

# Whole Grains and Health

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## Abstract

Epidemiologic studies support that whole grains may protect against cardiovascular disease, diabetes, obesity and cancer. Whole grains contain all parts of the grain, the bran, the germ, and the endosperm. Whole grains are rich in nutrients and phytochemicals with known health benefits such as dietary fibre, antioxidants including trace minerals and phenolic compounds, phytoestrogens such as lignan, vitamins and minerals. Whole grain feeding studies report improvements in desirable biomarkers with whole grain consumption, including blood lipid lowering, improved laxation, and antioxidant protection. Despite universal recommendations, including the United States 2005 Dietary Guidelines to consume at least 3 servings of whole grains each day, the usual whole grain intake in Western countries is only about 1 serving per day. Although grains are popular food sources in Latin America, except for traditional eating patterns like corn tortillas, most grain intake is refined. Strategies to increase whole grain consumption in Latin America are urgently needed to help combat the growing problem of chronic disease, especially obesity.

## Nutritional issues in Latin America

Latin American represents a large land mass and a culturally diverse population. Yet with urbanization throughout the region, emerging health issues parallel those found in

other Westernized countries. Chronic diseases associated with consumption of energy-dense foods combined with less physical activities are increasing in prevalence (1). This rapid increase of non-communicable chronic diseases and obesity is found within an environment where low intake of micronutrients and high quality protein is also present. The rapid rise in obesity and diabetes in women and children is particularly alarming and dietary strategies to improve public health are urgently needed (2).

## Food patterns in Latin America

With urbanization comes a shift from traditional eating patterns to a more Westernized eating pattern. The trend of increased consumption of white bread, sweetened beverages, snacks and desserts is of concern to public health nutritionists in Latin America. Because of the looming problems of obesity and associated diseases, public health messages must reinforce a shift from consumption of carbohydrate foods with lower nutrient density to carbohydrate foods with higher nutrient density. Foods rich in nutrients including dietary fiber, minerals, vitamins, and phytochemicals must be promoted in Latin America to help in the prevention of obesity and other chronic diseases.

## What are whole grains

Whole grain includes cereal grains that consist of the in-



tact, ground, cracked or flaked fruit of the grains whose principal components – the starch endosperm, germ and bran – are present in the same relative proportions as they exist in the intact grain (3). Health aspects of whole grains have long been known. Physicians and scientists in the 1800s to mid 1900s recommended whole grains to prevent constipation. The “fiber hypothesis”, published in the early 1970s, suggested that whole foods, such as whole grains, fruits, and vegetables, provide fiber along with other constituents that have health benefits.

For the last 3,000 years, most of the world has relied upon whole grains as a main portion of the diet. It is only within the past 100 years that people have consumed refined grain products. Prior to this time, gristmills were used for grinding grains and they did not separate the bran and germ from the white endosperm. In 1873, the roller mill was introduced and it efficiently separated the bran and germ from the endosperm causing a dramatic decline in whole grain consumption observed from about 1870 to 1970 (4).

The most commonly consumed grains are wheat, oats, rice, corn, and rye (Table 1), with wheat constituting 66–75% of the total (5). Buckwheat, wild rice, and amaranth are not botanically true grains, but are typically associated with the grain family due to their similar composition. The United States Food and Drug Administration guidance on whole grains released on 2/15/2006 listed amaranth, barley, buckwheat, bulgur, corn (including popcorn), millet, quinoa, rice, rye, oats, sorghum, teff, triticale, wheat, and wild rice as whole grains (3). The FDA also listed what was not a whole grain, i.e. legumes (such as soybeans and chickpeas), oilseeds (such as sunflower and flax), and roots (such as arrowroot).

All grains have a bark-like, protective hull, beneath which are the endosperm, bran, and germ (Figure 1). Relatively few vitamins, minerals, fibre, or phytochemicals are located in the endosperm fraction. The germ is a relatively minor contributor to the dry weight of most grains (typically 4–5% in wheat and barley). The germ of corn contributes a much higher proportion to the total grain structure than that of wheat, barley, or oats. The fibre content of whole grains also varies greatly, with whole wheat being concentrated in fibre while brown rice is particularly low in fibre (Table 2).

Generally, grains are ground into flour and processed into grain-based foods. Whole grains foods are made with the entire grain seed (kernel). If the kernel has been cracked, crushed, or flaked it must retain nearly the same relative proportions of bran, germ, and endosperm as the original grains. Grains are milled to enhance desirability, improve texture, flavor, and appearance or to increase shelf life.

A nutrient comparison of wholewheat flour and enriched, white wheat flour is shown in Table 3 (6). Most of the dietary fibre is lost in the milling process, with significant losses in calcium, magnesium, and potassium also particularly evident. White flour is enriched in thiamin,

riboflavin, niacin, iron, and folic acid; some whole grain products are also enriched with folic acid. Processing of whole grains does not remove biologically important compounds (5). Analysis of processed breads and cereals indicate that they are a rich source of antioxidants (7). Processing may open up the food matrix, thereby allowing the release of tightly bound phytochemicals from the grain structure (8).

