.

Evidence for Health Benefits of Whole Grains

Observational Studies. During the latter part of the 20th century research highlighting the benefits of consuming whole grain foods started to appear in the nutrition literature. What started as a slow realization has become a global movement supported by a steady and rapid increase in publications investigating the positive relationships between whole grain intake and improved markers of health. These studies fall into two categories—those based on observational studies (epidemiological studies) and those based on dietary interventions (13). The former continue to provide the most convincing evidence, showing strong and consistent associations between higher whole grain intake and improved indicators of health. These indicators include risk of chronic disease incidence and death from chronic diseases, as well as biomarkers of health (e.g., blood lipid profile, blood pressure, inflammatory status).

These observational studies stem from the largest long-running cohort studies and have been subjected to many systematic reviews and meta-analyses. One of the largest and most recent studies investigating all-cause, cardiovascular disease (CVD) and cancer mortality in a meta-regression analysis is that from Benisi-Kohansal et al. (3), who included data from 20 prospective cohort studies with more than 2.2 million participants covering between 5.5 and 26 years of follow-up. The results showed strong inverse associations between higher whole grain and whole grain food intakes and lower risk of all-cause mortality during follow-up in the meta-analysis. The pooled relative risk (RR) for all-cause mortality for an increase of 3 servings of total whole grain foods/day (90 g/day) was 0.83 (95% CI: 0.79, 0.88). Similar RR values were obtained for risk of mortality from CVD for total whole grain intake (RR = 0.84; 95% CI: 0.76, 0.93) and specific whole grain foods (RR = 0.82; 95% CI: 0.75, 0.90); there was a 25% lower risk of mortality from CVD for each additional 3 servings of total whole grains/day. The associations with mortality from total cancers were less strong but nonetheless significant (RR = 0.94; 95% CI: 0.91, 0.98). So many meta-analyses have been performed that an "umbrella review" was recently published by McRae (10). The study identified 21 meta-analysis studies published between 1980 and 2016 (not including the study by Benisi-Kohansal et al. [3]) that described the effects of whole grain intake on type 2 diabetes, CVD, cancer, and weight loss. Every one of the meta-analyses reported positive benefits for reducing the incidence of type 2 diabetes (RR = 0.68–0.80), CVD (RR = 0.63–0.79), and gastrointestinal cancers (RR = 0.57–0.94), with a modest effect on body weight, body fat mass, and waist

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circumference. McRae (10) did identify problems with heterogeneity, publication bias, and quality assessment among the studies. The overall conclusion from the paper was that "there is some evidence for dietary whole grain intake to be beneficial" for the diseases described and that the "findings suggest that the consumption of 2 to 3 servings per day (≈45g/day) of whole grains may be a justifiable public health goal" (10).

As with almost any scientific approach, observational research has some shortcomings. Given its nature, it does not demonstrate causality. In addition, some (mainly) older epidemiological studies failed to properly report on whole grain food versus whole grain intake. This shortcoming may be due, in part, to food composition databases that lack the appropriate information. Despite considering a number of confounders in the various analyses, it cannot be ruled out that the beneficial effects of whole grain are also partially due to healthier lifestyles, of which whole grain consumption can be a marker. Nonetheless, when taken together the observational evidence supports health benefits of whole grain in a strong and consistent manner.

Intervention Studies. One of the most commonly reported biomarkers of CVD risk is blood lipid profile, and the impact of whole grain on blood lipids has been subjected to a thorough systematic review and meta-analysis by Hollænder et al. (7). The authors screened more than 6,000 articles before including data from 24 studies published between 1988 and 2015 that met their stringent inclusion criteria for both parallel and cross-over intervention studies with apparently healthy male and female adults over the age of 18 years who were not taking statins. Studies were only included if they investigated the effects of consuming either specific whole grain foods (e.g., whole grain bread, brown rice), mixed diets high in whole grain compared with refined grain alternatives (e.g., white bread, white rice), or mixed diets devoid or low in whole grain foods. Overall the data set included data for total, LDL, and HDL cholesterol and triglyceride concentrations for up to 2,275 subjects, three orders of magnitude less than the data available from the observational studies discussed above. The results showed that when averaged across intake of all whole grains there was a small but significant reduction in LDL cholesterol of –0.09 mM (95% CI: –0.15 and –0.03 mM; $P < 0.01$) and in total cholesterol of –0.12 mM (95% CI: –0.19 and –0.05 mM; $P < 0.001$) compared with refined grain control. The effect was greater for oats (which contributed about 50% to the "weight" of the analysis) when considered alone, with a mean difference of –0.17 mM (95% CI: –0.25 and –0.10 mM; $P < 0.001$) compared with refined grain control. No effects on HDL cholesterol were observed, and triglyceride concentrations only tended to be lower with whole grain intake, –0.04 mM (95% CI: –0.08 and 0.01 mM; $P < 0.10$), compared with refined grain control. There was considerable heterogeneity in several components of the database, but this did not affect the outcome measures, although an energy-restricted diet appeared to augment the results.

The duration of intervention studies is often cited as an important factor for determining the likelihood of seeing changes in lipid profile (longer is considered better), so it is interesting that in a regression analysis duration of study appeared to be positively correlated with change in plasma cholesterol concentration (i.e., longer study duration showed less negative change from control), although this may be confounded because many of the oat studies included in the analysis were of shorter duration and resulted in the greatest reduction in plasma cholesterol concentration. The effects reported in this paper for changes in cholesterol concentration are smaller than the weighted mean differences reported by Ye et al. (20), which may be related to the methods used to estimate the effect size in the latter study. Nevertheless, the papers demonstrate significant benefits of consuming whole grains on fasting lipid profiles and fasting glucose concentrations.

Whole Grain Dietary Guidelines and Intake

The process for developing dietary guidelines and recommendations for the population is generally similar for different countries and regions. An expert scientific committee is convened to review the available evidence for dietary requirements. For single nutrients such as a vitamin or mineral the process is relatively straightforward because the requirement can be judged against clear biochemical and/or clinical deficiency symptoms, and the expert committee can make recommendations to prevent these symptoms and achieve an identified optimal nutritional status for the nutrient. For food-based dietary guidelines the process is more complex and is most often based on evidence linking the foodstuff to disease prevention. The role of the expert committee is the same, but it must evaluate the range of data showing relationships between consumption of the foodstuff and risk of disease. As illustrated in the previous section, the evidence is sometimes inconsistent.

The consequence for whole grains is that government agencies and professional bodies have interpreted the available evidence differently, resulting in a range of dietary recommendations for whole grain foods, or possibly the absence thereof. A recent survey of 55 different countries identified 127 separate organizations, including 46 government agencies and 81 non-governmental organizations (NGOs), charities, professional bodies, the WHO, and EFSA responsible for providing nutrition guidance in these countries (14). From these 127 organizations only 48 recommendations were found. Of these, 29 were considered primary recommendations with a specific target for whole grain intake. The remaining 19 were secondary recommendations to consume whole grains in order to achieve a second (primary) target, often dietary fiber intake. The recommendations ranged from nonspecific statements (e.g., to eat more whole grains, choose whole grains where possible) to semiquantitative guidelines (e.g., to eat 3 servings of whole grains/day) to very specific quantitative recommendations (consume 75 g of whole grain/10 MJ of energy/day) (14).

The lack of consistent messages is likely to create confusion among consumers and is a problem for multinational food companies seeking to develop and market whole grain foods in different countries. Data reporting current levels of whole grain consumption are few but show that whole grain intake is very low in most countries, ranging from a little as 4 g/day for adults in Italy to around 24 g/day in the United Kingdom and 1 oz-equivalent (~20 g/day) in the United States (9). The highest intake levels are found in Denmark and other Northern European countries where there is a stronger tradition of whole grain consumption (9). Comparing intake in different countries with the type of dietary recommendation in the country suggests no relationship and little or no change in intake over time where longitudinal data are available. For example, a whole grain intake recommendation has been in place through two revisions of the *Dietary Guidelines for Americans* (15), but whole grain intake in the U.S. adult population has barely changed over this period (2). The exception is Denmark, where whole grain intake recommendations have been supported by a strong public-private partnership (Danish Whole Grain Campaign), resulting in significantly increased whole grain intake for the population (4). On average, Danes ate 36 g of whole grain/10 MJ/day at the start of the campaign in 2008. The implementation of the Whole Grain Campaign has resulted in an increase in the average consumption of whole grain to 63 g/10 MJ/day. This suggests that any dietary recommendation must be supported by stakeholders from government, health NGOs, and the food industry to be successful.

Identifying Whole Grains and Whole Grain Foods

Increasing whole grain intake requires that consumers be able to identify whole grain foods and have confidence in their health benefits. In the United States, the Oldways Whole Grains Council (11) administers a "Whole Grain Stamp" for labeling of whole grain products; different "stamps" are used to identify products depending on the whole grain delivered per labeled serving of the foodstuff. Whole Grain Stamps include the "100% Stamp," which identifies products in which all of the grain ingredients are whole grain and a serving of the product delivers a minimum 16 g of whole grain. For a product bearing the "50%+ Stamp," which was introduced in January 2017, at least half of the grain ingredients must be whole grain, and the product must deliver at least 8 g of whole grain per labeled serving. Finally, a product bearing the "Basic Stamp" must contain at least 8 g of whole grain per serving, but may also contain some refined grain. As part of the Danish Whole Grain Campaign a similar logo was developed that can be applied to foods containing whole grains, with strict criteria for different food types (5).

