With the Grain:
A closer look at the nutrient quality of grain, grain-based products, and the role of organic agriculture

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Preface

Organic production systems have distinct impacts on both grain quality and safety, in addition to well-documented environmental benefits. Yet there is remarkably little information available on the nutritional and food safety advantages of organic farming and food manufacturing in the grains and grain-based food product sector.

To close this knowledge gap, The Organic Center is conducting a multi-year grain study to document the nutritional differences between conventional, “natural,” and organically farmed grains and grain-based products. We are systematically seeking answers to the following critical questions: How do conventional and organic farming and manufacturing processes impact food quality? What toxins and food additives are present in raw and finished products? How do milling and cooking alter nutrient composition?

The study will draw on published research and data from our own testing, and encompass the following topics:

- Nutrients and calories per serving
- Protein levels and fiber content
- Pesticide residues and risk levels
- Mycotoxins
- Total antioxidant capacity (as measured by ORAC)
- Mineral levels
- Presence/absence of additives
- Presence/absence of preservatives
- Taste and organoleptic quality

In this report—the second of a series of reports to be issued as part of the study—we explore the nutrient content of grain and grain-based products. Our goal is to provide a broad overview of the differences in nutrient content between organic and non-organic grains. We hope that a better understanding of these differences will highlight the need for agricultural scientists to focus on nutrients as much as yields and also empower consumers to make healthier choices.

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Executive Summary

Grains are often an important part of a healthy and nutritious diet. But not all grains or grain products are created equal. Whole grains provide many health benefits and are important in the prevention of chronic diseases. Increasing research has shown that many of the health benefits of whole grains come from not only the higher fiber content, but also their rich variety of vitamins, minerals and health-promoting phytochemicals, many with antioxidant activity (Jonnalagadda et al., 2011). While most antioxidant research has focused on fruits and vegetables (Asami et al., 2003; Benbrook, 2006; Boxin et al., 2004; Dewanto et al., 2002; Ferguson et al., 2002; Jiratanan and Liu, 2004), whole grains are also valuable sources of antioxidants. As grains are the largest single source of calories consumed worldwide, they are arguably one of the most important sources of antioxidants.

Using our new nutrient profiling system, The Organic Center Nutrient Quality Index (TOC-NQI), we are able to take a closer look at the nutrient content of whole grains and grain-based products and their contribution to recommended daily intakes. The results show that whole grains are indeed an excellent source of many essential nutrients and often more nutrient-rich than their refined grain counterparts.

But are we really getting the most out of our grains? Is there a way to improve the nutrient quality of even whole grains and grain-based products? What role might organic farming and manufacturing play in further enhancing organic grain-based product quality?

Scientists have known for years that many of the health-promoting nutrients in grain are lost before they reach the table. Consumer preference for fine white flour and grains (such as white rice) means that, on average, about 75% of the nutrients found in grains, including protein, fiber, vitamins, minerals and antioxidants, are left in the mill (Davis, 1981). But there is more to the nutrient story. There are many variables that influence grains in the field and each of these have their own impact on nutrient content.

It begins with the seed. Nutrient content can differ, often significantly, between different varieties of grain. For example, nearly all of the wheat grown today is varietals of two species—Durum wheat (*Triticum durum*) and common or bread wheat (*Triticum aestivum*). Common bread wheat makes up 90-95% of the wheat cultivated worldwide (Pena, 2002). This was not always the case. Historically a number of other species were also cultivated, including einkorn (*T. monococcum*), emmer (*T. dicoccum*), spelt (*T. spelta*), and Kamut® khorasan (*T. turgidum ssp. turanicum*). There are also numerous landraces or native varieties found throughout the world. Recent research has shown that many of these older varieties are higher in micronutrients, including calcium, magnesium, iron, zinc, copper, selenium and most notably antioxidants (Serpen et al., 2008; Gianotti et al., 2011). By decreasing the diversity of the grain we grow, the grain we eat is not as nutrient-rich as it could be.

But genetic diversity is only one player in the game of nutrition and, alone, does not always guarantee increased nutrient levels. Over the past century, plant scientists and breeders have focused more attention on breeding and planting of higher-yielding varieties rather than nutrient content. As a result of American agriculture's laser-like focus on yield growth, today's farmers grow far more pounds of grain per acre of land than decades ago. Within the past 50 years, yields of most major crops, including wheat, have doubled or tripled. But in step with increased yields, nutrient concentrations have declined—a phenomenon known as the "dilution effect." As a result, today's crops are less nutritious and deliver fewer nutrients per serving and per calorie (Halweil, 2007; Di Silvestro, 2012).

In addition to plant genetics, soil type and soil quality, growing temperatures, moisture levels, and other climatic differences and pests can all affect the total nutrient content of grains at time of harvest (Benbrook, 2006; Brandt et al., 2002; Wang et al., 2000; Wang et al., 2002). Harvesting time and "ripeness" also have an impact. These variables will always differ from year to year and farm to farm, and impact the performance of all farming systems in exceedingly complex ways.

But what role does organic farming have to play in improving nutrient content?

Organic farming systems do have impacts that could lead to greater nutrient content in grain crops. Conventional agricultural methods, with their abundance of certain soil nutrients, water, and other resources, produce grains that are less nutrient rich and/or less optimally balanced nutritionally. Soil nutrients in organic form—whether from compost, manure, or other decomposing organic matter—can meet the needs of a growing crop and are often more readily available to plant roots and the resulting crop. Biologically-based sources of plant nutrients tend to be released more slowly, and as a result, remain available over more of the season. In addition, organic matter stimulates healthy root growth, allowing plants to reach nutrients found in deeper soil. Organic matter-rich soils also serve as a buffer against weather extremes by absorbing and retaining excess water in wet periods and releasing water in dry periods. Soil microorganisms, fungi, and bacteria that depend on organic matter help nourish the soil. Research has found that mycorrhizal (a type of beneficial fungi) treatment can increase copper, selenium and zinc uptake by almost 30% (Jarrell and Beverly, 1981; Ward et al., 2001).