## Whole grain consumption

Many consumers are unaware of the health benefits of whole grains or the recommendations regarding increased intake. Also, there is much confusion on which products are truly whole grain. The bran portion of a whole grain may be highly colored and contain stringent, intensely flavored compounds that are not always appealing in taste. Other barriers to whole grain consumption include price, softness, texture, and moisture content.

Americans consume far less than the recommended 3 servings of whole grains on a daily basis. According to a survey of Americans 20 years and older (9), total grain intake was 6.7 servings per day with only 1.0 of these servings being whole grain. Only eight percent of the study participants consumed the recommended 3 servings of whole grains on a daily basis. Another investigation (10) reported that less than two percent of the study population consumed 2 or more whole grain servings per day, and 23% consumed no whole grains over the 2-week reporting period. Average whole grain consumption for this study was 0.5 servings per day. A study of United States children and teens reported consumption of whole grains was less than 1 serving per day (11).

Whole grain intake studies in other countries find similar results. Except for parts of Scandinavia where whole grains breads are the norm, whole grain consumption is low (12). In the UK, median consumption of whole grains was less than one serving per day (12). Thane et al (13) estimated whole-grain intake in a nationally representative sample of young people aged 4-18 years living in Great Britain. Whole-grain intake was estimated using 7 d weighed dietary records from 1583 young people participating in the National Diet and Nutrition Survey in 1997. Whole grain intake was quantified from the consumption of all foods containing > 10% whole grain content. Median whole grain intake was 7 g/day with a mean of 13 g/day. There was no whole-grain intake for 27% of the participants. The main sources of whole grain intake were breakfast cereals and bread.

There are no published studies on whole grain intake in Latin America. Different countries in Latin America have different grain consumption patterns. Corn tortillas traditionally have been a staple in the Mexican diet and would be considered whole grain. However, recent trends in Mexico find more consumption of white bread and less consumption of traditional corn-based tortillas. Elsewhere in Latin America, biscuits, white rice, and breads are popular, but in general with urbanization, less traditional food preparation methods are used and Latin American con-



sumers are choosing more refined grain products.

### **Components in whole grains that deliver health benefits**

The “fibre hypothesis”, published in the early 1970s, suggested that whole foods, such as whole grains, fruits, and vegetables, provide fiber along with other constituents that have health benefits. The bran and germ fractions derived from conventional milling provide the majority of the biologically active compounds found in a grain. Specific nutrients include high concentrations of B vitamins (thiamin, niacin, riboflavin, and pantothenic acid) and minerals (calcium, magnesium, potassium, phosphorus, sodium, and iron), elevated levels of basic amino acids (e.g., arginine and lysine), and elevated total levels in the lipids. Numerous phytochemicals, some common in many plant foods (phytates and phenolic compounds) and some unique to grain products (avenanthramides, avenalumic acid), are responsible for the high antioxidant activity of whole grain foods (7).

Table 4 lists some of the potential bioactive compounds in whole grains. As most research has been conducted on the antioxidant activity of whole grains, details on this mechanism will be presented.

### **Antioxidants**

Whole grain products are relatively high in antioxidant activity. Naturally-occurring antioxidants found in whole grain foods are water-soluble, fat-soluble and approximately half are insoluble. Soluble antioxidants include phenolic acids, flavonoids, tocopherols, and avenanthramides in oats. A large part of insoluble antioxidants are bound as cinnamic acid esters to arabinoxylan side chains of hemicellulose. Wheat bran insoluble fiber contains approximately 0.5-1.0% phenolic groups. Covalently bound phenolic acids are good free radical scavengers. About two-thirds of whole grain antioxidant activity is not soluble in water, aqueous methanol or hexane.

In addition to natural antioxidants, antioxidant activity is created in grain based foods by browning reactions during baking and toasting processes that increases total activity in the final product as compared to raw ingredients. For example, the crust of white bread has double the antioxidant activity of the starting flour or crust free bread. Reductone intermediates from Maillard reactions may explain the increase in antioxidant activity. The total antioxidant activity of whole grain products is similar to that of fruits or vegetables on a per serving basis (14).

Adom and Liu (15) suggest that the antioxidant activity of grains reported in the literature has been underestimated since only unbound antioxidants are usually studied. They report that in wheat 90% of the antioxidants are bound. Bound phytochemicals could survive stomach and intestinal digestion, but would then be released in the large intestine and potentially play a protective role. When they compared antioxidant activity of various grains, corn had the highest total antioxidant activity,

followed by wheat, oats and then rice. In wheat, bound phenolics contribute more antioxidant protection than either free or esterified (16). Additionally, 85% of the total hydrophilic antioxidant activity and 94% of the total lipophilic antioxidant activity is in the bran/germ fraction of wheat, again supporting the importance of including the whole grain in human foods (17).

### **The health benefits of whole grains**

#### **Whole Grains and Cardiovascular Disease**

There is strong epidemiological and clinical evidence linking consumption of whole grains to a reduced risk for coronary heart disease (18). Morris et al (19) followed 337 subjects for 10-20 years and concluded that a reduction in heart disease risk was attributable to a higher intake of cereal fiber, while indicating soluble sources such as pectin and guar did not account for the lower coronary heart disease (CHD). A pooled analysis of cohort studies on dietary fiber and risk of coronary heart disease found that consumption of dietary fiber from cereals and fruits was inversely associated with risk of coronary heart disease (20).