A definition of "whole grain" was originally proposed by AACC International (AACCI) in 1999 and subsequently modified in 2008 to allow the inclusion of malted and sprouted grains (1). This definition was adopted by the U.S. Food and Drug Administration (FDA) and formed the basis for the identification of foods that can carry the FDA approved whole grain health claim (16–18). This health claim requires that a whole grain food must contain more than 51% whole grain ingredient(s) by weight per reference amount customarily consumed. The AACCI definition of whole grain has been widely adopted, but it is only a voluntary standard outside the United States. The Healthgrain Forum proposed a modified definition of whole grain based on the AACCI definition that allows for small but inevitable losses during processing (19) and is promoting adoption of this standard in other countries. AACCI has also proposed

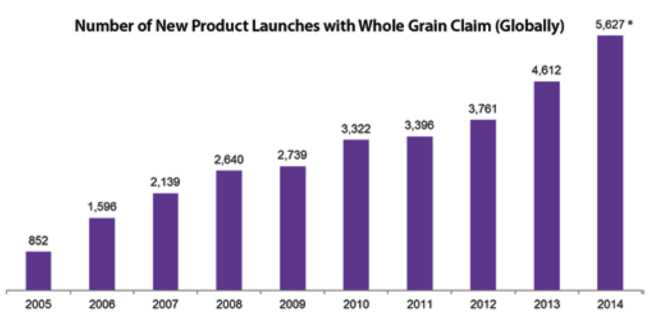

Fig. 1. Annual growth in the number of new products featuring whole grain benefit claims. * Of new food and beverage launches in 2014, 2.5% featured whole grain claims, accounting for 5,627 new product launches globally. (Figure provided courtesy of Cereal Partners Worldwide from Mintel data)

a definition characterizing a whole grain food as a food that "must contain 8 grams or more of whole grain per 30 grams of product" (1). This follows a similar recommendation from an academic-industry roundtable consensus statement (6). The Healthgrain Forum recently proposed a definition for whole grain foods (12) to support its definition of whole grain. This definition proposes that foods can be called whole grain on the front of food packages if the food contains more than 30% by weight whole grain and contains more whole grain than refined grain. Crucially, the proposal requires that foods labeled in this way must also comply with national requirements for food profiles that are lower in fat, sugar, and salt. The range of definitions for whole grain and whole grain foods was discussed at the 2017 Whole Grain Summit in Vienna, continuing on from similar discussions at the 2015 summit (8). Further discussion will be needed if global definitions are to be achieved to support the development of dietary recommendations and the enforcement of labeling standards. The purpose of stamps and clear labeling requirements is to provide information for consumers and to help consumers choose foods that have a higher carbohydrate quality and can be consumed as part of a healthy dietary pattern, as well as provide guidelines for food manufacturers and for the development and advertisement of new whole grain products.

The desire to offer healthy food products is motivating food manufacturers to increase the use of whole grain in cereal products. Consequently, there appears to be a continuing global trend to add whole grain claims to product labels, as indicated by the increase in the number of new product launches over time (Fig. 1). This expansion in the availability of whole grain foods is reflected in the number of foods bearing the Whole Grain Stamp, which now exceeds 120,000 different products in 58 countries worldwide (11). Given the growth in the number of whole grain foods available in the marketplace, it is disappointing to see the low levels of intake in many countries. Understanding and overcoming the barriers to whole grain consumption will be a key area for focus for public health researchers and policymakers.

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Quality of Sugars and Sugar-Containing Foods

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ABSTRACT

Dietary sugars are mono- and disaccharides that are naturally present in fruits, vegetables, and natural syrups or are added to foods as refined sucrose or high-fructose corn syrup. Dietary sugars are absorbed in the bloodstream as glucose (indistinguishable from that released from starch), fructose, and galactose. Galactose is converted into glucose, and fructose is converted into glucose, lactate, and fatty acids in splanchnic organs. The main nutritional function of sugars is to provide usable energy to all cells in the human body. The efficiency of usable energy transfer is very high for glucose; lower for galactose, lactose, and sucrose; and lower still for fructose. High dietary sugar intake may be associated with an increased risk for cardiovascular and metabolic diseases. This is especially true for fructose and sucrose, which increase blood lipids and impair hepatic insulin sensitivity when consumed in high doses. The effects of sugar-containing foods vary according to food group: fruit and vegetable consumption significantly protects against cardiovascular and metabolic diseases, while consumption of sugar-sweetened beverages is associated with an increased risk. The quality of sugar-containing foods should be assessed not only based on their sugar content, but also on their overall energy, dietary fiber, and micronutrient contents.

Glucose is a key energy substrate for most cells in the human body and the predominant source of energy for the brain. Blood glucose concentration is normally regulated within relatively narrow limits, and episodes of low blood glucose are associated with acute cognitive dysfunctions, neurological symptoms, fatigue, and decreased exercise performance. In addition to its prominent role in energy homeostasis, glucose is also required for the glycosylation of various lipids and peptides, which play essential roles in cell regulation. Glucose and other monosaccharides, such as galactose and fructose, play key roles in the normal functioning of some cells, such as glycosylation with galactose residues of glycoproteins and glycolipids or energy provision from fructose to sperm cells. However, dietary carbohydrates, which are direct providers of glucose, fructose, and galactose in our diet, are not strictly speaking essential nutrients: glucose can be synthesized endogenously from amino acids or glycerol, while fructose and galactose can be synthesized from glucose. Nonetheless, given the large energy requirements of the human body and the fact that carbohydrates represent a large portion of the energy content of available foods in most regions of the world, most populations rely on the daily intake of substantial amounts of carbohydrate.

Sugar is the generic name used for all mono- and disaccharides. The main dietary sugars are glucose; fructose; sucrose, which is a dimer formed from one glucose and one fructose; and lactose, which is a dimer formed from glucose and galactose. Glucose, fructose and sucrose are found in variable proportions in fruits and vegetables, honey, and natural syrups (e.g., maple and agave syrups). Lactose is present in milk and many dairy products. Galactose is only present in very low amounts in some vegetables and fruits. Modern diets also include variable amounts of crystalline sucrose refined from sugarcane or beet or glucose-fructose syrups industrially prepared from cereals or potatoes. The most commonly used glucose-fructose syrup in North America is high-fructose corn syrup (HFCS) (37).

No universally accepted tool exists for evaluating the quality of a nutrient. Such evaluation would imply assessment of a large number of parameters related to how a nutrient exerts its function(s) in the body, whether it has direct or indirect adverse effects, what the nutritional properties of foods that contain it are, how its consumption affects the consumption of other dietary nutrients, etc. For practical purposes, this article was written following the assumption that the only function of sugars is to transfer usable energy to cells in the body and that different sugars may possibly exert different effects on obesity, cardiovascular, and metabolic risk factors. The quality of sugars, therefore, was addressed in terms of

- How efficient sugars are in exerting their main function, i.e., transferring usable energy.
- How sugars impact the risk of cardiovascular and metabolic diseases.
- How sugars can be qualified as nutrients and how sugar-containing foods can be qualified.

EFFICIENCY OF SUGARS IN TRANSFERRING USABLE ENERGY TO CELLS

Bioavailability of Sugars

Mono- and disaccharides may not be digested by pancreatic enzymes and reach the small intestine, where sucrose and lactose are cleaved into monosaccharides by disaccharidases (sucrase-isomaltase and lactase) located at the luminal surface of the gut (18,36). Disaccharide digestion is a rapid and highly efficient process and is not considered rate-limiting for sugar absorption. Lactase, however, is not expressed in about 25% of adults, resulting in lactose intolerance (36). Glucose and galactose are transported from the gut lumen to the blood by an energy-dependent cotransport with sodium, which allows for their nearly complete intestinal absorption (54). In contrast, fructose is absorbed from the gut by passive diffusion, facilitated by the fructose-specific transporter GLUT5 (27,45). Fructose absorption is markedly increased when it is ingested together with glucose. Gut fructose absorption also increases with chronic fructose intake due to rapid up-regulation of GLUT5 expression (13,14,27).

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Metabolism of Monosaccharides Absorbed from the Gut

Once absorbed into the circulation, glucose, either ingested as a monosaccharide or provided from sucrose or starch digestion, is initially delivered into the hepatic portal vein. About 10–20% of a 75 g oral glucose load is retained in the liver to resynthesize the glycogen used between meals, and the rest enters systemic circulation, thus increasing blood glucose concentration, which in turn stimulates insulin secretion. Circulating glucose is then taken up by most of the cells in the body to be used as an energy substrate (3,19).

Galactose present in hepatic portal blood is almost completely extracted in the liver during the first pass. It is metabolized inside the hepatocytes—first to galactose-1-phosphate and then to uridine-diphosphate-glucose, which is a direct precursor for hepatic glycogen synthesis. Galactose, therefore, quickly mixes with the hepatic glucose pool and is subjected to the same regulatory factors as glucose (34,53).

When ingested in very small amounts, most of the fructose appears to be metabolized in small bowel enterocytes, where it is mainly converted into glucose and lactate (23). When consumed in larger amounts, a major portion of the fructose absorbed by enterocytes is released into the hepatic portal blood and then extracted in the liver, where specific fructolytic enzymes (fructokinase, aldolase B) convert it into trioses-phosphate. These compounds then can be metabolized further to lactate, glucose, or fatty acids and triglycerides (31). Based on various experimental studies relying on carbon 13- or deuterium-labeled substrates to trace specific metabolic pathways, it is currently estimated that about 30–50% of an ingested fructose load recirculates as glucose, and about 25% recirculates as lactate within 4–6 hr of eating a meal; a smaller portion is temporarily stored as hepatic glycogen or intrahepatic fat or is secreted in the circulation as triglycerides associated with very low-density lipoproteins (43). Fructolytic enzymes are also expressed in kidney proximal tubular cells and may contribute to the metabolism of fructose that escapes first-pass splanchnic extraction (9).