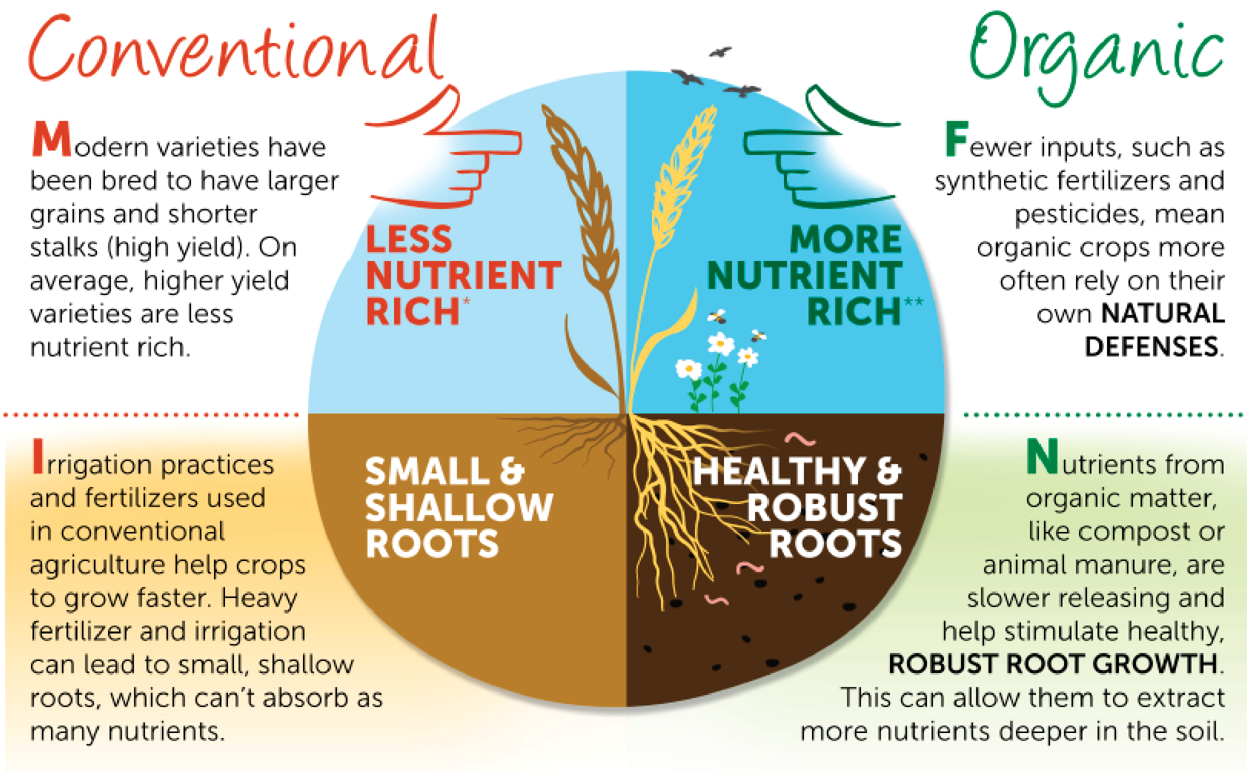
The nutrient differences between organic and conventional grains tend to be less than those found in fruits and vegetables. But overall, there is agreement that consistent differences do exist, especially in antioxidant levels (Adom et al., 2003; DiSilvestro et al., 2012; Fardet, 2010; Gianotti et al., 2011; Liu et al., 2010; Moore et al., 2005; Orkater and Liu, 2010; Serpen et al., 2008; Yu et al., 2002). Many phytochemicals found to have strong antioxidant activity are produced in plants in response to environmental stresses, such as insect attacks and plant disease threats. Organic and other low-input agricultural systems, with their lack of chemical pesticide use, are exposed to more of these external stresses and as a result their phytochemical content is often higher than those grown in conventional conditions (Manach et al., 2004; Zuchowski et al., 2010; Lammerts van Bueren et al., 2011).

Recent research shows that all varieties of wheat contain significant amounts of phenolic acids, flavonoids, and carotenoids, including lutein, zeaxanthin, and β-carotene. There are currently no official government RDAs for these antioxidants, but because of the wealth of research on their important roles in health, they are found in many multivitamins and sold in stand-alone products. With greater research, we are beginning to gain a better understanding of how they work in the body and are now able to estimate the amounts needed to maintain and promote health.

The factors that influence nutrient content are many and varied and some, such as climatic differences, are uncontrollable. But there are steps along the market chain from field to table where changes can be made to ensure bread is as nutrient rich as possible. In the field, the planting of varieties known to have higher nutrient content, including older varieties and landraces, is an important first step. The additional benefits of organic system management can lead to substantial differences in antioxidant and nutrient levels. As demand continues to grow for organic grain-based products, yield growth will remain important and within reach, as scientists use breeding techniques to identify genes associated with high-nutrient levels in older varieties and work to incorporate just those genes in otherwise well adapted, high-yielding modern varieties.

Another critical challenge for organic farmers is to determine if there is a way to improve yields in more nutrient and antioxidant-rich organic grain, by building soil quality, and delay the onset of the dilution effect.

A deeper understanding is needed of the relationships between plant genetics, yields, soil quality, and management practices to find the best balance. With appropriately targeted research focused equally on grain quality and crop yields, grains will take their rightful place as one of the global food system's vital sources of nutritious food.



Introduction

Grains are often an important part of a healthy and nutritious diet. But not all grains or grain products are created equal. Whole grains provide many health benefits and are important in the prevention of chronic diseases. Research has shown that increased consumption of whole grains can substantially reduce heart disease (Steffen et al., 2003), play an important role in maintaining a healthy weight and body mass index (BMI), and regulate blood glucose and insulin responses, helping to prevent Type 2 diabetes (Jonnalagadda et al., 2011). The fiber in whole grains helps maintain gastrointestinal health. Because of these benefits, the USDA's 2010 Dietary Guidelines for Americans recommend that at least three servings a day should be of whole grains.

Consumption of whole grains is rising. According to the Whole Grains Council, whole grain consumption increased 20% between 2005 and 2008, but it is still far below the USDA's recommendation. Americans love refined grains and grain products. On average in 2008 they consumed less than one serving per day of whole grains, or 11% of their daily grain consumption (Whole Grains Council, 2009). Another study based on USDA data found higher levels of whole grain consumption—15% in 1994–1995 (Cleveland, et al., 2000). However, both estimates are far less than the 50% or more recommended by the USDA (2010). Most of us are not getting the full health benefits of grains.

Increasing research has shown that many of the health benefits of whole grains come from not just the higher fiber content but also their rich variety of vitamins, minerals and health promoting phytochemicals. In particular, whole grains are a rich source of many antioxidants. The Organic Center Nutrient Quality Index (TOC-NQI) is an exciting new tool that provides a broad-based measure of the nutritional benefits of food, including individual foods, multi-ingredient foods, and whole meals. Using this nutrient profiling system, we are able to take a closer look at the nutrient content of whole grains and grain-based products and their contribution to recommended daily intakes. The results show that whole grains are indeed an excellent source of many essential nutrients and more nutrient-rich than their refined grain counterparts.

And yet, the effect of processing is only one piece of the nutrient puzzle. Most grains harvested today are not as nutritious as they once were or could be. In the field, genetics, climate, and soil richness all influence nutrient content in various ways. Different farming systems also have an important impact, and there are emerging answers to the question—are organic grains more nutritious than those grown conventionally? Together these factors form a mosaic of influence that dramatically affect the nutritional quality of grain consumed today.

The Organic Center is taking a closer look at the factors that influence the nutrient content of grains, and asking—are there ways to improve the nutrient quality of grains? What role does organic cultivation have to play in this? Can organic grains help further boost the nutrient advantage of whole grains?

We hope a better understanding of the nutritional quality of grains will help consumers make smarter food choices and benefit from the potential health-promoting qualities of whole grains. In addition, a better understanding of the influences from seed to table will show ways in which nutrient contents can be improved.

What is a Whole Grain?

There is currently no accepted international definition of whole grains. The Whole Grains Council, a North American nonprofit consumer advocacy group, defines whole grains as "grains or foods that contain all the essential parts and naturally-occurring nutrients of the entire grain seed. If the grain has been processed (e.g., cracked, crushed, rolled, extruded, and/or cooked), the food product should deliver approximately the same rich balance of nutrients that are found in the original grain seed."

Food labeled as "whole grain" must contain at least 51% intact whole grain (other than bread, for which "whole wheat" means 100% whole wheat) or components of whole grains recombined to the relative proportion of those naturally occurring in the grain. Most whole grain products are made from recombining whole grain components (Jonnagaladda et al., 2011).

However, some argue that recombined whole grain parts should not be considered a true whole grain as they rarely contain the same proportions of bran, germ and endosperm as intact grain. The germ, which is often the most nutrient rich portion of grains, is almost always removed because of its high fat content that can go rancid during storage (Fardet, 2010).

Grains and Nutrients

While whole grains are well known as rich sources of fiber, they are also an excellent source of vitamins, minerals, inulin and numerous health-promoting phytochemicals, including cinnamic acids, anthocyanins, quinones, flavonols, phenolic compounds, tocols, and carotenoids. Some of these compounds are not present in significant amounts in fruits and vegetables. Many of them have antioxidant activity, play a role in hormone function, and boost the immune system (Adom et al., 2003).

Wheat is the most widely consumed grain in the U.S., with the average consumption per capita of 148 pounds per year (United States Department of Agriculture, 2006), followed by corn, oats, barley and rice. In addition to fiber and protein, whole wheat is an excellent source of B vitamins, such as thiamin, riboflavin, niacin, vitamin B_6, and pantothenic acid, plus minerals such as iron, zinc, magnesium, and selenium. It is also a good source of the many health promoting phytochemicals mentioned above. Most of the wheat consumed today is a varietal of two species—durum wheat (*Triticum durum)*, a hard wheat used to make pasta, and common or bread wheat (*Triticum aestivum*). Other types of wheat include spelt, Kamut®, triticale, emmer, and einkorn.