Large prospective epidemiologic studies have found a moderately strong association between whole grain intake and decreased CHD risk. Post-menopausal women (34,492), age 55-69 years and free of CHD were followed in the large prospective Iowa Women's Health Study for occurrence of CHD mortality (n=387) between baseline (1986) and 1994 (21). Whole-grain intake was determined by 7 items in a 127-item food frequency questionnaire which was used to divide participants into quintiles based on mean servings of whole-grain intake per day. The risk reduction in higher whole-grain intake quintiles was controlled for more than 15 confounding variables, and was not explained by adjustment for dietary fiber intake. This suggests that whole grain components other than dietary fiber may reduce risk for CHD.

In a Finnish study, 21,930 male smokers (aged 50-69 years) were followed for 6.1 years (22). Reduced risk of CHD death was associated with increased intake of rye products. Rimm et al (23) examined the association between cereal intake and risk for myocardial infarction (MI) in 43,757 US health professionals, aged 40 to 75 years. Cereal fiber was most strongly associated with reduced risk for MI with a 0.71 decrease in risk for each 10 g increase in cereal fiber intake.

The Nurses' Health Study, a large, prospective cohort study of US women followed up for 10 years, was also used to examine the relationship between grain intake and cardiovascular risk (24). A total of 68,782 women aged 37 to 64 years without previously diagnosed angina, myocardial infarction, stroke, cancer, hypercholesterolemia, or diabetes at baseline were studied. Dietary data were collected with a validated semiquantitative food frequency questionnaire. Because of confounding, the authors controlled for age, cardiovascular risk factors, dietary factors, and multivitamin supplement use.



For a 10 g/day increase in total fiber intake (the difference between the lowest and highest quintiles), the multivariate RR of total CHD events was 0.81 (95% CI, 0.66 - 0.99). Among different sources of dietary fiber (cereal, vegetable, fruit), only cereal fiber was strongly associated with a reduce risk of CHD (multivariate RR, 0.63; 95% CI, 0.49 - 0.81 for each 5 g/d increase in cereal fiber). The authors conclude that higher fiber intake, particularly from cereal sources, reduces the risk of CHD.

Since whole grains are the predominant dietary fiber source in the United States, it is difficult to separate out the protection of dietary fiber from whole grains. Jensen et al (25) examined intakes of whole grains, bran, and germ and risk of coronary heart disease from food frequency data in the Health Professionals Follow-Up study. Added germ was not associated with CHD risk and the authors conclude that the study supports the reported beneficial association of whole-grain intake with CHD and suggests that the bran component of whole grain could be a key factor in this relation.

Food consumption patterns that include whole grains appear protective for cardiovascular disease. Van Dam et al (26) report that intake of refined diets which do not include whole grains was associated with higher serum cholesterol levels and lower intakes of micronutrients. A prudent dietary pattern, including intake of whole grains, was associated with lower C-reactive protein levels and endothelial dysfunction, an early step in the development of atherosclerosis (27). Whole grain food intake was also associated with lower levels of C-reactive protein in the Nurses Health Study (28). A prospective cohort study of post-menopausal women found that consumption of cereal fiber and whole-grain intake reduced progression of coronary-artery atherosclerosis (29).

A wide range of biomarkers relevant to CVD was measured within a healthy subsample of the Health Professionals Follow-up Study and the Nurses' Health Study II (30). Higher intake of whole grain was associated with lower homocysteine and total cholesterol. The results suggest a lower risk of heart disease in persons who consume diets high in whole grains. Sahyoun et al (31) recently reported a significant inverse trend between whole grain intake and mortality from cardiovascular disease, independent of demographic, lifestyle and dietary facts. In addition, fasting glucose and body mass index decreased across increasing quartile categories of whole grain intake.

### Whole Grains and Blood Glucose

Epidemiologic studies consistently show that risk for type 2 diabetes mellitus is decreased with consumption of whole grains (32). Intake of fiber from whole-grain cereals has also been found to be inversely related to type 2 diabetes. In a long-term study of almost 90,000 (33) women and in a similar study of about 45,000 men (34), researchers found that those with higher intakes of cereal fiber had about a 30% lower risk for developing type 2 diabetes, compared to those with the lowest

intakes. Montonen et al (35) reported an inverse association between whole-grain intake and risk of type 2 diabetes in a cohort study. Cereal fiber intake was also associated with a reduced risk of type 2 diabetes.

Additionally, the Iowa Women's Health Study found that dietary fiber and whole grain intake were protective against type 2 diabetes (36). In another study (37), individuals consuming mostly refined grains and little whole grain had a 57% higher risk of type 2 DM than did those consuming larger amounts of whole grains. In the Health Professional Follow-up Study, an investigation following 42,898 men, a 37% lower risk of type 2 DM was associated with about 3 servings/day of whole grain intake (38). Liu (39) pooled data from prospective cohort studies of whole grain intakes and type 2 diabetes; whole grain intake reduced relative risk of diabetes by 30%.