Fructose metabolism and the effects of dietary fructose on glucose and lipid metabolism differ from those of glucose, because fructolysis, in contrast to glycolysis, is a completely unregulated process. When portal glucose is metabolized in hepatocytes, the glycolytic degradation of glucose carbons occurs until oxidation of trioses-phosphate covers cellular ATP needs, at which point the cellular ATP and citrate levels rise and strongly inhibit glycolysis. In contrast, no such inhibition takes place during fructolysis, and degradation of fructose carbons to trioses-phosphate proceeds as long as fructose is available (31). Even with moderate 20–30 g fructose loads, a portion of the trioses-phosphate is converted into glucose by gluconeogenesis, eventually ending up in glycogen stores or as blood glucose. Trioses-phosphate can also be converted into fatty acids through de novo lipogenesis and, as a result, end up as triglycerides. The amount of fructose converted into triglycerides is generally estimated to be much smaller than that converted into glucose and glycogen but has not been quantified accurately. De novo lipogenesis activity is markedly increased by exposure to high fructose intakes, however, and it is likely that the proportion of fructose converted into lipids is dependent on both daily fructose intake and duration of exposure.

Provision of Energy from Sugars to Cells in the Body

The primary role of dietary carbohydrate is to provide monosaccharides as energy substrates to cells in the human body. In this regard, all digestible carbohydrate contains about 4 kcal/g. However, the amount of energy actually made available to cells may vary according to the number of transformations a monosaccharide undergoes before being delivered as either glucose or fatty acids to cells in the body.

About 80–90% of glucose absorbed from the gut escapes hepatic uptake and reaches systemic circulation, from which it can be directly transported to and oxidized by cells without any prior energy loss. The 10–20% of glucose taken up by the liver is temporarily stored as hepatic glycogen before being subsequently released into the blood as glucose. In this process, about 5% of its energy is used for glycogen synthesis and is lost to heat when glycogen is hydrolyzed back to glucose, thus constituting a "futile cycle" (24). The same 5% energy loss can be extrapolated for galactose, which is initially converted into hepatic glycogen before being released as glucose in the blood. In contrast, fructose absorbed from the gut lumen is first degraded into trioses-phosphate, which subsequently enters either gluconeogenesis or de novo fatty acid synthesis. These two processes use considerable amounts of energy, corresponding to about 8–10% of initial energy from fructose used for glucose/glycogen synthesis and up to 25–30% used for fructose conversion into fatty acids (44).

The estimated percentage of energy made available to cells in the body is, therefore, about 99% for glucose (assuming 15% cycling in hepatic glycogen), about 95% for galactose, and about 70–92% for fructose. For disaccharides, the percentage of energy made available can be estimated as the average of its constituent monosaccharides, i.e., 97.5% for lactose (assuming no lactase deficiency) and 86–96% for sucrose.

IMPACT OF SUGARS ON RISK OF CARDIOVASCULAR AND METABOLIC DISEASES

Effects on Food Intake

The control of food intake and whole body energy homeostasis is highly complex and still not well understood, but it appears obvious that obesity results from food overconsumption, escaping feedback inhibition from high body energy stores. Schematically, two distinct systems interact to determine food intake in humans: a "homeostatic" food intake control system located in the hypothalamus and brain stem that responds to neuroendocrine signals such as leptin, insulin, and GLP-1, providing information on the level of energy present in the organism, and a "hedonic system," involving mesolimbic dopaminergic brain reward pathways, that qualitatively evaluates foods and promotes the intake of palatable foods.

The effects of sugars on hormones signaling to the homeostatic system differ markedly from those of starch. This difference stems from the fact that starch is entirely absorbed as glucose, while sugars are absorbed as a mixture of monosaccharides, with glucose representing between 0% (as with pure fructose) and 50% (as with sucrose) of the sugar load. Pure glucose ingestion (which can be assumed to be equivalent to isocaloric starch ingestion) stimulates secretion of the anorexigenic peptides GLP-1 and PYY from intestinal endocrine cells and is associated, through mechanisms involving insulin, with increased secretion of the anorexigenic hormone leptin and decreased secretion of the orexigenic hormone ghrelin. These responses are markedly attenuated when fructose (48) or sucrose (40,41) replace glucose, suggesting that fructose and sucrose may have lower satietogenic effects than starch or glucose.

When present in solution in the mouth, all sugars activate the same sweet taste receptor, T1R2-T1R3, but with marked differences in potency. Fructose and sucrose have higher sweetening potency than glucose, and lactose has only a weak sweetening potency (26). Foods with a sweet taste are often evaluated as pleasant, or palatable, when eaten. This is usually associated with activation of the mesolimbic dopaminergic brain reward pathways, and the hedonic tone elicited by ingestion of sweet products is certainly a driver in their overconsumption (10,26). Some authors have also pointed to the fact that sugars activate the same brain reward pathways as cocaine and, therefore, may potentially be addictive (2). This theory remains highly controversial, however.

Effects of High Dietary Sugar Intake on Glucose and Lipid Metabolism

In many countries, energy-dense foods are widely available at affordable prices, and the prevalence of noncommunicable diseases such as obesity, diabetes, and cardiovascular diseases is high. The risk for developing these diseases is markedly determined by nutritional factors, suggesting that identification of the associations between consumption of specific foods or nutrients and incidence of these diseases is of major importance for public health. A brief outline of how dietary sugars may impact the risk for two common noncommunicable diseases—type 2 diabetes mellitus and cardiovascular disease—through alteration of glucose and lipid homeostasis is provided in this section.

Acute Effects of Sugars. The specific effects of individual carbohydrate-containing foods on postprandial glycemia are reflected in their glycemic index. Glycemic index is defined as 100 times the ratio of the postprandial glucose response produced by ingestion of a portion of a food to that produced by ingestion of the same amount of carbohydrate as pure glucose (6). Fructose and galactose both have a glycemic index of about 25%; sucrose has a glycemic index of about 65%. The fact that fructose has a lower glycemic index than many starchy foods may provide an advantage for individuals with diabetes mellitus, for whom blood glucose control is the primary goal of their treatment. Indeed, there is evidence that for individuals with diabetes replacing sucrose with pure fructose actually improves diabetes control (12,17). This beneficial effect may be counterbalanced, however, by the adverse effects of sugars on lipids (discussed in next section). For the general population, however, blood glucose control is not an issue, and there is no evidence supporting beneficial effects of certain sugars due to their low glycemic index.

Chronic Effects of Sugars. A study by Johnston et al. (25) found that replacement of starch with an isocaloric amount of glucose in the diet of healthy volunteers for 2 weeks did not significantly alter blood glucose and triglyceride concentrations. It also did not alter intrahepatic lipid concentration (25). This is not surprising, because ingestion of isocaloric amounts of starch or glucose is expected to result in the absorption of the same amount of glucose in the blood. Consumption of a hypercaloric (about 130% of energy requirements), high-glucose (25–30% of total energy) diet did not change fasting blood glucose and insulin, nor insulin sensitivity, compared with a baseline weight-maintaining diet (25,42). Some studies, however, have reported an increase in blood triglycerides and intrahepatic fat concentrations (25,33). To my knowledge, no study has addressed the effects of a high-galactose or high-lactose diet on glucose or lipid metabolism in humans. This can be explained by the fact that total dietary galactose intake from dairy products and vegetables represents only a minor portion of total energy intake.

Many studies have assessed the effects of high-fructose diets in normal weight and obese volunteers over periods ranging from a few days to 6 months. Fructose typically contributed 15–30% of total energy intake and, hence, largely exceeded the current recommendations of a maximal added-sugar intake of ≤10% total energy. These studies have consistently reported that fructose, consumed as part of a hypercaloric diet, produces a modest, yet significant, increase in fasting insulin concentration. Studies that used dynamic tests to assess glucose homeostasis have reported that hepatic insulin sensitivity decreased and postprandial blood glucose responses significantly increased with high daily fructose intake. In contrast, whole body insulin-mediated glucose disposal, which mainly reflects muscle insulin sensitivity, was not altered (49).

High intakes of fructose, sucrose, or HFCS also consistently increased fasting and postprandial blood triglyceride concentration. This effect is mainly related to an increase in triglycerides associated with very low-density lipoproteins, suggesting that their origin is hepatic. This is mainly observed when fructose is consumed together with excess total energy (11), but some studies also have reported stimulation of hepatic de novo lipogenesis and an increase in blood triglycerides when fructose isocalorically replaced starch (15,38). In addition, many studies have reported that consumption of a hypercaloric, high-fructose diet increased intrahepatic fat concentration in normal weight and obese volunteers (25,42). Some studies, however, have reported similar effects with high-glucose and high-fat diets (25, 33), raising the possibility that increased intrahepatic fat concentration is due to excess energy intake rather than to a specific effect of sugars.

Effects of Sugar-Containing Foods on Cardiometabolic Risk

The most commonly consumed sugar-containing food groups in the United States and Europe are sugar-sweetened beverages (SSBs) and fruit juices, fruits and vegetables, grain products (e.g., breakfast cereals, cookies), dairy products with added sugar, and sweets and desserts (e.g., chocolate, candies, ice-cream, etc.) (1,29,30,51). Although epidemiological studies indicate that total sugar consumption is associated with adverse health effects, the relative contribution of sugars from various food groups is still debated. Prospective cohort studies show strong positive associations between SSB intake and body weight gain and between SSB intake and total energy intake (50). Addition of SSBs to the diet of adults or children has been shown to cause a significant increase in body weight (46). This strongly suggests that SSB consumption may contribute to the development of obesity by increasing total energy intake. The same conclusions were reached when assessing the effects of sugar-sweetened fruit juices, whereas the effects of 100% fruit juices with no added sugar remain controversial (22,35). SSB intake was also positively associated with increased blood lipids and increased risk for diabetes, but this was mediated, in part, by its effect on adiposity (47).