Figures 1-3 show the breakdown of the vitamins and minerals found in 440 calories (20% of the energy RDA for women age 19-30) of whole wheat and white flour in the U.S. in comparison with the RDA or estimated RDA for each nutrient. Wheat contains modest to substantial amounts of 25 nutrients that are essential for human health. It lacks only vitamins A, B_{12}, D and C, and iodide.

Figure 1. Percentage of RDAs for nutrients and minerals found in 440 calories of whole wheat and white flour.

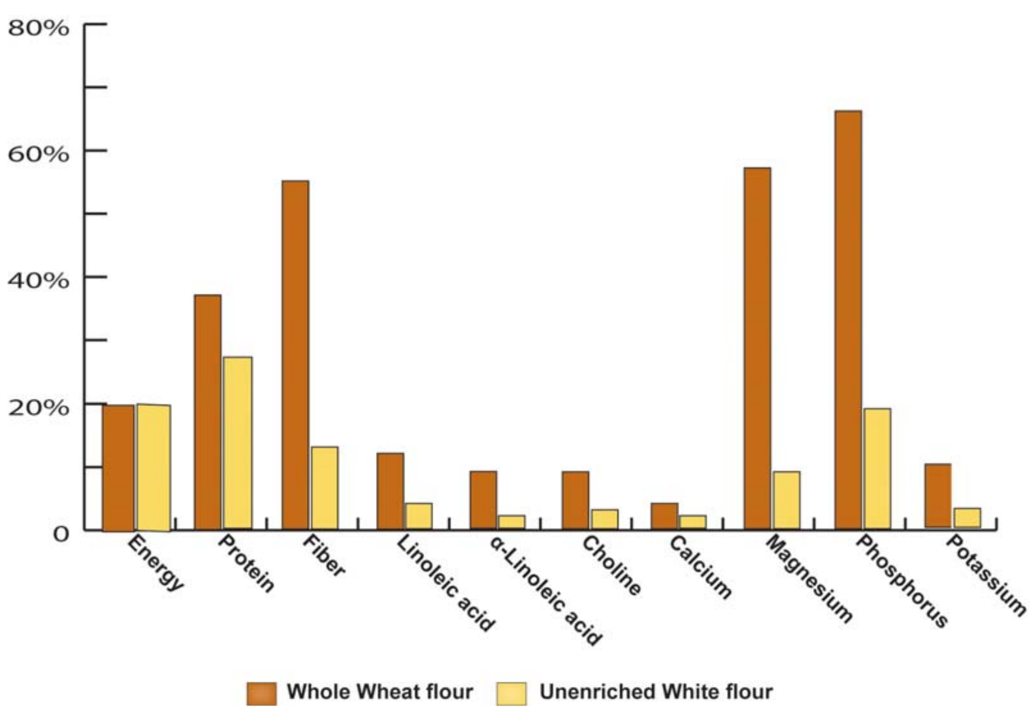


Figure 2. Percentage of RDAs for additional minerals found in 440 calories of whole wheat and white flour (the rose colored bar represents added iron with enrichment).

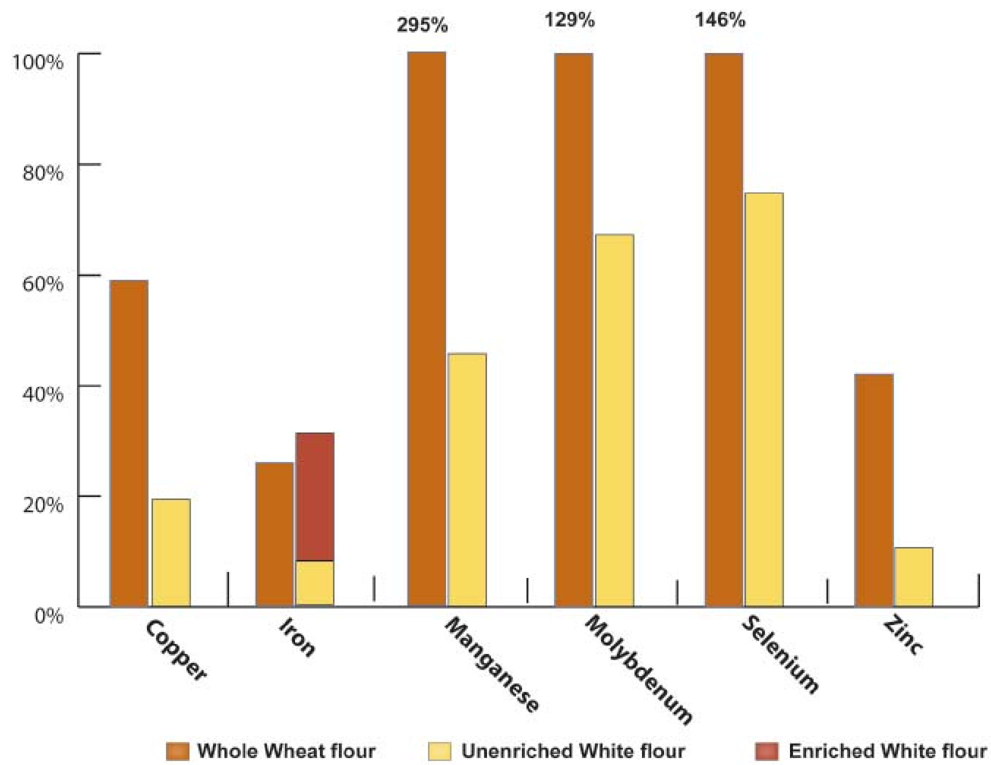
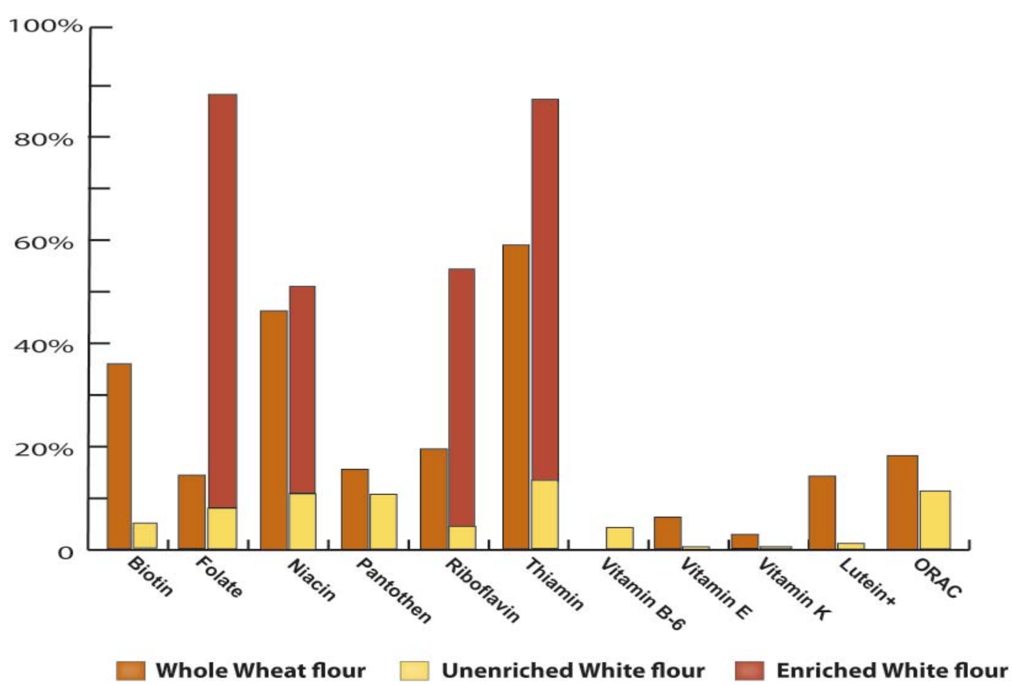


Figure 3. Percentage of RDAs for vitamins found in 440 calories of whole wheat and white flour (the rose colored bar represents added vitamins with enrichment).