Some feeding studies have been conducted to evaluate the relationship between whole grains and glucose metabolism. Periera et al (40) tested the hypothesis that whole-grain consumption improves insulin sensitivity in overweight and obese adults. Eleven overweight or obese hyperinsulinemic adults aged 25-56 years consumed 2 diets, each for 6 weeks. Diets were identical, except that refined grain products were replaced by whole products. At the end of each treatment, subjects consumed 355 ml of a liquid mixed meal, and blood samples were taken over 2 hours. Fasting insulin was 10% lower during consumption of the whole-grain diet. The authors conclude that insulin sensitivity may be an important mechanism whereby whole grain foods reduce the risk of type 2 diabetes and heart disease.

Juntunen et al (41) evaluated what factors in grain products affected human glucose and insulin responses. They fed the following grain products: whole-kernel rye bread, whole-meal rye bread containing oat beta-glucan concentrate, dark durum wheat pasta, and wheat bread made from white wheat flour. Glucose responses and the rate of gastric emptying after consumption of the 2 rye breads and pasta did not differ from those after consumption of white wheat bread. Insulin, glucose-dependent insulinotropic polypeptide, and glucagon-like peptide1, were lower after consumption of rye breads and pasta than after consumption of white wheat bread. Postprandial insulin responses to grain products may be determined by the form of food and botanical structure rather than by the amount of fiber or type of cereal in the food.

McKeown et al (42) reported that whole grain intake was inversely associated with body mass index and fasting insulin in the Framingham Offspring Study. Juntunen et al (43) fed high-fiber rye bread and white-wheat bread to postmenopausal women and measured glucose and insulin metabolism. Acute insulin response increased significantly more during the rye bread periods than during the wheat bread period. They suggest that high-fiber rye bread appears to enhance insulin secretion.

McIntosh et al (44) fed rye and wheat foods to over-



weight middle-aged men. The men were fed low-fiber cereal grains foods providing 5 grams of dietary fiber for the refined grain diet and 18 grams of dietary fiber for the whole grain diet, either high in rye or wheat. This was in addition to a baseline diet that contained 14 grams of dietary fiber. Postprandial plasma insulin was decreased by 46-49% and postprandial plasma glucose by 16-19% after consumption of the whole grain diet. Qi et al (45) examined whether intake of whole grains and dietary fiber was associated with inflammatory indicators among 902 diabetic women in the Nurses' Health Study. They suggest that whole grains and a low-glycemic index diet may reduce systemic inflammation among women with type 2 diabetes. Jensen et al (30) found that whole-grain intake was most strongly inversely associated with plasma markers of glycemic control (fasting insulin, hemoglobin A1c, C-peptide, and leptin) in 938 healthy men and women.

### Body Weight Regulation

Epidemiologic evidence supports that increased dietary fiber intake may play a role in obesity prevention (46). Studies also suggest an association between whole grain intake and the regulation of body weight. In the Coronary Artery Risk Development in Young Adults (CARDIA) Study, whole grains were inversely associated with BMI and waist-hip ratio at baseline and 7 years later (47). Although the differences were modest, the risk for weight gain and the development of overweight or obesity could be substantially decreased if the associations are true. A 10-year follow-up to the CARDIA study looked at dietary fiber, of which whole grains are a good source. Individuals with the highest dietary fiber intake (>21 g/2000 kcal) gained approximately eight fewer pounds of weight than did those with the lowest intake (<12 g/2000 kcal). Similar results were found for the waist-hip ratio (48).

The associations between the intakes of dietary fiber and whole- or refined-grain products and weight gain over time were determined for the Nurses' Health Study (49). Women who consumed more whole grains consistently weighed less than did women who consumed less whole grains. Over 12 years, those with the greatest increase in intake of dietary fiber gained an average of 1.52 kg less than did those with the smallest increase in intake of dietary fiber. Women in the highest quintile of dietary fiber intake had a 49% lower risk of major weight gain than did women in the lowest quintile.

Weight gain among men in the Health Professionals Follow-up Study was followed over 8 years and compared to changes in whole-grain, bran, and cereal fiber intake (50). The increased consumption of whole grains was inversely related to weight gain, and the associations persisted after changes in added bran or fiber intakes were accounted for. This suggests that the components in whole grains beyond dietary fiber may contribute to favorable metabolic changes that reduce long-term weight gain. These findings also indicate that compounds botanically linked to fiber may confer benefits beyond the

effect of fiber itself. In particular, vitamins, minerals, phenolic compounds, and phytoestrogens are abundant in the bran and not in the starchy endosperm.

Several factors may explain the influence of whole grains on body weight regulation. The high volume, low energy density and the relatively lower palatability of whole grain foods may promote satiation (regulation of energy intake per eating occasion through effects of hormones influenced by chewing and swallowing mechanics). Additionally, whole grains may enhance satiety (delayed return of hunger following a meal) for up to several hours following a meal. Grains rich in viscous soluble fibers (e.g., oats and barley) tend to increase intraluminal viscosity, prolong gastric emptying time, and slow nutrient absorption in the small intestine.

