

The State of Science Regarding Consumption of Refined and Enriched Grains

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The AACC International (AACCI) Scientific Advisory Panel and AACCI leaders have identified “Unifying the Grain Health Benefits Message” as one of five scientific opportunity areas. To this end, a two-day thought-leader meeting was held in January 2013 (17). One of the proposed action steps from this meeting was to develop a review of the benefits of grains. This is the second in a series of papers that will be published in Cereal Foods World to provide unified grain health messages as part of this scientific initiative.



Sometimes called “the quiet miracle,” enrichment of refined flour was initiated voluntarily in 1941 during World War II by U.S. bakers and millers (and was later mandated by the War Food Administration). The three main B vitamins (riboflavin, niacin, and thiamin) and iron were added back into refined flour in amounts equal to or higher than those found in whole grain flour. This health initiative eradicated beriberi and pellagra from the United States.

Immediately before the National Labeling and Education Act (NLEA) (10) was enacted by Congress in 1990, 37 U.S. states mandated that all refined flour be enriched. NLEA superseded those laws and made enrichment not mandatory anywhere in the United States. However, the act does require that if flour is enriched it must contain specific nutrients at mandated levels. According to the *Code of Federal Regulations*, 21 CFR 135.165 (12), enriched flour must “contain in each pound 2.9 milligrams of thiamin, 1.8 milligrams of riboflavin, 24 milligrams of niacin, 0.7 milligrams of folic acid, and 20 milligrams of iron.... It may contain added calcium in such quantity that the total calcium content is 960 milligrams per pound. Enriched flour may be acidified with monocalcium phosphate within the limits prescribed by 137.175 for phosphated flour, but, if insufficient additional calcium is present to meet the 960 milligram level, no claim may be made on the label for calcium as a nutrient.”

In 1996 the U.S. Food and Drug Administration (FDA) mandated that folic acid be added to all enriched flour at 140 µg/100 g of cereal-grain product by January 1, 1998, for the prevention of neural tube birth defects (51). It is estimated that ≈95% of the white (wheat) flour milled in the United States is enriched, and therefore, most Americans will never consume refined wheat flour that is not enriched.

This report provides an overview of research on the impact of grain consumption on health. It concentrates on enriched grains because the nutritional value of unenriched white flour is minimal: refined grain contains only one-quarter of the fiber and three-quarters of the protein found in whole grain, and 17 key nutrients are lost (52).

Wheat Allergies

A food allergy is an abnormal immune response to certain food proteins that cause the body to react to these proteins as if

they are harmful. An estimated 4–6% of U.S. children under age 18 and 4% of adults have food allergies (23). Although wheat is one of the eight most common food allergens in the United States, less than 0.5% of Americans are allergic to wheat. Nonetheless, as one of the “big eight,” it is covered under the food allergy labeling law of 2004, and food manufacturers are required to clearly list wheat on food labels (11).

It is important to distinguish food allergies from other non-immune-mediated adverse reactions to foods, particularly since more than 20% of adults and children alter their diets due to perceived food allergies (45). People who are allergic to wheat have an IgE (immunoglobulin)-mediated response to wheat protein. These individuals must avoid only wheat, not other grains. Although most children “outgrow” allergies to milk, egg, soy, and wheat, allergies to peanut, tree nuts, fish, and shellfish are often lifelong conditions (50). Diagnosis of a food allergy requires a detailed history, diagnostic tests such as skin prick tests and/or testing for a serum-specific IgE response to foods, and, in some cases, oral food challenges.

An allergic reaction to wheat involves IgE antibodies to one of the protein classes found in wheat—usually the seed-storage gliadin and glutenin proteins, although the allergic reaction can also be to some albumins and globulins. While reactions to gliadins are the most severe, reactions to glutenins occur more often.

Twenty-eight children with hypersensitivity to wheat proven by an open oral challenge at a median age of 21 months (range of 6 to 75 months) were studied by Kotaniemi-Syrjänen et al. (20). Wheat was subsequently tolerated by 59, 69, 84, and 96% of the children by age 4, 6, 10, and 16, respectively (20). Mostly small, short studies have been performed on those with wheat allergies (11). In three small studies, 25% of the children studied outgrew their wheat allergy after 1 year and 33% outgrew it after 2 years (39,40,54).

Some individuals have an allergic reaction when they inhale wheat flour, while others need to consume wheat to experience symptoms. There is also a condition called wheat-dependent, exercise-induced anaphylaxis, in which wheat is an allergen only during exercise. An allergic reaction can occur within minutes, or sometimes hours, of either consuming or inhaling wheat.