Additional grains widely consumed in the U.S.:

Corn is the second most consumed grain in the U.S. Most corn products are degermed. Increasing amounts of whole corn products are available, but relatively few are marked as such. Popcorn is the most consumed form of whole corn, but most corn tortillas are also made from nearly whole corn. Corn is a good source of B vitamins, magnesium, and phosphorus. Yellow corn is also high in carotenoids, particularly lutein + zeaxanthin. Recent research suggests whole corn might also help increase healthy gut flora (Carvalho-Wells, 2010).

Rice is the second most consumed grain globally, with an average per capita consumption of 126 pounds per year (Food and Agricultural Organization). Most rice consumed in the U.S. and elsewhere is refined white rice, with the bran and germ removed. Whole grain rice, with the bran and the germ, can be found in various colors, including brown, red, and black. Whole rice is high in antioxidants, manganese, B vitamins, magnesium and phosphorus and has been shown to play an important role in lowering the risk of Type 2 diabetes (Sun et al., 2010). Wild rice (*Zizania spp.*) is not related to Asian rice but is also high in essential nutrients, including zinc, niacin and folic acid.

Barley is largely consumed refined as it has a particularly tough hull that is difficult to remove without losing some of the bran. Pearled barley has the bran and germ removed and is commonly used in breads and other multigrain products. Whole barley, with intact germ and bran retains more of its nutrients, but is very slow-cooking. Recent research shows that barley helps regulate blood sugar levels and lower cholesterol (Priebe et al., 2010; Talati et al., 2009). Barley is rich in vitamin E, niacin, folic acid and magnesium. Whole barley is high in phenolic compounds, particularly *p*-coumaric acid.

Oats are one of the few grains that are primarily consumed in their whole form. Oat fiber is rich in β-glucan that lowers cholesterol (Tiwari and Cummins, 2011). Oats also improve gastrointestinal health, boost the immune system, are anti-inflammatory and help lower blood sugar levels. Oats are very high in thiamin, a B vitamin important in cardiovascular and nervous system health. In addition, they are rich in vitamin E, iron, zinc and phenolic acids.

In addition to the many vitamins and minerals essential to overall health, wheat and other grains are an excellent source of phytochemicals. Many of these are secondary compounds found in plants. While they are not essential for the life of the plant, these compounds have supporting functions, such as protecting the plant from external stresses like pests and weather extremes. In humans, many have antioxidant activity and are important for the prevention of many chronic diseases, including obesity, heart disease and certain cancers. The main phytochemicals found in grains include:

Phenolic compounds are part of the chemical defense system of plants, protecting against pathogens, parasites, and other predators. In humans they function as antioxidants. Ferulic acid is the most studied and is particularly high in wheat (Jonnagladda et al., 2011;

Manach et al., 2004; Benbrook, 2006). It is an important antioxidant believed to have anti-tumor properties and lowers the risk of certain cancers, such as colon cancer (Moore et al., 2009; Chatenaud et al., 1998). Additional phenolic compounds include flavonoids, resveratrol, and anthocyanins. Corn has the highest phenolic content, followed by wheat, oats, and rice (Jonnagaladda et al., 2011).

Carotenoids are a group of compounds that provide pigment and play an important role in plant reproduction and protection. In humans, they act as antioxidants, and some are precursors to vitamin A, specifically β-carotene, β-crytoxanthin, and α-carotene. Other carotenoids include lutein and zeaxanthin. These are molecularly very similar and are often reported together as lutein+zeaxanthin. Both are believed to be important for the eyes and vision and have been associated with reduced risk for cataracts and age-related macular degeneration.

Vitamin E, as tocopherols and tocotrienols, are fat-soluble compounds found in various proportions in grains and function in the body as antioxidants that help maintain cellular membrane integrity. Wheat tocopherols are more easily assimilated than other Vitamin E food sources (Di Silvestro, 2012).

Many researchers feel these phytochemicals are mostly responsible for the health promoting effects of whole grains. While each of these nutrients has their own individual health benefits, some researchers feel the beneficial effect comes from a synergistic contribution of all the nutrients (Jonnagalada et al., 2011; Liu, 2004; Okarter and Liu, 2010; Gianotti et al., 2011; Benedetti et al., 2012).

Other important nutrients found in grains include:

Dietary fiber is the indigestible portion of plant foods and plays an important role in digestive health. It helps lower cholesterol, prevent colon cancer, and maintain healthy blood glucose and insulin levels. Fiber also includes β-glucans, oligosaccharides and inulin that act as prebiotics, helping feed intestinal flora and supporting the immune system. Lignans, also found in fiber, have phytoestrogenic effects and may help prevent hormone related cancers (Buck et al., 2010).

Other nutrients found in grains include essential and non-essential fatty acids, primarily oleic and linoleic acid, both of which have been found to lower cholesterol levels and prevent heart disease.

Grains today are mostly consumed in grain products rather than whole. Processing has a significant impact on nutrient content and many of these important nutrients are lost in the mill. This makes it difficult for consumers to know which grain products make the most nutritional sense.

The Organic Center's Nutrient Quality Index

The Organic Center's Nutrient Quality Index (TOC-NQI), launched in Identifying Smart Food Choices on the Path to Healthier Diets (www.organic-center.org/science.environment.php?action=view&report_id=188), is a new nutrient profiling tool to help consumers identify the best nutritional food choices. The TOC-NQI quantifies and adds together the nutritional contribution of each food by measuring the levels of 27 nutrients relative to the recommended daily intakes of these nutrients.

These 27 nutrients (most of which are found in grains) include eleven vitamins, eight minerals, protein, fiber, antioxidant capacity as measured by total ORAC, lutein+zeaxanthin, linoleic and linolenic acid, lycopene and choline. A food's TOC-NQI value is the sum of that food's contribution to daily nutrient needs across these 27 nutrients. The food's contribution of a single nutrient, say vitamin C, is a simple ratio—the amount of vitamin C in the food, divided by the recommended daily intake of vitamin C. The combined contributions of all 27 nutrients can be calculated per serving, per calorie, or per gram and the resulting TOC-NQI values can be compared for single foods (tomato versus apple), multi-ingredient foods (pepperoni pizza), meals, and even daily diets. TOC-NQI values are scaled so that a daily diet that supplies exactly the recommended amounts of all 27 nutrients—no more, no less—will have the value of 1, or one "nutrition unit." But no food or diet has such an exact distribution of all 27 nutrients. Some nutrients are always present at higher than recommended amounts. To account for these surpluses, a healthy diet should have a total TOC-NQI value of about 1.5 or higher.

Fresh vegetables deliver the greatest nutrient bang per calorie. A 100-calorie portion of the top 10 most widely consumed vegetables delivers an average TOC-NQI of 0.25, or 0.25 "nutrition units." So, very roughly speaking, if all 27 nutrients were distributed exactly in line with RDAs across four different vegetables, just four 100-calorie portions of vegetables could provide adequate amounts of the nutrients needed by a person in a given day.

Whole Grains

Data on the nutrient content of grains and grain products shows the strong impact of refining and processing on their nutrient levels. There are significant differences between whole grain and refined grain products, because their nutrients are concentrated in different parts of the grain. Whole grain seeds consist of multiple layers: the outer bran layer contains most of the phenolic compounds, vitamins, minerals, and fiber; the inner germ, which contains most of the fat, including vitamin E; and endosperm (the largest part of the grain), contains some of the vitamins and minerals and most of the carbohydrates, protein, and oligosaccharides. During the refining of wheat seeds into white flour, the outer bran and inner germ layers are removed and the remaining endosperm is processed into flour. Most white flour is 70–75% "extraction," meaning up to 25% of the original grain is not in the flour. Whole grain flour includes all parts of the seed and is 100% extraction.