### Whole Grains and Cancer

There is substantial scientific evidence that whole grains as commonly consumed can contribute to reduced risk of cancer. In a meta-analysis of whole grain intake and cancer, whole grains were found to be protective in 46 of 51 mentions of whole-grain intake, and in 43 of 45 mentions after exclusion of 6 mentions with design/reporting flaws or low intake (51). Odds ratios were <1 in 9 of 10 mentions of studies of colorectal cancers and polyps, 7 of 7 mentions of gastric and 6 of 6 mentions of other digestive tract cancers, 7 of 7 mentions of hormone-related cancers, 4 of 4 mentions of pancreatic cancer, and 10 of 11 mentions of 8 other cancers. The pooled odds ratio was similar in studies that adjusted for few or many covariates. A systemic review of case-control studies conducted using a common protocol in Northern Italy between 1983 and 1996 indicates that a higher frequency of whole grain consumption is associated with reduced risk for cancer (52). Whole grain was consumed primarily as whole grain bread and some whole grain pasta in the Italian studies.

Cohort studies have demonstrated a lower risk for specific cancers, such as colorectal cancer in women (53) stomach (54), mouth/throat and upper digestive tract (55), and endometrial (56). Epidemiological studies have reported that higher serum insulin levels are associated with increased risk of colon, breast, and possibly other cancers. Reduction of these insulin levels by whole grains may be an indirect way in which the reduction in cancer risk occurs.

Dietary factors, such as fiber, vegetables, fruits, antioxidants, vitamin B6 and phytoestrogen intake and lifestyle factors such as exercise, smoking and alcohol use, which are controlled for in most epidemiologic studies, do not explain the apparent protective effect of whole grains against cancer, again suggesting it's the whole-grain "package" that is effective. Several theories have been offered to explain the protective effects of whole grains. Due to the complex nature of whole grains, there are many potential mechanisms that could be responsible for their protective properties.



Increased fecal bulk and decreased transit time allow less opportunity for fecal mutagens to interact with the intestinal epithelium. Secondary bile acids are thought to promote cell proliferation, thus allowing increased opportunity for mutations to occur and abnormal cells to multiply. The effect of fiber on the actions of bile acids may be attributable to the binding or diluting of bile acids.

Whole grains also contain several antinutrients, such as protease inhibitors, phytic acid, phenolics and saponins, which until recently were thought to have only negative nutritional consequences. Some of these antinutrient compounds may act as cancer inhibitors by preventing the formation of carcinogens and by blocking the interaction of carcinogens with cells. Other potential mechanisms linking whole grains to reduced cancer risk include large bowel effects, antioxidants, alterations in blood glucose levels, hormonal effects, and the influence of numerous biologically active compounds.

Hormonally active compounds in grains called lignans may also protect against diseases. Lignans are compounds possessing a 2,3-dibenzylbutane structure and exist as minor constituents of many plants where they form the building blocks for the formation of lignin in the plant cell wall. The plant lignans secoisolariciresinol and matairesinol are converted by human gut bacteria to the mammalian lignans, enterolactone and enterodiol. Due to the association of lignan excretion with fiber intake, it is assumed that plant lignans are contained in the outer layers of the grain. Concentrated sources of lignans include whole grain wheat, whole grain oats, and rye meal. Seeds are also concentrated sources of lignans including flaxseed seeds (the most concentrated source), pumpkin seeds, caraway seeds, and sunflower seeds.

Grains and other high fiber foods increase urinary lignan excretion, an indirect measure of lignan content in foods (57). Differences in metabolism of phytoestrogens among individuals have been noted. Adlercreutz et al (58) found total urinary lignan excretion in Finnish women to be positively correlated with total fiber intake, total fiber intake per kg body weight and grain fiber intake per kg body weight. Similarly, the geometric mean excretion of enterolactone was positively correlated with the geometric mean intake of dietary grain products (kcal/day) of five groups of women ( $r=0.996$ ).

Due to the association of lignan excretion with fiber intake, plant lignans are probably concentrated in the outer layers of the grain. Because current processing techniques eliminate this fraction of the grain, lignans may not be found in processed grain products on the market and would only be found in whole grain foods. Serum enterolactone was measured in a cross-sectional study in Finnish adults (59). In men, serum enterolactone concentrations were positively associated with consumption of whole-grain products. Variability in serum enterolactone concentration was great, suggesting the role of gut microflora in the metabolism of lignans may be important. Kiilkinen et al (60) also report that intake of lignans is associated with serum enterolactone

concentration in Finnish men and women. These studies suggest that serum enterolactone is a feasible biomarker of lignan intake.

Jacobs et al (61) found similar results in a US study. Subjects were fed either whole grain or refined grain foods for 6 weeks. Most of the increase in serum enterolactone when eating the wholegrain diet occurred within 2 weeks, though the serum enterolactone difference between wholegrain and refined-grain diets continued to increase throughout the 6-week study. Serum enterolactone was associated with reduced cardiovascular disease-related and all-cause death in middle-aged Finnish men (62).