In contrast, high-fruit and -vegetable intake has been shown to provide protective effects against obesity (8,32,39), dyslipidemia, and risk for diabetes and cardiovascular diseases (7,20, 21,55). The intake of vegetables, which have lower sugar contents, is particularly effective in this regard, but intake of fruits exerts the same effect, in spite of their higher sugar contents. The beneficial effects of eating fruits are unlikely to be due to their sugar being "natural" as opposed to "industrial," because sugars in fruits are chemically identical to their refined, industrial counterparts. Rather, the beneficial effects of fruits versus other sugar-containing foods may be due to their low sugar content by portion relative to other sugar-containing foods. An average fruit portion is 100–150 g, and the sugar contents of apples, peaches, and pineapples are about 9, 8, and 10 g/100 g, respectively, which is significantly lower than the sugar content of a can of sugar-sweetened soda (about 30 g) (5). Due to the relatively low sugar content of whole fruits, their consumption is unlikely to be associated with a daily intake of fructose higher than 50 g, which is the minimal dose at which some adverse metabolic effects are observed (4,28). In addition, fruits do not contain significant amounts of fat or protein and, hence, have a low caloric content compared with other sugar-containing foods. Finally, many fruits have a high dietary fiber content, which may induce satiety through a bulking effect and, as a result, may prevent overfeeding. These key properties of whole fruits (i.e., low sugar intake per portion and high fiber content, most likely contributing to reduced food intake) may not be retained in fruit juices, however. A 3 dL portion of unsweetened orange or apple juice contains 24–30 g of sugar (i.e., similar to that of a can of sugar-sweetened soda), and a 3 dL portion of grape juice contains about 48 g of sugar. In contrast, the dietary fiber to sugar (g/g) ratio decreases from 0.28 in a whole orange and 0.15 in a whole apple to only 0.01–0.02 in orange or apple juice (5).

Other sugar-containing foods constitute a very inhomogeneous group with wide variations in their macro- and micronutrient contents. For example, some candies contain no or very few nutrients other than sugar, whereas sugar-sweetened dairy products or breakfast cereals may also contain proteins, fat, calcium, dietary fibers, and many other micronutrients. Unfortunately, the available scientific literature does not allow an evaluation of the associations between consumption of each of these subgroups and health-related outcomes.

HOW TO QUALIFY SUGARS AS NUTRIENTS AND HOW TO QUALIFY SUGAR-CONTAINING FOODS

The "quality" of a food depends on how adequately it meets one or several nutritional requirements, while at the same time being associated with the lowest possible risk for noncommunicable diseases.

The only known nutritional function of sugars is to provide energy, and their quality, therefore, may be assessed based on how efficiently they provide usable energy to support the needs of all the cells in the human body. However, there is also strong evidence that a high sugar intake may alter glucose and lipid homeostasis in ways that may predispose a person to develop metabolic and cardiovascular diseases or negatively impact their evolution in individuals with these diseases. Finally, although refined sugars do not contain other nutrients of interest they are mainly consumed in foods and beverages that do contain other nutrients that are important for health. Sugar quality, therefore, may also be assessed based on the group of sugar-containing foods from which it is obtained (i.e., fruits versus grain products versus beverages, etc.).

Most of the dietary glucose reaches cells in the body unchanged, with only minimal energy loss due to hepatic glycogen cycling and, hence, is highly efficient in transferring usable energy to cells. All other sugars require preliminary (mainly hepatic) transformations, with small losses of energy for sucrose and galactose and moderate to large losses for fructose (Fig. 1A).

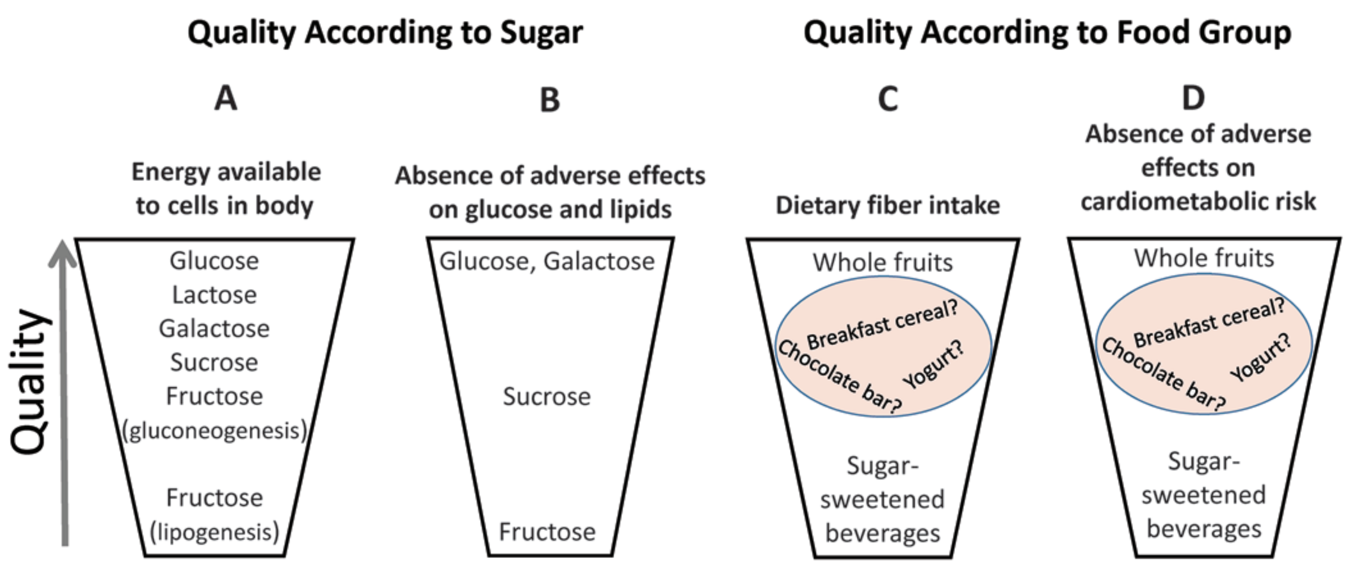

Fig. 1. Illustration of how the quality of sugars may be evaluated based on several complementary criteria. **A** and **B** depict quality of sugars as nutrients; **C** and **D,** depict quality of sugar-containing foods, which depends on sugar and other nutrient contents beneficial for health. **A,** Sugar quality ranked in terms of efficiency of usable energy transfer to cells in the body. Between-sugar variations are explained by specific metabolic pathways for individual monosaccharides. **B,** Sugar quality ranked in term of potential adverse effects associated with equimolar amounts of sugars. Adverse effects are represented as changes in cardiometabolic risk factors. Between-sugar variations are explained, as for **A**, by specific metabolic pathways for individual monosaccharides. **C,** Sugar-containing food quality ranked in terms of fiber content per gram of sugar; similar representation may be used for other nutrients. Whole fruits have a high fiber to sugar content ratio and, hence, a high nutritional quality compared with sugar-sweetened beverages. **D,** Sugar-containing food quality ranked in term of potential adverse effects (per gram of sugar). Unlike for **B**, between-food variations are not due to sugar content but to other food-related nutritional factors. Whole fruits are strongly associated with low and sugar-sweetened beverages are strongly associated with high cardiometabolic disease risk. Effects of other sugar-containing foods remain to be evaluated.

Ingestion of fructose and sucrose has a greater impact on hepatic insulin sensitivity and blood lipids than does ingestion of isocaloric amounts of glucose. These effects are mainly observed when fructose and sucrose are included in a diet that also provides an excess of total energy. Such effects have not been documented for lactose and galactose but are very unlikely to occur at the level of intake observed in common dietary patterns. This implies that the quality of dietary sugars is inversely proportional to their fructose content due to the potential adverse metabolic effects of fructose (Fig. 1B).

High consumption of fruits and vegetables is strongly associated with lower risk and SSB consumption with increased risk of metabolic and cardiovascular diseases. It may be inferred from this that fruits and vegetables have higher nutritional quality (most likely unrelated to the quality of their sugars). Currently, there is insufficient information to evaluate the risk associated with other sugar-containing foods (Fig. 1C). Nonetheless, the observation that consumption of fruits, which contain sugars, is associated with beneficial health effects, whereas consumption of total sugar, particularly SSBs, is associated with adverse health effects, has led many agencies to provide recommendations to reduce the consumption of sugar that is not associated with fruits and vegetables. Sugars not associated with fruits or vegetables are defined as "added" or "free" sugars, i.e., all monosaccharides and disaccharides added to foods by the manufacturer, cook, or consumer (16). Free and added sugars include honey and natural syrups (e.g., agave syrup, maple syrup). Unsweetened, 100% fruit juice remains an area of controversy and is included in the definition of free sugars, but not in that of added sugars. Most national and international dietary recommendations propose the specific limitation of consumption of free or added sugars.

The impact of sugar-containing foods on health goes beyond energy production and cardiometabolic risk, because balanced nutritional intake implies that one consumes a variety of foods that covers not only basic energy requirements, but also provides a sufficient supply of essential macro- and micronutrients. At similar energy contents, foods containing high levels of these nutrients would, therefore, have higher overall quality compared with foods that are devoid of them. Fruits and vegetables have low energy densities but have high fiber, vitamin, and antioxidant contents, whereas most sodas contain sugars, but no micronutrients or fiber. As a result, fruits and vegetables have higher overall nutritional quality than sodas (Fig. 1D). No system for assessing the overall nutritional quality of other sugar-containing foods has been agreed on; some breakfast cereals may provide a large quantity of fiber and micronutrients relative to their caloric content and, therefore, may have a high nutritional quality; the same may be true for some sugar-containing dairy products with a high calcium versus calorie content.

Finally, one key issue regarding the role of sugar in the pathogenesis of cardiovascular and metabolic diseases may be that consumption of sugar-containing foods is often associated with a high energy intake, which promotes obesity (50,52). This may be due to lower satiety signals produced with sugars than with other macronutrients, but also to the fact that sugar combined with other nutrients, such as starches and fats, may confer a strong hedonic tone to foods. The latter remains difficult to evaluate in terms of quality because the preparation of foods that people enjoy eating is a key factor in gastronomy and nutrition.