The most commonly consumed whole grains supply about 0.03–0.06 TOC-NQI units per 100 calories. While this is much less than vegetables and fruits, whole grains are valuable as low-cost sources of protein, fiber and many other nutrients, especially antioxidants. The largest contributors to most grain TOC-NQIs are fiber, protein, and total antioxidant capacity as measured by ORAC. Lutein+zeaxanthin is the largest contributor in corn meal and α-linolenic acid (ALA) and magnesium are high in flax meal. ALA is an essential fatty acid that has been shown to help prevent heart disease and certain cancers. The top three whole grains based on their TOC-NQI values are dark rye flour at 0.088 per 100 calories, barley at 0.062, and triticale at 0.058.

Table 1. Whole Grains Nutritional Quality Index (NQI)					
Whole Grains	**Per 100 Grams**	**Per 100 Calories**	**Per Serving**	**Serving Size**	**Serving Calories**
Whole wheat flour	0.191	0.056	0.054	1 ounce	97
Brown rice, raw	0.119	0.032	0.034	1 ounce	105
Corn meal, whole	0.170	0.047	0.048	1 ounce	103
Oatmeal, dry	0.171	0.045	0.049	1 ounce	108
Rye flour, dark (whole)	0.285	0.088	0.081	1 ounce	92
Wild rice, raw	0.171	0.048	0.048	1 ounce	101
Barley (whole), raw	0.221	0.062	0.063	1 ounce	101
Triticale flour, whole	0.196	0.058	0.056	1 ounce	96
Amaranth grain, raw	0.181	0.049	0.051	1 ounce	105
Kamut ® grain, raw	0.190	0.056	0.054	1 ounce	96
Average NQI Score	**0.190**	**0.054**	**0.056**		**95**

Most people consume grains in grain products such as bread, crackers and cereals. According to the Whole Grains Council, households eating mostly "whole wheat bread" increased from 45% in 2004 to 52% in 2008 (although most likely this refers to partially whole wheat breads). A one-slice serving of whole wheat bread delivers 0.037 nutrition units, compared to 0.055 nutrition units for one medium apple. The 0.037 nutrition units in a slice of whole wheat bread exceed the ratings for typical servings of four of the top 10 most consumed vegetables—potatoes (0.034), onions (0.031), iceberg lettuce (0.021), and cucumbers (0.009).

Other whole grain products such as Shredded Wheat have TOC-NQIs per 100 calories similar to whole wheat grain. The relatively higher values for Wheaties, Cheerios and All-Bran cereals reflect the presence of added nutrients, delivering 10% to 100% of the RDAs in a single serving. Nutrient fortification in these brands doubles or triples their TOC-NQIs compared to the grain ingredients alone.

Table 2. Whole Grain Products Nutritional Quality Index (NQI)					
Whole Grain Products	**Per 100 Grams**	**Per 100 Calories**	**Per Serving**	**Serving Size**	**Serving Calories**
Bread, whole wheat	0.138	0.056	0.037	1 slice	67
Bread, 7-grain (whole)	0.141	0.053	0.037	1 slice	69
English Muffin, whole wheat	0.126	0.062	0.083	1 each	134
Cracker, whole wheat (Triscuit)	0.178	0.043	0.053	6 crackers	120
Shredded Wheat cereal	0.170	0.050	0.048	1 ounce	96
Rice cake, brown rice	0.110	0.028	0.030	2 cakes	104
Tortilla, corn*	0.116	0.052	0.030	1 tortilla	58
Wheaties cereal	0.488	0.141	0.139	1 ounce	99
Cheerios cereal	0.448	0.122	0.127	1 ounce	104
All-Bran cereal	0.767	0.295	0.218	1 ounce	74
Average NQI Score	**0.268**	**0.090**	**0.080**		**93**
*Lightly refined—the bran is partially removed in the processing of corn tortillas (de la Parra, 2007).					

Refined Grains

Many nutrients are lost during the milling process to refine grains, which removes the more nutrient- and fiber-rich portions of grain to leave a finer and whiter flour preferred by most consumers. On average only about 20–30% of the original vitamins and minerals found in whole wheat remain in refined flours (before enrichment) (Davis, 1981).

Refined grain products consistently score lower on the TOC-NQI, illustrating the nutrients lost in the nutrient-rich germ and bran portions of the grain. A whole wheat English muffin has a TOC-NQI value of 0.126 per 100 g, whereas a refined English muffin served at McDonald's is 0.091 per 100 g. On top of this the McDonald's English muffin is higher in calories. Similarly, whole-wheat Triscuit crackers have a TOC-NQI score of 0.178 per 100 g and a refined Saltine cracker is 0.124 per 100 g. The greatest contributors to the TOC-NQI value for the whole-wheat cracker and English muffin are fiber and ORAC.

Table 3. Refined Grain Products Nutritional Quality Index (NQI)

Refined Grain Products	Per 100 Grams	Per 100 Calories	Per Serving	Serving Size	Serving Calories
Bread, wheat, enriched	0.110	0.041	0.027	1 slice	67
Bread, white, enriched	0.094	0.035	0.023	1 slice	67
Bread, rye	0.111	0.043	0.022	1 slice	52
Bread, oatmeal	0.099	0.037	0.027	1 slice	73
Bread, French	0.096	0.033	0.024	1 slice	72
Cornbread	0.075	0.024	0.021	1 ounce	89
English Muffin, McDonald's	0.091	0.032	0.052	1 each	162
Cracker, Saltine	0.124	0.030	0.019	5 crackers	63
Pancake, complete mix	0.061	0.031	0.047	1 (6")	149
Average NQI Score	**0.096**	**0.034**	**0.029**		**88.2**

Enrichment and Fortification

Enrichment of refined flours began in the United States in the 1940s, and it has remained almost unchanged since then. Iron, niacin, riboflavin, and thiamin are added in amounts approximating those lost in milling or more depending on their known health benefits. Calcium is also commonly added to bread. Since 1996, folic acid is also added for its role in preventing neural tube birth defects. All refined or partially refined wheat, rice, and corn meal are enriched with these added nutrients.

Yet as seen with the TOC-NQI, even these added nutrients do not fully make up for those lost in the refining process. The TOC-NQI per 100g for refined grain breads is only about 0.10 even after being "enriched," compared to about 0.15 for whole grain breads. Despite the added nutrients, their TOC-NQIs are less than the values for whole grain breads, reflecting their losses of fiber, magnesium, potassium, vitamin B_6, and health promoting phytochemicals that are not added.

Refined or white flour is the leading ingredient in most breads, including some with names that may suggest otherwise, such as Bran and Wheat Bread, most Multigrain Breads, and Oatmeal Bread. Only 100% Whole Wheat Bread is certain to list no white flour as an ingredient. White flour can be confusingly labeled as "flour," "wheat flour," or "unbleached flour."

Refined grain cereals also lack bran and germ, and most of them contain 20% to 40% added sugar. Many cereals like Wheaties, Cheerios, Special K, and All-Bran are fortified with substantial amounts of 10 to 12 vitamins and minerals, including some not naturally present in whole grains. This fortification doubles or triples their TOC-NQIs compared to whole-grain cereals like Shredded Wheat that are not fortified. But they still lack several essential or beneficial nutrients, like fiber, potassium and antioxidants that are stripped from enriched flour during the milling process. Despite their enhanced TOC-NQIs, the USDA recommends reducing consumption of refined cereal products and choosing whole grain cereals with minimal added sugar.