McIntosh et al (44) fed rye and wheat foods to overweight middle-aged men and measured markers of bowel health. The men were fed low-fiber cereal grains foods providing 5 grams of dietary fiber for the refined grain diet and 18 grams of dietary fiber for the whole grain diet, either high in rye or wheat. This was in addition to a baseline diet that contained 14 grams of dietary fiber. Both the high-fiber rye and wheat foods increased fecal output by 33-36% and reduced fecal  $\beta$ -glucuronidase activity by 29%. Rye foods were associated with significantly increased plasma enterolactone and fecal butyrate, relative to wheat and low-fiber diets. The authors conclude that rye appears more effective than wheat in overall improvement of biomarkers of bowel health.

### All-Cause Mortality

Several epidemiological studies suggest whole grains reduce the risk for all-cause mortality or all-cause death. In the Iowa Women's Health Study, whole grains and cereal fiber lowered all-cause death in postmenopausal women (63,64), and a Norwegian study showed a lower mortality rate for men and women with a high whole grain bread intake (65). Liu et al (66) reported that both total mortality and CVD-specific mortality were inversely associated with whole-grain but not refined-grain breakfast cereal intake in the Physicians' Health study.

### Recommendations for intake of whole grains

The 2005 Dietary Guidelines for Americans placed particular emphasis on eating more whole grain foods (Table 1) (6). It is recommended that at least 3 servings, or one-half of grain foods consumed daily, be whole grain with the remainder either enriched or whole grain. The highest caloric intake (3200 kcal/d) recommends consumption of 11 servings of grains per day.

Consumption of whole grains remains low. Except for parts of Scandinavia where whole grains breads are the norm, whole grain consumption is low. Studies find that convenience foods such as breakfast cereals, breads, crackers, and snacks are often the most commonly consumed whole grain foods (11, 13).



## Finding whole grain foods – new labeling (U.S. Specific)

Efforts have been made to increase whole grain consumption. A whole grain health claim exists in the United States related to a reduced risk of heart disease and some cancer. For a whole grain food to meet the whole grain health claim standards, the food must include 51% whole grain flour by weight of final product and contain at least 1.7 grams of dietary fiber. The health claim states: diets rich in whole grain foods and other plant foods and low in total fat, saturated fat, and cholesterol, may help reduce the risk of heart disease and certain cancers.

The Whole Grain Stamp was recently introduced by the Whole Grains Council to represent the amount of whole grain per serving in consumer food products (67). A “good source of whole grain” must contain 8 grams of whole grain per serving, an “excellent source of whole grain” must contain 16 grams of whole grain per serving, and 100% whole grain must contain 16 grams of whole grain per serving and no refined grain. The United States Food and Drug Administration released a draft guidance statement on whole grains on 2/15/2006. There is a 60-day comment period, after which FDA will review the comments and will release a final Guidance Statement on whole grains. Efforts to define and label whole grain foods are also underway in Europe and other countries (68).

### Conclusion

Whole grains are rich in many components, including dietary fiber, starch, antioxidant nutrients, minerals, vitamin, lignans, and phenolic compounds that may reduce the risk of coronary heart disease, cancer, diabetes, obesity and other chronic diseases. Most of the protective components are found in the germ and bran, which are reduced in the grain refining process. Based on epidemiological studies and biologically plausible mechanisms, the scientific evidence shows that regular consumption of whole-grain foods provides health benefits. More research is needed on the mechanisms for this protection. Also, some components in whole grains may be most important in this protection and should be retained in food processing.

Traditional eating patterns in Latin America include sources of whole grains such as whole corn tortillas. With urbanization, consumers are less receptive to increasing whole grain intake and usual intake is only 1 serving per day while a minimum of 3 whole grains or half of grain servings per day of whole grains are recommended. Successful implementation and promotion of these whole grain recommendations will require the cooperative efforts of industry, government, academia, non-profit health organizations, and the media. Additional work is needed to confirm the health benefits of whole grains, develop processing techniques that will improve the palatability of whole grain products, and educate consumers about the benefits of whole grain consumption across the life cycle to improve overall health.

**Table 1.** Available whole grains

Whole wheat	Wild rice
Whole oats/oatmeal	Buckwheat
Whole-grain corn	Triticale
Popcorn	Bulgur (cracked wheat)
Brown rice	Millet
Whole rye	Quinoa
Whole-grain barley	Sorghum

Source: 2005 Dietary Guidelines for Americans

**Table 2.** Differences in dietary fiber content among whole grains (100 grams as eaten)

	Dietary fiber – g
Brown rice	1.8
Whole grain cornmeal	7.3
Whole oats	10.3
Whole grain wheat	12.2

**Table 3.** Comparison of 100 grams of whole-grain wheat flour and enriched, white, all-purpose flour

	Whole-grain wheat flour	White flour
Calories	339	364
Dietary fiber – g	12.2	2.7
Calcium – mg	34	15
Magnesium – mg	138	22
Potassium – mg	405	107
Folate – ug	44	291
Thiamin – mg	0.5	0.8
Riboflavin – mg	0.2	0.5
Niacin – mg	6.4	5.9
Iron – mg	3.9	4.6

Source: 2005 Dietary Guidelines for Americans

**Table 4.** Compounds in whole grains with potential health effects

Dietary fiber
Lignans
Phytosterols
Unsaturated fats
Vitamin E
Magnesium
Antinutrients (protease and amylase inhibitors, phytic acid, phenolics/tannins)



Figure 1: Diagrammatic view of a wheat kernel (longitudinal section) showing tissue relationships. Note indicated aleurone and bran structure.