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Conflicts of Interests

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PERSPECTIVE

Effects of Processing on the Functionality of Cereal Polysaccharides

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Cereal polysaccharides, which can be divided into starch and nonstarch polysaccharides, are an important source of energy and dietary fiber in the human diet. From an energy perspective, it is well known that starch is poorly digested in its native form. Thermal treatment is required to induce changes (gelatinization) in the native starch granule structure that render starch molecules more accessible for digestion by enzymes. However, the increasing occurrence of type 2 diabetes, which is due, in part, to consumption of high levels of rapidly digestible, refined starches, has led to increased demand for low glycemic index (GI) foods.

The role of cereal fibers in the prevention of many chronic diseases is well established in the literature (a summary of the most recent published papers is presented by the Oldways Whole Grains Council online at https://wholegrainscouncil.org/whole-grains-101/health-studies-health-benefits/what-are-health-benefits), which has led to dietary recommendations that call for increased intake of whole grain products or products rich in cereal fibers. In response, food manufacturers are tailoring processing conditions to develop food structures that deliver the desired physiological functionality (e.g., high fiber, low GI, cholesterol lowering effects, etc.) while maintaining good sensory properties. This article highlights the influence of common cereal processing operations, such as milling, fermentation, baking, and extrusion, on the predominant functional cereal polysaccharides: arabinoxylan and β-glucan.

Milling and Fractionation

Dry milling and fractionation generally results in flour fractions that are enriched with different components of cereal polysaccharides. The mechanical forces experienced during dry milling and fractionation have a minimal effect on cereal fiber properties (e.g., molar mass, solubility, etc.), and the process does not induce enzymatic activity that can degrade the fiber. Djurle et al. (7) found that other than an improvement in extractability there was no difference in the molar mass distribution of arabinoxylans in kernels or flour. Improved extractability of fiber due to degradation of the native grain macro structure and reduced particle size is important for subsequent processing and physiological functionality of cereal polysaccharides.

The combination of different ingredients, including water and lipids, during cereal processing can result in degradation of cereal fiber due to enzymatic and microbial activity, depending on the conditions encountered. Rakha et al. (13) studied the fate of arabinoxylans and β-glucan during the making of porridge using whole grain rye. The study showed arabinoxylans were more stable than β-glucan. This can be attributed to the simpler structure of β-glucan compared with arabinoxylans, which makes β-glucan readily accessible to digestion by β-glucanases. Extensive enzymatic degradation of β-glucan is expected, therefore, in processes involving long incubation times (e.g., during proofing in breadmaking). Shortening proofing, omitting fermentation, or incorporating barley flour after fermentation of wheat dough to obtain a final bread product with high molar mass β-glucan has been suggested. Furthermore, coarsely ground flour or intact flakes that limit enzyme access during breadmaking can be used to obtain high molar mass β-glucan in the final product (2,14). Kilning of oats, the primary aim of which is to inactivate lipases, results in inactivation of endogenous β-glucanases as well (1). Consequently, the degradation of kilned oat β-glucan is mainly due to the activity of β-glucanases from other ingredients, such as wheat flour.

Fermentation

Fermentation, either during bread baking or sourdough fermentation, has a significant influence on fiber properties. Lactic acid bacteria fermentation of whole grain flour or bran increases solubilization of arabinoxylans, decreases the molecular weight of arabinoxylans, and/or induces formation of prebiotic arabinoxylan-oligosaccharides (6,10). These effects can be achieved using fermentation alone or specific enzyme hydrolysis. Cereal β-glucan is very easily degraded during short yeast fermentation (3,14,17) and even more intensively degraded during sourdough fermentation (15).

Thermal Treatment

Baking, extrusion, steaming, and boiling are the common thermal treatment processes utilized in cereal processing. Cereal fibers are generally heat stable, but their stability can be altered depending on processing conditions, such as low pH or the presences of oxidants such as ascorbic acid, which heighten the susceptibility of cereal fibers to nonenzymatic degradation during thermal treatment (5,8,9,11,12,16). Baking typically has minimal effects on the molar mass distribution of arabinoxylans and β-glucan (2,14). Therefore, in bakery products the main changes in cereal fiber quality occur during mixing, proofing, or sourdough production.

Extrusion

Extrusion, in which a combination of high heat, high pressure, and shear forces are utilized, affects the extractability, solubility, and molar mass distribution of cereal fibers. Extruded bran has been shown to have a higher solubility and swelling capacity and an increase in apparent viscosity compared with nonextruded bran (4,7,18). These changes result from the disruption of cross-linking between cereal polysaccharides, disag-

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gregation, and/or thermal degradation of the polysaccharides. In addition to variation in extrusion conditions and raw material characteristics, the simultaneous occurrence of these changes (e.g., matrix disruption, disaggregation, thermal degradation) may explain the varying results obtained in extrusion studies (4).

Conclusions

Cereal processing can have a profound influence on the functional properties of cereal polysaccharides. However, effects are fiber dependent and can be tailored using optimized processing conditions. Alterations in the nutritional properties of fibers are likely to be dependent on processing-induced changes in these polysaccharides, and a more in-depth understanding is required to create or maintain polysaccharide properties that provide both nutritional and technological functionality. A more detailed evaluation of the effects of processing on cereal fiber is currently being reviewed by members of the Health Grain Forum and will be published in 2018.

Cereal processing has a significant influence on the quality of grain polysaccharides and is very likely to alter the physiological functionality of grains processed using different methods. However, the exact impact of processing on human responses to grain polysaccharides is not well understood or studied. An example is the degradation of β-glucan during processing, which influences its viscosity-forming ability and may reduce the cholesterol-lowering properties of β-glucan. On the other hand, low molar mass glucans can have prebiotic effects on gut microbiota, providing health-promoting properties that have not yet been identified.

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Is Everyone Really on a Low-Carbohydrate Diet? Consumer Perceptions of Carbohydrates and Sugars

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ABSTRACT

Public perception and consumer opinions are major drivers of shifts in dietary trends, as has been demonstrated most recently by the increased attention paid by consumers to low-carbohydrate eating patterns and concerns about added sugars. It is important for nutrition and food industry professionals to understand the factors that determine food intake and purchasing behaviors and observe how and why these behaviors, attitudes, and beliefs change over time. The International Food Information Council (IFIC) Foundation has administered its annual Food & Health Survey since 2006, which has yielded relevant, applicable information on public perceptions and purchasing drivers of nationally representative samples of the U.S. adult population. In this article evolving public perceptions of carbohydrates and sugars are illustrated by highlighting findings from IFIC Foundation consumer research, correlating perception with actionable behavior changes, and discussing new food and diet trends. Consumer education efforts are an important component in public understanding of evidence-based information on carbohydrates and added sugars. These efforts are discussed using the updated Nutrition Facts label as an example of a critical opportunity for engaging with consumers.

As both a food-loving and food-phobic society, Americans have grown accustomed to obsessing over certain foods and diet trends—vilifying them after they lose their allure and championing them anew when they return to favor. Some of these shifts are driven by emerging research or a reframing of the science; however, public perception and consumer opinions are a major driver of these transitions. The evolution of perceptions surrounding dietary fats is a classic example of this phenomenon. In the 1980s and 1990s, no- and low-fat products occupied valuable real estate on grocery store shelves. "Eating fat makes you fat" became a message—however misleading—that a large swath of Americans had a hard time letting go of (7). Even after extensive scientific research clarified the health impacts of a variety of dietary fatty acids by the mid-2000s, it took more than a decade for public acceptance to really gain momentum (5).

By tracking consumer views on dietary trends and food choices over the last 12 years, the International Food Information Council (IFIC) Foundation has documented the pendulum swing of public opinion toward a more positive outlook on dietary fats, while at the same time observing shifts in consumer perspectives on carbohydrates, particularly sugars, which are now under a bright spotlight of public scrutiny (10). These evolving viewpoints raise a number of interesting questions. For example, are these opinions indicative of measurable changes in dietary intake? What nutritional risks are posed by limiting carbohydrate and sugar intakes? Finally, are as many people following a low-carbohydrate diet as it seems?

Nutrition and food industry professionals can maximize their impact on the health and wellness of the public by understanding the factors that determine food intake and purchasing behaviors and observing how and why these behaviors, attitudes, and beliefs change over time (2). In this article, evolving public perceptions of carbohydrates and sugars are illustrated by highlighting findings from IFIC Foundation consumer research, correlating perception with actionable behavior changes, and discussing new food and diet trends, with full recognition of their cyclical nature.

Consumer Research on Carbohydrates: Where Are We Now?

Capturing population-level dietary intake data is like tracking a moving target. Agencies and programs funded by the federal government, such as the National Center for Health Statistics (NCHS) and the long-running National Health and Nutrition Examination Survey (NHANES), are critical for assessing and understanding the dietary patterns, health statistics, and epidemiologic trends of representative samples of the U.S. population. However, the most recently available results from national health surveys are typically two to three years old, at best, due to the time needed for data collection, analysis, and interpretation. Consumer research fills an important gap by providing current assessments of attitudes, eating patterns, and health behaviors, while complementing the research performed by the aforementioned institutions. The IFIC Foundation has conducted its annual Food & Health Survey since 2006, yielding relevant, applicable information on public perceptions and purchasing drivers of nationally representative samples of the U.S. adult population.

The longest-running question in the annual Food & Health Survey has been, "What source of calories is the most likely to cause weight gain?" In 2011, "sugars" was added as a response option to this question, and since that time consumers have increasingly shifted blame to sugars as the primary culprit for weight gain, reaching a new high of 33% of responses in 2018. One in four respondents placed the blame on carbohydrates in general—a statistically significant increase of 5 percentage points since 2017 (10). The shifting trend in consumer opinion surrounding sugars and carbohydrates is consistent with prevalent media headlines alleging their role in obesity and other chronic health conditions. Interestingly, the proportion of individuals responding that "all calorie sources contribute equally" to weight gain (i.e., a calorie is a calorie, no matter what the source) has steadily declined, along with the number of people who responded that they are "not sure" (10).