Celiac Disease

Celiac disease (CD) is not an allergic response, but is instead an autoimmune disease with a multitude of possible symptoms. To acquire CD one must be born with one or more susceptible genes. However, the presence of a susceptible gene does not mean that CD will occur. Two other factors need to be present as well—gluten protein and an autoimmune trigger. The trigger

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is usually an infection, but it can be an extreme stress, including psychological stress. To determine if one has CD, a blood test is needed, and if it is positive, then an intestinal biopsy is essential to confirm a CD diagnosis. Less than 1% of the U.S. population, or 3 million Americans (1 in 133), is affected by CD. There has been a rise in diagnosed cases, which has been attributed to heredity and may be partially due to improved testing methods and greater awareness on the part of the public and health professionals. Several other environment-based theories are currently being researched:

- Less breast feeding (antibodies are not passed to the infant)
- Introducing gluten too early or in too large quantities to infants who are no longer breast feeding (15,42)
- Keeping a child's environment too aseptic (they don't build up antibodies)
- Added gluten in the food supply
- Shortened fermentation times for commercial breads (14)
- Food-borne infections and viruses
- Increased incidence of cesarean births (infants do not receive bacterial flora during birth) (28)
- Excessive use of antibiotics and antacids
- Excessive salt intake (19)
- Changes in gut bacteria (41,43,55)

Non-celiac Gluten Sensitivity

Non-celiac gluten sensitivity (NCGS) is a new name for those who are sensitive to gluten and show some of the same symptoms as those with CD but who do not have a susceptible gene or damage to their intestinal tract (26). A gluten-free diet may be necessary to eliminate symptoms; however, some people with NCGS may be able to tolerate a minimal intake of gluten. The Center for Celiac Research and Treatment at Massachusetts General Hospital estimates that as much as 6% of the population may have NCGS (www.celiaccenter.org), while other researchers give estimates as low as 1% (7). There currently is no test for gluten sensitivity (www.bidmc.org).

Gluten Quantity and Quality

In spite of claims about the quality and quantity of gluten in modern wheat varieties, scientific evidence indicates there was no change in the gluten content of wheat in the United States during the 20th century (18). According to the U.S. Wheat Associates ("On-farm Protein 1979–2011"), the quantity of protein has stayed the same for 30 years, although this obviously does not equate with the quality of the gluten. Elsewhere, research conducted in the Netherlands (49) has found increased gliadin in 36 modern varieties of wheat compared with 50 older varieties. The GliA- α 9 epitope content was higher and the GliA- α 20 epitope content was lower in modern varieties compared with older varieties. Both modern and older varieties were identified that have relatively low contents of both epitopes, which might provide opportunities for breeding wheat varieties that are better tolerated (49).

A 2011 study in Europe concluded that breeding for yield and protein quality has been neutral for other grain components (44). Similar research has not been done in the United States, and the varieties and breeding are completely different, even between the United States and Canada. More research in this area must be conducted.

Acrylamide

Acrylamide was revealed as a major threat to the carbohydrate industry in 2002 when a Swedish study reported major amounts were found in the food supply (46). The International Agency for Cancer Research has classified acrylamide as a probable carcinogen in humans and a neurotoxin. It has also been shown to be a carcinogen and genotoxin in animals (22).

Acrylamide is formed at temperatures above 120°C when the amino acid asparagine reacts with carbohydrate foods as one of the many reactions that occur during the Maillard browning process. Thus, it has been present in the food supply since humans began cooking with fire. Foods in the American diet with the largest amounts of acrylamide include French fries, potato chips, cereal products, and brewed coffee; however, acrylamide can be formed in any food. Therefore, elimination of any food group will not eradicate this compound from the diet.

Manufacturers around the world have been working to reduce acrylamide in their products and have been quite successful. To date, no country has set regulatory limits on acrylamide in foods because there is not enough conclusive evidence to support it. Acrylamide is a chemical that is regularly reviewed in Europe, the United States, and Canada; however, until more research suggests dietary guidance should change, the current recommendations will remain in place.

Microbes in Wheat and Wheat Flour

Wheat and wheat flour are subject to contamination by the numerous microbial agents with which they come in contact during growing and processing. They have low moisture levels, so it has been assumed that they cannot support bacterial growth and that even if bacteria is present cooking eliminates it (21). However, Eglezos (6) discovered that even though wheat and wheat flour cannot support bacterial growth at normal moisture levels, bacteria can remain dormant for years. This was verified recently when 77 people in 30 states contracted *E. coli* from eating commercially available raw cookie dough. It was suggested that the wheat flour in the dough was the source (32).

According to a 2011 survey by ConAgra Mills, more than half of U.S. consumers have tasted raw commercial cookie dough, and 80% have licked the beaters or eaten raw dough when making baked goods at home (4). This suggests that consumers are not aware of the risks they are taking. Because the industry has only recently been made aware of these concerns, new treatments and sanitation techniques at the mill and processing, packaging, shipping, and storage facilities are still being sought (38).

It is notable that refined and enriched grains generally contain lower levels of heavy metals, mycotoxins, pesticides, and other mycotoxins because the outer layers of the kernel have been removed (31).