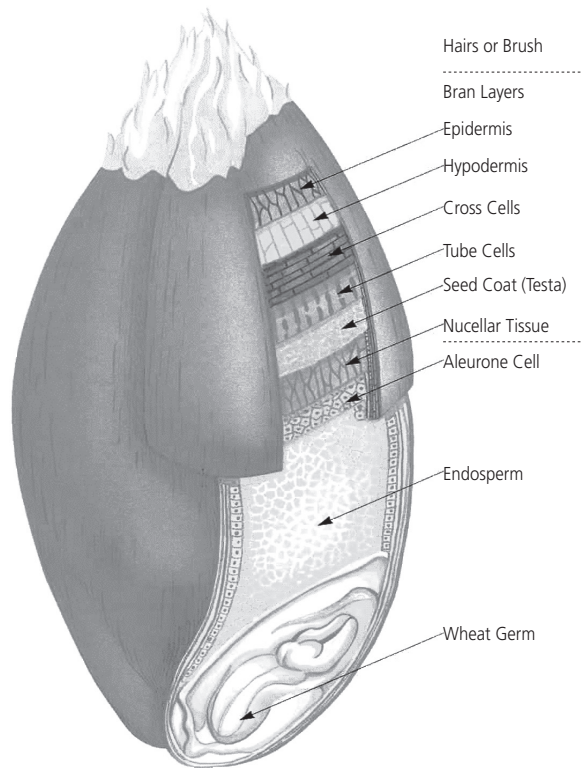
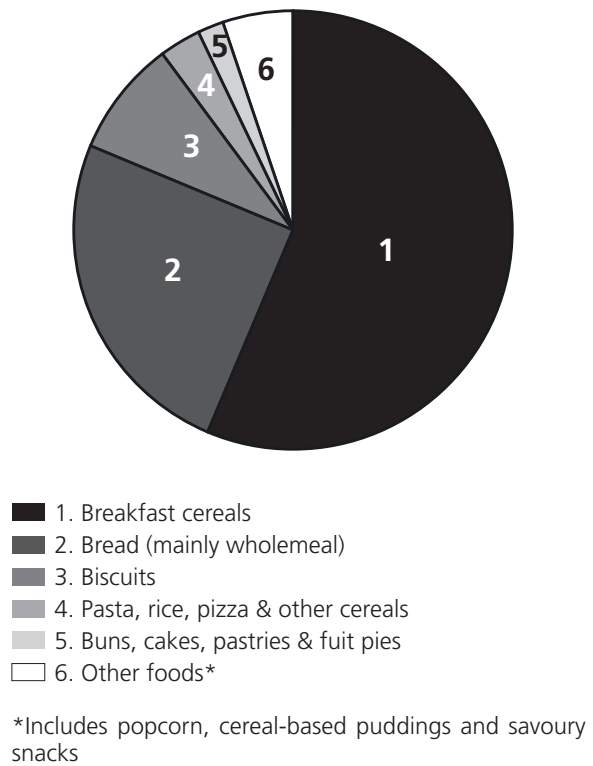


Figure 2. Sources of wholegrain in UK children aged 4 - 18 years. Thane et al. 2005 (13)



Dr. J. Slavin wrote this document about Whole Grains and Health.