With amplified attention on carbohydrates, primarily sugars, one could assume that measurable concern over their consumption would have increased significantly in the last 10 years. From 2006 to 2015, the data demonstrate that consumer concerns over

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types and amounts of carbohydrates remained relatively stable (47 and 51% in 2006 versus 51 and 52% in 2015, respectively), while concerns regarding sugars grew (53 and 63% in 2006 versus 64 and 71% in 2015, respectively) (4,8). The Food & Health Survey also measures intent to consume or avoid certain carbohydrates. From 2012 to 2016, the percentage of respondents stating that they were attempting to consume whole grains, both complex and refined carbohydrates, sugars in general, and high-fructose corn syrup stayed relatively constant. This was also true for respondents stating they were attempting to consume and avoid fiber, as well as those trying to avoid sugars in general. Trends toward avoiding whole grains, both complex and refined carbohydrates, and high-fructose corn syrup showed more movement (Table I) (6–9).

It is important to understand whether these stated concerns and attempts to consume or avoid dietary components translate into modification of eating patterns. Consumer research coupled with epidemiologic data suggests a branch point between carbohydrates and sugars in this respect. 2013–2014 NHANES data for adults show that carbohydrate intake has consistently accounted for approximately 50% of total calories consumed in both men and women (12). Trends for absolute intakes of specific sources of carbohydrates, however, have increased (whole grains), declined (vegetables, refined grains, added sugars), and remained stable (fruits) (13). On the other hand, consumption of added sugars as a percentage of total calories has decreased over the past two decades, although mean energy intake from added sugars still remains above national targets (1).

Is Everybody on a Low-Carbohydrate Diet?

Although dietary intake data collected by federal agencies do not show a reduction in total carbohydrate consumption, many popular diets have gained notoriety for their promotion of the benefits of severely restricting carbohydrate intake. Paleolithic and ketogenic diets are perhaps the most topical low-carbohydrate diets in 2018, although Google Trends data demonstrate that searches for "low-carbohydrate diet" in general have increased by 50% over the past two years (3). It is difficult to say what impact these popular diets will have on population-wide trends in carbohydrate and sugar intakes (as well as downstream effects on health outcomes), especially since personal definitions of low-carbohydrate diets are highly variable and difficult to quantify, both in terms of adherence and total intake. One in three respondents in the 2018 Food & Health Survey reported following a specific eating pattern in the past year. However, only 16% of these individuals followed a low-carbohydrate diet (defined as a paleo, low-carbohydrate, ketogenic, or high-protein diet), amounting to 5.7% of the total survey population (10). This suggests that while it may appear that a large proportion of the population is following some kind of low-carbohydrate diet, in reality far fewer people are actually making this commitment.

As the food industry, nutrition and health professionals, and food scientists grapple with the consequences of trends surrounding carbohydrate intake, it must also be acknowledged that American diets have historically been deficient in many food groups and nutrients that are known to be beneficial to health. Consumption of whole grains, fruits, and vegetables is well below recommendations in the United States and has been so for decades (13). Many of these high-carbohydrate foods are rich in other essential nutrients, such as calcium, potassium, iron, vitamin C, B vitamins, and fat-soluble vitamins. They also provide key carbohydrate components such as dietary fiber. As a result, their avoidance has major implications for the healthfulness of a diet.

Where Do We Go from Here? Educational Opportunities Abound

With the barrage of information faced by consumers every day, it is not surprising that confusion surrounding food and nutrition seems to continually increase. It is not possible to compare the most recent iterations of perception surveys like the Food & Health Survey with epidemiologic research from the same time frame because these data are still years from being made public. However, a key value of current consumer data is the ability to quickly identify gaps in public knowledge and behavior. Providing a deeper understanding of these gaps can inform novel edu-

Table I. Responses to International Food Information Council (IFIC) Foundation Food & Health Survey question: "To what extent do you try to consume or avoid the following?"

Response Food Category	2012 (%) (*N* = 1,057)	2013[a] (%) (*N* = 1,006)	2014 (%) (*N* = 1,005)	2015 (%) (*N* = 1,007)	2016 (%) (*N* = 1,003)
Try to limit or entirely avoid					
Complex carbohydrates	11	13	16	21[b]	NA[c]
Refined carbohydrates	19	20	24[b]	26	NA
Fiber	1	2	2	4[b]	4
Whole grains	3	2	4[b]	5	7[b]
Sugars in general	51	58	50[d]	55	52
High-fructose corn syrup	44	51	48	48	53[b]
Try to get as much as I can or at least a certain amount of					
Complex carbohydrates	11	12	10	9	NA
Refined carbohydrates	3	3	3	4	NA
Fiber	56	62	53[d]	55	60[b]
Whole grains	57	62	53[d]	56	59
Sugars in general	4	4	5	6	4[d]
High-fructose corn syrup	1	1	1	3[b]	1[d]

[a] Statistical analysis comparing 2013 with 2012 data was not conducted due to a change in survey administrator.
[b] Statistically significant increase versus previous year ($P = 0.05$).
[c] NA = not applicable; question sets about complex and refined carbohydrates were not asked in the 2016 survey.
[d] Statistically significant decrease versus previous year ($P = 0.05$).

cational campaigns designed to improve public health. The inconsistencies in intentions, concerns, and actions surrounding carbohydrates and added sugars illustrate that there is a critical need for improved consumer education. Innovative strategies need to be developed to inform the public using evidence-based research with scientifically sound conclusions. Social media influencers and advertisers are increasingly able to reach consumers and impact their perceptions with messaging that may not be backed by credible science. It is critical that researchers, health professionals, and science communicators break through this media noise.

The newly updated Nutrition Facts label offers a significant opportunity for educating and engaging with the public. Perhaps the most definitive change to the new label is the addition of specific labeling of added sugars. The intent of the added information is to increase consumer awareness of the amount of added sugars in foods, thus aiding Americans in continuing to reduce intake of added sugars and meet the recommendations in the U.S. Department of Agriculture *Dietary Guidelines for Americans* (14). Separate consumer research projects conducted by both the IFIC Foundation and the U.S. Food and Drug Administration have highlighted the need for improving consumer knowledge and translation of the Nutrition Facts label (11,15). If conducted effectively, outreach efforts could have lasting impacts on public understanding and decision-making concerning intake of carbohydrates and sugars, as well as other important food groups and nutrients. When opportunities like this arise, it is vital that unified, consistent, and fact-based messaging extend across all food and nutrition stakeholders in order to build trust and improve public health and well-being.

Conflicts of Interest

A. Dostal Webster and K. Sollid are staff members of the International Food Information Council (IFIC) and IFIC Foundation, which are primarily supported by the broad-based food, beverage, and agricultural industries. The IFIC Foundation, a 501(c)(3) nonprofit, nonpartisan, public educational foundation, commissions and funds the annual Food & Health Survey.

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Preview of Point/Counterpoint Articles on the Glycemic Index and Glycemic Load Debate

The following abstracts summarize opposing points-of-view in the debate on glycemic index and glycemic load and their role in building healthy diets. The full articles for these abstracts will be published in the July-August 2018 issue of *Cereal Foods World*.

Point: Glycemic Index—An Important but Oft Misunderstood Marker of Carbohydrate Quality

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ABSTRACT

The glycemic index (GI) is a measure of carbohydrate quality that is supported by many international health organizations for the management of chronic diseases and is included on food labels in several different countries to help consumers make healthier food choices. Despite its endorsement by various health and governmental organizations the GI concept remains controversial. The aim of this article is to address the most recent criticisms of the GI, related to its accuracy, precision, and role in chronic disease prevention and management. Many of the criticisms appear to stem from a misunderstanding of the GI and do not undermine the best evidence from prospective cohort studies and randomized controlled trials, which show important clinical and public health benefits of reducing the GI of the diet.

Counterpoint: Glycemic Index Is Not a Useful Consumer Tool

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ABSTRACT

Glycemic index (GI) and glycemic load (GL) were proposed in 1980 as a way to determine carbohydrate quality. Despite extensive research, there is inconsistency in the findings published in the literature with respect to most health outcomes. In addition, published values for GI in tables and on packages may not characterize the glycemic response of a food as eaten, especially when it is eaten as part of a meal. Further, the values do not consider variability introduced by any number of factors, such as variety, ripeness, degree and mode of cooking or processing, presence of other foods or ingredients, temperature of food when eaten, amount eaten, etc. The use GI as a touchstone in food selection, diet planning, and other applications is concerning due to its wide variability and limited precision and accuracy. With standard deviations that are equal to class boundaries for medium-GI foods, designation of foods as high, medium, or low GI is prone to error. This discussion identifies some of the limitations surrounding the measure and its use and outlines the weak evidence for many health outcomes. Further, the assignment of GI values to food intake data collected in dietary surveys by food frequency and other vehicles is questioned. It is unclear whether GI and GL can help consumers determine carbohydrate quality and guide them to food choices that may reduce their risk of associated chronic diseases. Although a group of noted scientists has met and published a consensus on carbohydrate quality, their findings are not aligned with those of other recognized health-promotion organizations, such as the American Diabetes Association or the Academy of Nutrition and Dietetics Evidence Analysis Library. Thus, their conclusion that GI and GL are measures of carbohydrate quality is not substantiated by the state of the research at this point in time, which makes the publication of a consensus on the subject premature.

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AACCI Approved Methods Technical Committee Report on the Guidelines for Laboratory Preparation of Japanese Ramen Noodles (AACCI Approved Method 66-65.01)

Larisa Cato,[1] Gary G. Hou,[2] and Hideki Okusu[3]

Background

Yellow alkaline noodles (YAN), referred to as "ramen" noodles in Japan, represent more than 40% of all noodles manufactured in that country (3). YAN are typically made from flour, water, salt (1%), and alkaline salts (1%) based on flour weight. The most commonly used alkaline salts are a mixture of potassium and sodium carbonates. YAN are very popular in Japan, Korea, China, and many other countries in Southeast Asia. There are very distinct differences in preferences regarding both the color and eating properties of YAN among consumers in different countries, as well as regional differences within each country. Alkaline noodles also include the popular steamed and fried instant ramen; however, flour quality requirements for fresh ramen noodles are more complicated due to less stable color change in fresh ramen noodles (6). The YAN described in this report refer to Japanese ramen noodles, which were first described in a publication produced by the National Foods Research Institute, Ministry of Agriculture, Forestry and Fisheries in 1985 (8) and first translated into English by Tanaka and Crosbie (*unpublished*) (6).