There is debate about the effectiveness or safety of two nutrients added for enrichment or fortification. Ferrous sulfate, the form of iron commonly used, is not as well absorbed as naturally occurring forms, particularly by children (Hurrell, 2010). There is also debate about potential harm from free-form folic acid added to foods and supplements. Free folic acid in substantial amounts can lead to unmetabolized folic acid in the blood (Bailey et al., 2012), which theoretically might accelerate the growth of existing cancer cells (Gibson et al., 2011; Mason, 2011). Unmetabolized folic acid does not occur with the naturally occurring, bound forms of folic acid in foods. Folic acid naturally occurring in foods is known to help prevent some cancers.

While the latest figures on whole grain consumption show a continuing consumer preference for refined grain products over whole grain products, whole grain consumption is continually improving. More people are benefiting from the nutrient advantages and reduced risk of chronic diseases. Whole grain consumption increased by 20% from 2005 to 2008 alone (Whole Grains Council, 2009). Looking more globally and with the growing concern over global food security, the approximate one-third drop in TOC-NQIs between whole grain breads and refined breads represents a loss of valuable nutrients that can potentially play an important role in improving health and nutrition, and in advancing food security for all.

Top Nutrients Found in Grains

Nutrient	Grains	Selected Health Benefits
Protein	Amaranth, Barley, Buckwheat, Bulgur, Kamut®, Millet, Oats, Quinoa, Spelt, Teff, Wheat, Wild Rice, Triticale	Builds muscle and blood, supports strong immune system, essential for healthy skin, hair, nails and cartilage.
Fiber	Amaranth, Bulgur*, Barley*, Buckwheat, Cornmeal, Kamut®, Millet, Oats, Quinoa, Rice, Rye*, Sorghum, Spelt, Triticale*, Wild, Wheat*	Digestive health, helps prevent colon cancer
Iron	Amaranth, Oats, Quinoa, Teff, Kamut®, Spelt, Wheat	Helps build blood, healthy muscle development
Magnesium	Amaranth*, Buckwheat*, Cornmeal, Millet, Oats, Quinoa*, Brown Rice, Sorghum, Teff, Wild Rice, Bulgur, Kamut®, Spelt, Wheat, Barley, Rye, Triticale	Essential mineral for most biochemical reactions, including a healthy nervous system, metabolism, and immune system.
Phosphorus	Amaranth*, Buckwheat, Cornmeal, Millet, Oats, Quinoa*, Brown Rice, Sorghum, Teff, Wild Rice, Bulgur, Kamut ®, Spelt, Wheat (Durum*), Barley, Rye, Triticale	Essential for proper cellular function and repair, helps maintain a healthy heart and nervous system.
Manganese	Amaranth**, Buckwheat*, Cornmeal, Millet*, Oats**, Quinoa*, Brown Rice*, Sorghum*, Teff***, Bulgur**, Kamut®**, Spelt**, Wheat**, Barley*, Rye**, Triticale**	Essential for maintaining healthy metabolism and cholesterol levels, and healthy bones and cartilage.
Copper	Amaranth, Buckwheat*, Millet, Oats, Quinoa, Teff*, Kamut®, Spelt, Wheat, Barley, Rye, Triticale	Helps regulate blood pressure and heart rate.
Thiamin (Vitamin B_1)	Cornmeal, Millet, Oats, Quinoa, Brown Rice, Teff, Kamut®*, Spelt, Wheat, Barley*, Triticale	Helps maintain a healthy metabolism, neurological and cardiovascular health, eye health and vision.
Niacin (Vitamin B_3)	Buckwheat, Millet, Brown Rice, Sorghum, Wild Rice, Bulgur, Kamut®, Spelt, Wheat, Barley, Rye, Triticale	Helps prevent cardiovascular disease, maintain healthy cholesterol levels, and maintain healthy metabolism, hair and skin. Promotes a strong immune system.

*All grains listed provide a minimum of 10% of the RDA or Daily Value of the listed nutrient per 45g serving size, except for those marked as follows: * Provides greater than 20% of the RDA/DV per 45g; ** Provides greater than 50% of the RDA/DV per 45g, *** Provides 100% or more of the RDA/DV per 45g (Whole Grains Council, www.wholegrainscouncil.org)*

In the Field: A Closer Look at Influences on Nutrient Content

The nutrient content of grains is difficult to predict or guarantee. Before grain ever reaches the table or the mill, various factors influence its nutrient content. These variables, many of which are difficult to impossible to control, make it equally difficult to have consistency in nutrient levels.

Soil type and richness, growing temperatures, moisture levels, other climatic differences, and even pests can all affect the total nutrient content of grains at time of harvest (Benbrook, 2006; Brandt et al., 2002; Wang et al., 2000; Wang et al., 2002). Harvesting time and "ripeness" also have an impact. These variables will always differ and always have an impact—whether between farms, between fields, or from one year to the next. These natural fluctuations in nutrient content make it difficult to have nutrient consistency, even in harvests from the same farm.

On top of this, genetic differences also have a significant impact on nutrient content. There can be large differences in mineral and other nutrient content between different species. Modern high-yield varieties tend to be significantly lower in nutrients. As one of he most widely consumed grains, wheat is an excellent example to illustrate some of these influences.

Genetics and Nutrient Content

Most wheat varieties grown today are varietals of two species—Durum wheat (*Triticum durum*) and common or bread wheat (*Triticum aestivum*). Common bread wheat alone makes up 90–95% of the wheat cultivated worldwide (Pena, 2002). These two species have come to dominate the wheat market due to their varied uses, high yield and marketability. Durum is a very hard wheat commonly used to make pasta. Common or bread wheat (and its many varietals—hard red spring wheat, hard red winter wheat, soft red winter wheat, soft white winter wheat, and soft white spring wheat) is used to make bread, cakes, pastries, crackers, and other wheat-based products.

This was not always the case. Historically a number of other species were also cultivated, including einkorn (*T. monococcum*), emmer (*T. dicoccum*), spelt (*T. spelta*), and Kamut® khorasan (*T. turgidum ssp. turanicum*). Cultivation of these ancient wheats decreased significantly in the 1960s, with the introduction of higher yielding, threshable bread and durum wheat. There are also numerous "landraces" or native varieties found throughout the world. These are varieties of wheat, even of *T. durum* and *T. aestivum*, that have developed largely by natural processes in response to the climate and environment in which they are grown or perhaps through hand selection by generations of local farmers. Because of these slow evolutionary influences, they often still resemble other ancient species of wheat. While the cultivation of these is less than in the past, many landraces are still grown on a local scale.

In recent years, there has been resurging interest in these older wheat species and landrace varieties. Many claim that ancient wheats are higher in nutrients and less allergenic than the varieties commonly used today (see side box on page 15). As they are often locally adapted, they are also hardier and more resistant to climatic changes and pests.

Recent research supports these claims. Older varieties are often higher in micronutrients, including calcium, magnesium, iron, zinc, copper, selenium and most notably antioxidants. A 2008 study compared 18 samples of ancient wheat (12 of emmer and 6 of einkorn) to 2 modern bread wheat varieties from different regions in Turkey for their antioxidant capacity as measured by N, N-dimethyl-p-phenylenediamine (DMPD). Both species of ancient wheat were higher in antioxidants than the modern varieties. Lutein content was an extraordinary 15 to 30 times higher in einkorn and emmer samples than in the modern wheat varieties. Lutein is believed to be associated with reduced risk for cataracts and age-related macular degeneration (Serpen et al., 2008).

Similarly, Italian researchers compared the antioxidant activity as measured by 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) of bread made from whole grain durum wheat and regular and sourdough bread made from whole grain Kamut® khorasan wheat (*T. turgidum ssp. turanicum*). All breads had significant antioxidant levels, demonstrating the benefits of whole grains in general as a source of antioxidants. Kamut® khorasan had higher total antioxidant activity. While researchers stressed that antioxidant activity is a result of all antioxidant compounds working together synergistically, particular compounds were found to be significantly higher in Kamut® khorasan bread. For example, total polyphenol content was 19% higher in Kamut® khorasan than durum wheat bread. Selenium content, a micronutrient important for the healthy function of the thyroid, was found to be ten times higher in Kamut® khorasan bread. Protein content was higher and soluble carbohydrates lower in the Kamut® khorasan breads (Gianotti et al., 2011).