Glycemic Index and Glycemic Load

The glycemic index (GI) and glycemic load (GL) of enriched (and whole) grains have often been portrayed as negative attributes, and the health impacts of altering glycemic response remain a source of controversy for most health outcomes. Possible exceptions may include those with diabetes, certain populations, such as sedentary and overweight or obese women, and insulin resistant individuals (13).

GI is defined as the incremental area under the blood glucose response curve of 50 g of available carbohydrate of a test food, expressed as a percentage of the response to the same amount of

carbohydrate from 50 g of glucose ingested by the same subject. GI takes into consideration the quantity of food in addition to GL and, therefore, may be a more realistic measurement. GL is calculated by multiplying GI by the number of grams of carbohydrate in a serving of food.

Each person's glycemic response varies considerably from that of other people and from day to day even when the same food is eaten. Glycemic response also varies according to the meal eaten previously or even the night before (35). For example, when caffeine was consumed during a meal of either high- or low-GI cereals, blood glucose levels rose 147 or 216% higher, respectively (34).

Variability is also caused by the content and type of sugars in a food, the proportion of amylose and amylopectin and whether the starch in a food is raw or gelatinized, the kind and degree of cooking and processing of a food, and whether the food is eaten hot or cold and alone or with other foods. Foods eaten a day or more prior to the test, the degree of chewing, and the speed of ingestion and whether glucose and insulin secretion are normal also change the glycemic response (16). Finally, fat and protein lower the glycemic response to foods, which can lower the GI of a food if it is fried (e.g., French fried versus baked potatoes) or if it delivers a high quantity of protein.

Using GI to choose foods is not recommended by the 2005 and 2010 U.S. *Dietary Guidelines for Americans* because research has not shown it to be linked to body weight or other health outcomes (48). Increased cereal fiber content, on the other hand, is associated with lower body mass index (BMI), reduced risk of type 2 diabetes, and cardiovascular disease and is more indicative of a health-promoting diet than is use of GI or GL to select diets.

Loss of Vitamins and Minerals in Processing

Vitamins, minerals, and fiber are lost during the milling process, resulting in lower levels in refined grains than in whole grains. However, enriched grains contain 2 times more folic acid and riboflavin and 1.5 times more thiamin riboflavin and have been credited with eradicating pellagra and beriberi in the

United States. Neural tube birth defects have also decreased by one-third since folic acid fortification of enriched grains was mandated by the FDA in 1998. The Centers for Disease Control and Prevention named this fortification mandate as one of the top 10 most successful health initiatives of the first decade of the 21st century (3). Canada has experienced a 46% reduction in neural tube birth defects during the same time period as a result of folic acid fortification of enriched grains (5,24,36,37).

Chile began fortifying wheat flour with folic acid in 2000 and has reduced spina bifida by \approx 55%, while Argentina has reduced its incidence by 48% (25). Costa Rica reports a 60% reduction in spina bifida (2) and Oman a 70% decrease related to folic acid fortification (1). In the United States, the 36% decrease in neural tube birth defects due to folic acid fortification has resulted in a total savings of \$4.7 billion in direct healthcare costs (8). The Flour Fortification Initiative reports a decrease in neural tube birth defects of 30 to 70% in the 57 countries around the world that are fortifying flour with folic acid (9).

In April 2012, the Gruma Corporation and five public service organizations petitioned the FDA to allow corn masa flour to be fortified with folic acid at the same level as wheat flour (27). The Hispanic population experiences a disproportionately higher incidence of neural tube birth defects and consumes less folic acid in wheat flour because masa flour products often replace wheat flour products in the Hispanic diet.

Overall Effects of Enriched Grains in the Diet

Contrary to urban legend, a 2012 *Nutrition Reviews* article (53) reports that enriched grains are not detrimental to a balanced diet. In the article, Williams (53) reviewed 135 relevant articles published between 2000 and 2010 and concluded, "The totality of evidence shows that consumption of up to 50% of all grain foods as refined-grain foods (without high levels of added fat, sugar or sodium) is not associated with any increased disease risk." (However, he also highly recommends increased consumption of whole grains).

Two studies from the Framingham Offspring Cohort were used to support Williams' conclusions. The first study (2,941

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participants) found no negative association between BMI, waist-to-hip circumference, blood pressure, lipids, insulin, or glucose with servings of enriched grain at the highest quintile (5.5 servings/day) (30). The second study (2,834 subjects) found that enriched grains had no increased relationship with metabolic syndrome or insulin resistance (29). The Baltimore Longitudinal Study of Aging showed no relationship between enriched-grain intake at the highest quintile (103 g/day) with BMI, waist-to-hip circumference, blood pressure, overweight, cholesterol, or fasting glucose in 1,516 subjects (33).

Adding further weight to the argument for the benefits of enriched grains in the diet, the 2010 *Dietary Guidelines for Americans* (47), which are based on scientific research, recommends the consumption of both whole and enriched grains.

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