Introduction

Asian noodles are commonly classified according to the raw materials, type of salts, and method of preparation used, as well as the shape of the noodle strands (6). Wheat flour noodles can be divided into two groups based on the type of salt used in the formulation. Noodles made from flour, water, and salt (NaCl) belong to a family of white salted noodles (WSN), while noodles made with alkaline salts (typically Na_2CO_3 and/or K_2CO_3) belong to a family of yellow alkaline noodles (YAN). WSN were developed in northern China, while YAN originated in southern China (Canton and Fujian Provinces). Depending on the noodle type, other ingredients such as starches, gums, eggs, and food coloring agents can be used. After the flour and other dry ingredients are mixed with the salt and alkaline salt solution to form a crumbly dough, it is passed through a set of sheeting rolls to form a dough sheet. The dough sheet is often rested to allow the gluten network to relax and the water to distribute evenly throughout the sheet. Following the resting period, the dough sheet is passed through the sheeting rollers (to reduce sheet thickness) three to five times. Through this process the gluten–starch network is developed. Next, the dough sheets are cut into strands using slotted cutting rolls (with a defined width) and then cut to the desired length. The noodles can then be processed further to produce different types. Based on the additional processing, noodles can be classified as fresh, dried, steamed, boiled, frozen, or instant noodles (6). Instant noodles can be divided further into steamed and deep-fried instant noodle and steamed and air-dried instant noodle categories. Steamed and air-dried instant noodles have recently gained increased attention from consumers seeking healthier food options (1,4).

White Salted Noodles. WSN are typically made from a simple mixture of flour, water, and salt (typically 2–8%) that produces a crumbly dough. WSN are popular in Japan, Korea, and China but represent only a small proportion of the total noodles produced in Southeast Asia. The three most popular forms of WSN are fresh, dried, and boiled, while frozen noodles and noodles with an extended shelf life have become more popular in recent years, particularly in Japan. WSN can be divided further into *so-men* (very thin, 1.0–1.2 mm), *hiya-mugi* (thin, 1.3–1.7 mm), udon (standard thickness, 2.0–3.9 mm), and *hira-men* (flat, 5.0–7.5 mm) based on the width of the noodle strands (4).

Yellow Alkaline Noodles. The most common alkaline salts used today are sodium carbonate, potassium carbonate, or a mixture of the two. The addition of alkaline salts (also often referred to as *kan sui* or lye water) results in noodles with pH values ranging from 9 to 11 depending on the ionic strength of the salts used. YAN have a characteristic aroma, flavor, and yellow color. Today there are many different types of YAN produced in Southeast Asia, including fresh (Cantonese style), partially boiled (hokkien style), and fresh or steamed with egg as an ingredient (wonton noodles). The most popular YAN in Japan are ramen noodles, which originated in China and, thus, are often referred to as Chinese noodles in Japan). "Ramen" originally referred to hand-stretched noodles in China—"Ra" means "hand-stretching," and "men" means "noodle."

Due to the wide array of Asian noodle varieties produced and regional differences in processing equipment, no internationally approved standard methods or guidelines had previously been developed for noodle making and evaluation. In 2015 the AACC International Asian Products Technical Committee adopted and modified Guidelines for Making and Cooking Japanese Udon Noodles (AACCI Approved Method 66-60.01) (7). The AACCI Asian Products Technical Committee has now adopted and modified a new method for ramen noodles from the method approved by the Ministry of Agriculture, Forestry and Fisheries–National Food Research Institute of Japan (8): Guidelines for Making Japanese Ramen Noodles (AACCI Approved Method 66-65.01).

Specific Considerations for Preparation of Japanese Ramen Noodles in the Laboratory

To guide new researchers in the Asian noodle field, in 2005 Ross and Hatcher (9) compiled a list of general guidelines to assist in the development of valid, laboratory-scale noodle processing protocols. For laboratory preparation of Japanese Ramen

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noodles, it is recommended that the following specific suggestions be considered.

1) Noodle Dough Makeup
   a) *Flour Moisture Content.* Water addition in the noodle formulation is based on a flour moisture content of 13.5%. Both the actual flour weight and the water addition are adjusted based on the flour moisture content:

      Calculation (Flour Weight) = (100 – 13.5) × 400/(100 – Moisture Content)

      Calculation (Water Amount, based on 33% water addition at 13.5%) = 133 + (400 – Flour Weight)

   b) *Flour Particle Size and Water Absorption*. The guidelines specify use of 60% flour extraction, which minimizes variations in flour yield, particle size, and starch damage that could lead to heterogeneous hydration of the noodle crumb.
   c) *Determination of Optimum Water Addition for Dough Makeup.* In the guidelines, water addition is set at 32%, which works for the equipment and conditions prescribed. If other types of equipment are used, more or less water may need to be added to achieve optimum results (7).
   d) *Dissolving Salts*. Both salt and alkaline salts should be predissolved in water when mixing noodle dough because of the low moisture content of the noodle dough.
   e) *Water and Water Temperature*. In the laboratory, it is recommended that distilled or deionized water be used in noodle preparation to avoid a water effect on the noodle dough. Water should be kept in a water bath to reach the target final noodle crumb temperature of 24–26°C.

2) Dough Mixing

   In the guidelines, a horizontal Hobart N50 mixer fitted with a flat paddle is used (7).

   a) *Adding Salt Solution.* To assist uniform water distribution through the flour, water should be added in a steady stream into the already operating mixer (7).
   b) *Mixing Time*. Although in laboratory noodle manufacturing there are only a few different mixing protocols used, this guideline specifies a mixing time of 5 min in total at two different speeds: starting on speed 1 (slow) for 1 min, followed by mixing on speed 2 for 1 min, and finishing mixing on speed 1 for 3 min.

3) Dough Sheeting

   In laboratory-scale noodle production, a variety of noodle sheeting equipment has been used, ranging from table-top machines to pilot-scale equipment. In this guideline, an OHTAKE (www.ohtake.jp/product_e.html) noodle machine is used (7).

4) Raw Noodle Sheet—Color Measurement

   Noodle appearance is the first "assessment" of noodle quality made by consumers and is based on subjective evaluation at the point of purchase. Independent of the noodle type, WSN or YAN, a bright and speck-free appearance is a requirement common to all noodles. The optimum intensity of color depends on the noodle type, and any combination of creamy, white, yellow, and strong yellow is possible. For example, Japanese udon noodles should be a creamy (slightly yellow) color, Japanese ramen noodles should be a lemony yellow color, dry Chinese noodles are usually white, and Chinese hokkien noodles are usually a strong yellow color.

   Although there is no international standard method for noodle color measurement, there has been significant research that has provided guidelines for color measurement. Typically, there are two means by which noodle color is measured—the tristimulus method and the spectrometric method. The tristimulus method uses three sensors that reveal color as red, green, and blue, whereas the spectrometric method uses multiple sensors for each specific wavelength (5). The most common color components reported for noodles are L^*, measuring whiteness and brightness; b^*, measuring yellowness and blueness; and a^*, measuring redness and greenness. One reason for the lack of a standardized approach for measuring noodle color is the considerable ongoing debate on how noodles should be presented to the instrument for measurement, including the background to be used and noodle sheet thickness. In 2007 Solah et al. (10) suggested measuring the color of noodle sheets at infinite optical thickness, meaning the color measurement is unaffected by the background color—thus, using white, cream, or black tiles as a background does not impact the color readings. The color of boiled noodles can be assessed at infinite thickness using a method developed by Crosbie (2): after boiling, rinsing, and draining, 60 g of noodles were placed in a plastic jar, and the color was measured using an Agtron sample cup to compress the noodles and a Minolta CRC-310 chroma meter.

   In this method, the suggested procedure for measurement of raw noodle sheet color is as follows. After the second reduction, a piece from the noodle sheet is cut (14 cm long) and passed through the final roll gap; the sheet is cut into two halves and placed on top of each other, folded, and color is measured on all four sides (this is the 0 hr time) using a Minolta chroma meter. Once the measurement is complete, the noodle sheets are placed into the bag without stacking and kept at 25°C for 24 hr. After 24 hr color is remeasured using the method described above.

5) Noodle Cooking

   For optimum results, a gas cooker with sufficient water-holding and heating capacity should be used to control the boiling process. The ratio of boiling water amount to noodle weight should be at least 12–15 parts to 1 part.

   Preparation (boiling) of noodles is also a point often discussed and debated among researchers. Typically, there are two approaches in use today: the first is to cook all samples for the same (standard) amount of time, and the second is to cook each noodle sample to its optimum cooking time (OCT). Hatcher (5) discusses these approaches in detail, highlighting the strengths and weaknesses of both. He points out that boiling noodles to their OCT presents greater challenges for achieving consistency, because it is a subjective assessment of the disappearance of the "white noodle core" and requires a preliminary assessment of various noodles, and thus, it is both time-consuming and material (flour) intensive. Standardizing the time for noodle cooking improves method precision. Standardizing the time between noodle cooking and measurement of texture, as well as the number of strands to be used to measure noodle texture, is very important for achieving consistent and repeatable results.

Acknowledgments

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AACCI Introduces a New Guideline for Food Shelf-Life Studies (AACCI Method 35-01.01)

AACC International Chemical Leavening Committee

How does a scientist explain something that is not clearly defined? "Shelf life" has been used as an undefined vocabulary term since the beginning of food production. In the 1970s, it was first discussed as a possible required label. In the 1990s, legislation was introduced to clarify the term, but was never passed. Today the food industry still struggles with the terminology and whether it is a quality attribute or a food safety attribute that plays into the label and guidelines.