As we've narrowed the genetic diversity of wheat varieties that are cultivated today, we have also decreased the nutrients we consume. But genetics is only one player in the game of nutrition and does not always guarantee increased nutrition. Nutrient content has not been the focus of most plant scientists and breeders over the past century; their eyes have been on yields. While ancient and older variety wheat is higher in nutrients, it also tends to have lower yields.

Wheat and food allergies

While wheat is one of the most consumed grains globally, its consumption and that of other gluten-containing grains is the leading cause of celiac disease. Sensitivities to wheat and/or gluten have also been implicated as a factor in other inflammatory conditions including irritable bowel syndrome, migraine headaches, and arthritis. The increasing prevalence of these conditions in the past 50 years is partly due to improved awareness, diagnostics and early detection. However, some researchers credit changes in lifestyles and an increased consumption of wheat in general as contributing factors. Wheat products are introduced earlier in life and wheat gluten is increasingly used as an additive to the ever-growing array of processed foods and other products, including medicines (van de Broek, 2010).

Breeding is also an important factor. Over the past 100 years, emphasis has been placed on wheat varieties with higher gluten content as it makes wheat more conducive to baking. Even within high-yield varieties not specifically bred for gluten content, recent research has shown that an unintended side effect has been an increase in the offending T-cell stimulating "epitopes" when compared to older varieties. These cause an immune response in those with celiac disease and other conditions (van de Broek, 2010).

Do native, ancient or heirloom varieties of wheat also cause the same allergic response in those sensitive? In a recent study comparing modern varieties with landraces or native varieties of wheat, only 1 of 36 modern varieties demonstrated a low incidence of the T-cell stimulating epitopes, whereas 15 of the 50 landraces had a low incidence of these epitopes. This led researchers to conclude that the general "toxicity of modern wheat varieties has increased" (van de Broek, 2010). As such, wheat with low "celiac" epitopes could become an important new trait in wheat breeding.

The Game of Yields

Today's farmers grow more pounds of wheat per acre of land than decades ago. Within the past 50 years, yields of most major crops, including wheat, have doubled or tripled. As discussed in The Organic Center's Critical Issue Report, *Still No Free Lunch*, this has been made possible by the breeding of new plant varieties, increased use of synthetic fertilizer and advanced machinery. Despite these impressive increases, much of the global population remains malnourished. While poorer nations suffer from both caloric and micronutrient deficiencies, wealthy nations consume too many calories and yet still face deficiencies of several essential nutrients. In focusing purely on the quantity of calories generated per acre of land, we have neglected the quality of these calories. With increased yields, nutrient concentrations have declined. As a result, today's crops are less nutritious and deliver fewer nutrients per serving and per calorie (Halweil, 2007; Di Silvestro, 2012).

Over the years the nutrient contents of grain have decreased. Modern wheat and corn are lower in protein (Davis, 2009; Uribellaria et al., 2004; Kibite and Evans, 1984; Triboi et al., 2006; Simmonds, 1995), higher yield soybeans have lower protein and oil content (Leffel, 1989; Yina and Vynb, 2005), high-yield tomatoes tend to be lower in vitamin C and the cancer fighting compounds lycopene and β-carotene (Parisi and Villari, 2006; De Pascale et al., 2006).

This trend is known as the "dilution effect." While all the reasons for the dilution effect are not fully understood, it appears crops redesigned for one goal (yield) are less able to meet other goals, such as warding off disease and pests or accumulating phytochemicals and nutrients. As breeders have produced crops that generate higher yields—plants that can grow closer together and allow more plants per acre, produce larger fruits, and/or have more grain and less straw per plant—farmers are simultaneously utilizing more inputs, such as chemical fertilizers, pesticides, and irrigation. As a result, modern plant varieties grow faster and larger compared to varieties of the past or those grown today in low-input systems. This tends to dilute their concentrations of nutrients and phytochemicals.

A plant's chemical composition is partly shaped by its environment. Many phytochemicals are created in response to pest pressures and the resources available—the level of soil richness, water, and even other plants around it. Modern agriculture has an abundance of nutrients, water, and other resources at levels not normally found in nature. With increased use of pesticides and monoculture farming, plants do not fully develop their natural defense mechanisms. Water is often abundant and consistent, and chemical fertilizers provide easily accessible nutrients. All of this abundance encourages rapid growth. Faster growing plants have less time to grow deep roots and extract nutrients from the soil into the portions harvested for consumption. With far fewer pests and other environmental hazards, modern crops devote less energy to producing the phytochemicals of their natural defense system, many of which are health promoting for humans.

While declining nutrient and phytochemical concentrations were visible in the data over the years, they were often ignored or doubted due to potential confounding variables in old data. As there are many environmental factors that can influence nutrient concentrations in crops, the most powerful evidence for nutritional declines in wheat and corn comes from studies that grow older (low yield) and newer (high yield) varieties side-by-side. As they are grown under identical agronomic conditions (same soil, planting method, harvest timing and methods, etc.) it is possible to get a clear picture of one kind of dilution effect.

U.S. Department of Agriculture researchers used side-by-side plantings to compare the micronutrient concentrations of 14 varieties of wheat originally grown between 1919 and 2000, a period in which typical yields more than tripled. Average micronutrient concentrations declined dramatically. Over the 81 years, iron dropped by about 25%, zinc by 13 to 29%, and selenium by 19 to 31% (Garvin et al., 2006).

In the Broadbalk Wheat Experiment, established in 1843, wheat yields were measured under different conditions of organic and inorganic fertilizers. Sixteen cultivars over the years were grown in three plots with different fertilizers: a control plot with no fertilizers, one with chemical fertilizers, and one with farmyard manure. In 2008, researchers analyzed 160 years of archived wheat and soil samples and found striking declines in mineral concentrations in the wheat, but not in the soil. Prior to 1968, there were slight reductions in magnesium, copper, iron, and zinc in wheat from the plots using chemical fertilizers. Notably, there were slight increases in these nutrients in the plots using farmyard manure. Then post-1968, when high-yield wheat varieties came into use, grain from all plots showed marked declines of 20% to 49% in iron, copper, zinc, and magnesium, plus "broadly similar" declines in phosphorus, manganese, sulfur, and calcium (Fan et al. 2008).

All of this research points to one thing—it now takes more slices of bread and other wheat products to get the recommended dietary allowance of many important nutrients. And yet high yields are still the primary focus of breeders, farmers, and agribusiness. This focus is understandable when farm commodity markets, federal farm policy, and those funding agricultural research reward yield increases above all else. There are currently very few breeding efforts underway with the goal of raising the nutrient content of wheat and other major foods. It will most likely continue in this direction unless breeders are given more incentives to focus on the nutrient levels of wheat and other crops. For more information on the dilution effect and its effect on the nutrient content of foods, see Still No Free Lunch: nutrient levels in US food supply eroded by pursuits of high yields at http://www.organic-center.org/reportfiles/YieldsReport.pdf.

Organic Farming and Nutrient Content

In the Center's 2008 report, *New Evidence Confirms the Nutritional Superiority of Plant-Based Organic Foods*, we presented research demonstrating that organically grown crops, including grains, have on average higher nutrient contents than those grown conventionally. Many variables influence nutrient content, often making it difficult to determine the impact of farming systems on nutrient levels. Thus there are conflicting results about this issue, with some studies finding significant differences in organic crops, others showing little or no differences, and those that report—for a few nutrients—conventionally grown food with higher levels.