Even Wikipedia struggles with defining "shelf life" as a term that refers to a product that is "unfit for sale, but not yet unfit for use" or to a product that is "unfit for use." While the term shelf life has a broad overarching definition, it is typically thought of as a process used to determine a code date value that will be used in a product specification.

AACCI has decided to utilize this moment to help define and establish guidelines for shelf-life studies. It is a broad topic without any structured guidelines, and AACCI is working to establish a series of guidelines for cereal-based products and their ingredients. The shelf-life studies guidelines will not focus on the food safety aspect of shelf life. They will focus instead on the quality attributes of shelf life and act as a starting place from which to build a common basis for the generation of shelf-life data.

The guidelines have been established through the AACCI Chemical Leavening Technical Committee. The intent of the Guidelines for Shelf-Life Testing of Food and Ingredients for Key Quality Attributes (AACCI Method 35-01.01) is to establish a guide that can be used to determine shelf life for grain-based foods with water activity lower than 0.65. The guidelines discuss storage conditions for suggested shelf-life studies, with an emphasis on using WHO-suggested or average environmental conditions.

The guidelines suggest the use of evaluations, including sensory evaluation. A large section of the guidelines addresses the evaluation of trends versus time.

The shelf-life studies guidelines has been established as a working document to be utilized as a framework for other AACCI Technical Committees focused on different matrices and products. Each committee is invited and encouraged to utilize the information and build on it for products that are the subject of their expert focus. The guidelines utilize the real-world conditions available. They assume attributes have an influence on quality over time. They acknowledge critical levels in the product associated with the end of shelf life. Finally, they acknowledge the rate of change associated with product variability through average and product variability.

AACCI is providing this first guideline to help construct a framework for other guidelines associated with shelf life and establish how-to's for testing shelf life in other products. For more information, visit http://methods.aaccnet.org.

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Spotlight on Kaisa Poutanen

"Spotlights" is a series of individual and institutional interviews capturing the unique stories of our many volunteers and their journeys with AACCI.

Kaisa Poutanen
VTT Technical Centre of Finland

Q: What is your current position and what type of work do you do?

A: I am a research professor at VTT Technical Centre of Finland, leading our strategic area Food Economy 4.0 and developing technologies for a new consumer-centric sustainable food ecosystem in the digital era.

Q: When and how did you first decide you wanted to work in cereal grain science and whole grains?

A: Well, my grandfather had a wheat mill, so I may have been exposed already during my childhood. I actually started working with cereals a lot in the 1990s, after being appointed a research professor in food technology. The general motivation of my working life is to promote healthy eating and studying our national food, whole grain rye bread, brought me into the area of whole grains.

Q: How have you been involved with AACCI? How is AACCI viewed by whole grain scientists in the global community?

A: I do not really consider myself a "whole grain scientist," rather a scientist who is working to use grains in the best possible way, i.e., for human food, including eating the outer layers and grain fiber complex as well! AACCI has been an active forum for discussion, especially concerning definitions relating to whole grain. I attended my first AACCI Annual Meeting in the early 1990s and most of the meetings thereafter. I realized that meeting was an excellent opportunity for networking, as well as for learning about the broad field of cereal grain science. I was a member of several committees, including the Scientific Advisory Panel. I also was a founding member, chair, and board member of the AACCI European Section, Cereals and Europe—it must be over 15 years ago now!

Q: What do you see as important issues shaping global research on whole grains? How are these issues affecting cereal science and the cereal grain industry overall?

A: The expansion of knowledge on the composition and structure of whole grains, as well as the epidemiology of their relevance in human health has been substantial. Research on biomarkers of intake hopefully will link population level work to intervention level work identifying better product attributes that are important for long-term health outcomes. I think we really need to consider consumer experiences and communication more in the future, as well as develop new product concepts, especially in the snack food categories. For oat, barley, and rye processing there are traditional uses as whole grains, but consumption is low compared with refined wheat products. We need to develop new technologies for including wheat bran in foods as well.

Q: This issue of *Cereal Foods World* focuses on carbohydrate quality. Do you have any perspectives on this topic?

A: I have given numerous lectures on this topic—it is not really about the quality of carbohydrates, but about their source, i.e., what comes with the carbohydrates! A carrot or apple is actually mainly sugar, if you look at the energy nutrients, but what makes them healthy is the consumption of water, vitamins, and fiber as part of the solid matrix of an enjoyable fruit. Carbohydrate quality is strongly dependent on nutrient density, e.g., eating more of the raw plant materials, rather than squeezing out and consuming only the pure carbohydrates.

Q: You were recently honored at the Whole Grain Summit for your leadership in whole grain research. Tell us about the award and what it means to you.

A: I received the Clyde H. Bailey Medal, the most prestigious ICC Award, for outstanding achievements in the service of cereal science and technology. Of course one feels honored when receiving an award, but also kind of embarrassed, as you do not work with awards in mind. I also feel honored to have had the opportunity to work with so many inspiring and nice colleagues, both at VTT and internationally, such as the HEALTHGRAIN Forum, and would like to share the distinction with them. In the end, it is working together that makes the career worthwhile.

Q: What's next for you?

A: I am currently working quite a bit on new protein sources to valorize side-streams to produce new hybrid ingredients. These are plant ingredients that contain both fiber and protein and can be used in creating more nutritious foods. I am also very interested in personalized food delivery, extending the work from ingredient design to agile, automated production with digital interfaces that allow the consumer to become a prosumer, i.e., choose the kind of food they wish to be freshly produced at the point of purchase. On-the-go is also an expanding market with great potential for developing new kinds of healthy cereal-based foods.

Thank You AACC International Corporate Members

Thank you to all our corporate members, who contribute their knowledge, expertise, and professional involvement to ensure the continued strength of the association and to promote excellence in cereal grain science worldwide. We appreciate their support and encourage you to contact them directly for detailed information on their products. Visit the AACCI Corporate Member web page for comprehensive company and contact information.

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News

10th Annual Best Student Research Paper Competition

2018 Finalists Announced

Congratulations to the five finalists who have been chosen to present their papers in the 10th annual Best Student Research Paper Competition. These students will travel to London, U.K., to compete during Cereals and Grains 18, October 21–23.

The competition challenges students to demonstrate their superior presentation skills, offering an opportunity for students to present their research and interact with the AACCI community at an early stage in their careers. The 2018 finalists and their papers are

- **Anke Böeswetter,** Leibniz-Institute for Food Systems Biology at the Technical University of Munich: "Comparative Studies on the Aroma of Gluten-free Rice and Gluten-Containing Wheat Bread"
- **Sabina Jakobi,** Technical University of Munich, Institute of Brewing and Beverage Technology, Research Group Cereal Technology and Process Engineering: "Physical Modification of Cereal Biopolymers During Grinding—Suitable Method for Decoding Structure-Function Relationships of Wheat Based Matrices"
- **Emma Jobson,** Department of Plant Sciences, Montana State University: "The Impact of Rht-1 Semi-Dwarfing Alleles on End Use Quality in Wheat"
- **Ana Maria Magallanes Lopez,** North Dakota State University, Department of Plant Sciences, Cereal Science Graduate Program: "Value-Adding Strategies for Deoxynivalenol Contaminated Grain: Characterization of Wet-Milling Fractions"
- **Leigh Schmidt,** Whistler Center for Carbohydrate Research, Department of Food Science, Purdue University: "Developing Phenolic-Mediated Stable Protein Matrices in Cereal Grains for Potential Control of Starch Digestion"

Plan to support these students when you attend Cereals and Grains 18!

People

In January, Briess Malt & Ingredient Co. welcomed Greg Niemann as vice president of sales and marketing. Greg is responsible for leading the Briess Sales and Marketing teams, developing new business relationships, and creating malt and ingredient solutions to meet customer needs. Greg holds a B.S. degree in business administration and management from the University of Wisconsin and has more than 35 years of experience leading sales, marketing, and cross-functional teams across many food channels, including retail, ingredients, comanufacturing, and private label brands in U.S. and international markets.

New Members

Bresciani, A., University of Milan, Milan, Italy
Butt, T., R&D manager, Smucker Foods of Canada, Markham, ON, Canada
Cardone, G., University of Milan, Milan, Italy
Cork, S., Charles Sturt University, Wagga Wagga, NSW, Australia
Gómez, B., biochemistry, Latitud, Montevideo, Uruguay
Hite, S., food scientist, Dawn Food Products, Jackson, MI, U.S.A.
Lee, B.-H., Gachon University, Seongnam, South Korea
Nakhchian, H., graduate student, Ferdowsi University of Mashhad, Mashhad, Iran
Schneider, A. A., student, University of Minnesota, Minneapolis, MN, U.S.A.
Suárez Estrella, D. P., University of Milan, Milan, Italy
Terron, G., Lancaster, NY, U.S.A.
Toutounji, M., Wagga Wagga, NSW, Australia
Watanabe, A., assistant manager, Nisshin Flour Milling Inc., Chiyoda-ku, Tokyo, Japan
Zhong, Y., St. Paul, MN, U.S.A.
Zhu, L., Decatur, IL, U.S.A.

Important AACCI Dates

August 2018

20. Cereals & Grains 18 early registration deadline

September 2018

17. Reservation deadline for Hilton London Metropole

October 2018

19–20. Chemical Leavening Short Course, London, U.K.

20. Enzymes in Cereal Grains and Cereal-Based Foods Short Course, London, U.K.

20. Methods in Action Practical Baking Quality Workshop, London, U.K.

21–23. Cereals & Grains 18 – AACCI Annual Meeting, London, U.K.

24. Rothamsted Research Post-meeting Tour, Harpenden, U.K.

For more information visit
aaccnet.org

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