Matched-pair studies are the best way to control for these variables and to isolate their influences on nutrient content. For the 2008 report, The Organic Center developed a rigorous methodology to screen research studies comparing the nutrient content of organic and conventional crops. We identified 191 matched-pair studies that met our criteria designed to limit the influence of extraneous environmental and genetic factors on nutrients. These criteria required studies to use the same plant varieties in the same location during the same year. Out of these matched pairs, 62% of the organic samples, including fruits, vegetables and a few grains, had higher nutrient levels. Conventional systems had higher nutrient levels in 36% of the matched pairs. The average serving of organic plant-based food contained about 25% more of the nutrients encompassed in this study than a comparable-sized serving of the same food produced by conventional farming methods (See Table 4). The full report can be read at www.organic-center.org/reportfiles/NutrientContentReport.pdf

Table 4. Overview of Differences in the Nutrient Content in Organic and Conventional Foods in 191 Matched Pairs

Nutrient	Number of Matched Pairs	Number Organic Higher	Number Conventional Higher	Percent Organic Higher	Percent Conventional Higher
Antioxidants					
Total Phenolics	25	18	6	72%	24%
Total Antioxidant Capacity	8	7	1	88%	13%
Quercetin	15	13	1	87%	7%
Kaempferol	11	6	5	55%	45%
Vitamins					
Vitamin C/Ascorbic Acid	46	29	17	63%	37%
B-Carotene	8	4	4	50%	50%
a-Tocoperol (Vitamin E)	13	8	5	62%	38%
Minerals					
Phosphorus	32	20	10	63%	31%
Potassium	33	14	19	42%	58%
Totals and Averages	191	119	68	62%	36%

From The Organic Center's 2008 report New Evidence Confirms the Nutritional Superiority of Plant-based Organic Foods (www.organic-center.org/reportfiles/NutrientContentReport.pdf)

Organic Grains

Whereas most of the research conducted five or ten years ago focused on fruits and vegetables, there is now more research on organic grains (Hussain et al., 2010; Kokornaczyk, 2008; Murphy et al., 2008; Nitika et al., 2008; Roose et al., 2009; Silvestro et al., 2012; Zuchowski et al., 2011). These studies support the superiority of organic grains regarding some nutrients, especially antioxidants. The differences between organic and conventional grains tend to be less than those found in fruits and vegetables. But overall, there is agreement that consistent differences do exist, especially in antioxidant levels. This trend makes sense in light of the effects of conventional high-yield farming methods discussed earlier. Without chemical fertilizers and other inputs, grains grown organically are able to produce healthy roots and develop a more robust array of phytochemicals and micronutrients.

At the Organic World Congress in 2008, Murphy et al. presented a report on 35 different varieties of soft white wheat grown in side-by-side organic and conventional farming systems in Washington state. The organic crops were significantly higher in copper, magnesium, manganese, zinc and phosphorus. Only calcium was higher in conventionally grown grain. There was no difference found in iron content. Most of these minerals were not higher in the organic soil. In fact, copper, manganese, and zinc had lower concentrations in the organic soil. Only phosphorus had a greater concentration in both the soil and the grain.

Researchers suggest that mycorrhizal fungi present in organic fields from the application of organic matter may result in increased uptake of soil nutrients and higher concentration in wheat (Murphy et al., 2008). Genetics still plays an important role; even in organic systems the concentrations of many micronutrients and antioxidants still vary among varieties. Murphy et al. found significant difference in nutrient content between cultivars, particularly for calcium, copper, magnesium, manganese, and phosphorus. This led the researchers to conclude, "certain cultivars may be optimally adapted to organic farming systems in a way that allows for higher grain mineral concentration. These cultivars are likely capable of exploiting the higher organic matter in the organic systems to achieve higher nutritional value" (Murphy et al., 2008).

One of the greatest nutrient differences found between organic and non-organic grain is antioxidant content. With fewer inputs, such as synthetic pesticides and fertilizers, organic farming systems tend to mimic natural stress conditions. This encourages plants to produce a broader array of phytochemicals for protection from these stresses. Most of these phytochemicals have antioxidant activity in humans.

Whole grains are particularly high in phenolic compounds, tocopherols, and carotenoids (Cheng et al., 2006; Moore et al., 2005; Yu et al., 2002). These and other phytochemicals occur in plants in two forms—free/soluble and bound/insoluble. Free forms of phytochemicals dissolve quickly and are immediately absorbed into the bloodstream. Bound forms are attached to the wall of plant cells and must be released by intestinal bacteria during digestion before being absorbed. Bound forms are predominant in grains, but most research has measured only free forms. As such the antioxidant content of grains is often underestimated.

In a 2003 study, Adom et al. found that bound antioxidant compounds in wheat were as much as 17-fold higher than free antioxidant compounds. Interestingly, because most of the antioxidant activity in grains is released in the colon, this may partly explain the association between increased consumption of wheat and other whole grains and reduced incidence of gastrointestinal diseases (Adom et al., 2003; Di Silvestro, 2012).

In a forthcoming report, we will discuss in depth the difference in antioxidant content of organic and non-organic grains.

Organic grain is still susceptible to the dilution effect. As demand for organic grain increases, there is pressure for plant scientists to produce organic crops with higher yields. As yields increase, organic crops, including wheat and other grains, are at risk of losing this nutrient advantage. Some researchers hope that plant breeding that emphasizes both nutrient content and yield will minimize dilution effects in organic crops. Others believe that organic farming can already match conventional yields and maintain nutrient content if farmers continue to encourage healthy soils rich in organic matter and properly select varieties with both high yields and high concentrations of nutrients (Murphy et al., 2008; Mäder et al., 2007). In fact, according to some researchers, organic farming—at least in the developing world—is the only method that has been able to improve both yield and nutritional quality at the same time (Brandt and Kidmose, 2007). This is an important field of continued research. Is it possible with organic farming methods to increase the point where the dilution effect kicks in and thus allow for increased production of nutrient-rich wheat and other grains?

Looking Ahead

Grains are an important source of nutrients, including health-promoting antioxidants. But most grain that reaches the table has lost much of these valuable nutrients. Our preference for refined white flour and white rice, means a significant portion of these nutrients is left in the mill. Consuming more whole grains is an important step to improving the consumption of valuable, health-promoting nutrients. But there is more.

Genetics clearly plays a role and more attention needs to be paid to older varieties and landraces that are higher in many nutrients and antioxidants. Expanding the genetic diversity of wheat and other grain varieties could increase nutrient levels, particularly antioxidants. Farming systems are also important. Organic farms tend to plant a greater diversity of grain varieties, particularly ancient and older varieties, because these have proven superior in the low-nitrogen environments of organic farms. Modern varieties are strictly dependent on high levels of nitrogen (Di Silvestro, 2012). Organic farming techniques have been shown to improve nutrient content significantly, especially phenolic acids, Vitamin C and total antioxidant activity. In the case of antioxidants, this difference can be significant, especially for particular compounds.

Combining organic cultivation with these genetic advances could substantially improve antioxidant and nutrient levels. This may be particularly true when harder-to-control factors come into play, such as bad weather and other environmental factors.

Older varieties and organic and low-input farming systems are typically lower yielding, and farmers will continue to seek ways to increase yields by, in particular, enhancing nitrogen levels in the soil and improving weed management. As the yields increase on organic farms, there will likely be a point when the dilution effect kicks in. Most commercial farmers operate at yield levels that cause a clear dilution effect in most years. Deeper understanding is needed to find this point and the best balance between yields and nutrient levels.

Because organic systems tend to be adapted to their local environments, there is a wide diversity among them. Research, breeding, and selection of varieties for higher nutrients and yields will need to take these factors into consideration as well (Wolfe et al., 2008). Yields can be increased in organic systems if attention is paid to the varieties that are best adapted to these systems, rather than using varieties adapted to conventional systems (Murphy et al., 2007). The key is to gain a better understanding of where the balance lies.

We are optimistic that progress can be made. In reality today, very few varieties of grain have been bred for organic and other low input systems. It is estimated that more than 95% of current organic agriculture, including grains, is based on crop varieties bred for conventional, high-input systems (Lammerts van Bueren et al., 2011). When more varieties are bred for organic systems and nutrient content, the health-promoting benefits of organic grain production can be more fully realized.

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