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## References

1. Rivera JA, Barquera S, Campirano F, Campos I, Safdie M, Tovar V. Epidemiological and nutritional transition in Mexico: rapid increase of non-communicable chronic disease and obesity. *Public Health Nutrition* 2002;14:113-122.
2. Rivera JA, Amor JS. Conclusions from the Mexican National Nutrition Survey 1999; translating results into nutrition policy. *Salud Publica Mex* 2003; 45(suppl 4), S666-S575.
3. <http://www.fda.gov/bbs/topics/news/2006NEW01317.html>
4. Spiller GA. Whole grains, whole wheat, and white flours in history. In: Whole Grain Foods in Health and Disease, Marquart L, Slavin JL, Fulcher RG, Eds., Eagan Press, St. Paul, MN, pp 1-7, 2002.
5. Slavin JL, Jacobs D, Marquart L. Grain processing and nutrition. *Crit Rev Biotechnology* 2001;21: 49-66.
6. [www.health.gov/dietaryguidelines/dga2005/report](http://www.health.gov/dietaryguidelines/dga2005/report)
7. Miller G, Prakash A, Decker E. Whole-grain micronutrients. In: Whole Grain Foods in Health and Disease, Marquart L, Slavin JL, Fulcher RG, Eds, Eagan Press, St. Paul, MN, pp 243-260, 2002.
8. Fulcher RG, Rooney-Duke TK. Whole-grain structure and organization: implications for nutritionists and processors. In Whole- Grain Foods in Health and Disease, Marquart L, Slavin J, Fulcher RG, Eds, Eagan Press St. Paul, MN, pp 9-45, 2002,.
9. Cleveland LE, Moshfegh A, Albertson A, Goldman J. Dietary intake of whole grains. *J Am Coll Nutr* 2000;18:331S-338S.
10. Albertson AM & Tobelmann RC (2002) Consumption of grain and whole-grain foods by an American population during the years 1990 to 1998: *Whole Grain Foods in Health and Disease* (Marquart, Slavin, and Fulcher, eds.), Eagan Press, St. Paul, MN, 2002.
11. Harnack, L, Waltersm S, and Jacobs, J.R. Dietary intake and food sources of whole grains among US children and adolescents: Data from the 1994-1996 continuing survey of food intakes by individuals. *J Am Diet Assoc* 2003;10:1015-1019.
12. Lang R, Jebb SA Who consumes whole grains, and how much? *Proceedings Nutr Soc* 2003;62:123-127.
13. Thane CW, Jones AR, Stephen AM, Seal CJ, Jebb SA. Whole-grain intake of British young people aged 4-18 years. *Br J Nutr* 2005;94:825-831.
14. Miller G (2001) Whole grain, fiber and antioxidants. In *CRC Handbook of dietary fiber*. pp 453-460 [Spiller GA, editor]. Boca Raton, FL: CRC Press.
15. Adom KK, Liu RH Antioxidant activity of grains. *J Agric Food Chem* 2002;50:6182-6187.
16. Liyana-Pathirana C, Shahidi F. Importance of insoluble-bound phenolics to antioxidant properties of wheat. *J Agric Food Chem* 2006;54:1256-1264.
17. Adom KK, Sorrells ME, Liu RH. Phytochemicals and antioxidant activity of milled fractions of different wheat varieties. *J Agric Food Chem* 2005;53:2297-2306.
18. Anderson JW. Whole-grains intake and risk for coronary heart disease. In: Whole Grain Foods in Health and Disease, Marquart L Slavin JL, Fulcher RG, Eds, Eagan Press, St. Paul, MN, pp 187-200, 2002.
19. Morris J, Marr J, Clayton D. Diet and heart: a postscript. *Br Med J* 1977;2: 1307-1314.
20. Pereira MA, O'Reilly E, Augustsson K, Fraser GE, Goldbourt U, Heitmann BL, Hallmans G, Knekt P, Liu S, Pietinen P, Spiegelman D, Stevens J, Virtamo J, Willett WC, Ascherio A. Dietary fiber and risk of coronary heart disease. A pooled analysis of cohort studies. *Arch Intern Med* 2004;164:370-376.
21. Jacobs DR, Meyer KA, Kushi LH, Folsom AR. Whole-grain intake may reduce the risk of ischemic heart disease death in postmenopausal women: The Iowa Women's Health Study. *Am J Clin Nutr* 1998;68:248-257.
22. Pietinen P, Rimm EB, Korhonen P, Hartman AM, Willett WC, Albanes D, Virtamo J Intake of dietary fiber and risk of coronary heart disease in a cohort of Finnish men. The Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study. *Circulation* 1996;94:2720-2727.
23. Rimm EB, Ascherio A, Giovannucci E, Spiegelman D, Stampfer MJ, Willett WC Vegetable, fruit and cereal fiber intake and risk of coronary heart disease among men. *JAMA* 1996;275:447-451.
24. Liu SM, Stampfer, MJ, Hu FB, Giovannucci E, Rimm E, Manson JE, Hennekens CH, Willett WC. Whole-



grain consumption and risk of coronary heart disease: results from the Nurse's Health Study. *Am J Clin Nutr* 1999;70:412-429.

**25.** Jensen MK, Koh-Benerjee, Hu FB, Franz M, Sampson L, Cronbak M, Rimm EB. Intakes of whole grains, bran, and germ and the risk of coronary heart disease in men. *Am J Clin Nutr* 2004; 80:1492-1499.

**26.** Van Dam RM, Grievink L, Ocke MC, Feskens EJM. Patterns of food consumption and risk factors for cardiovascular disease in the general Dutch population. *Am J Clin Nutr* 2003;77:1156-1163.

**27.** Lopez-Garcia E, Schulze MB, Fung TT, Meigs JB, Rifai N, Monson JE, Hu FB. Major dietary patterns are related to plasma concentrations of markers of inflammation and endothelial dysfunction. *Am J Clin Nutr* 2004; 80:1029-1035.

**28.** Wu T, Giovannucci E, Pischon T, Hankinson SH, Ma J, Rifai N, Rimm EB. Fructose, glycemic load, and quantity and quality of carbohydrate in relation to plasma C-peptide concentrations in US women. *Am J Clin Nutr* 2004;80:1043-1049.

**29.** Erkkila AT, Herrington DM, Mozaffarian D, Lichtenstein AH. Cereal fiber and whole-grain intake are associated with reduced progression of coronary-artery atherosclerosis in postmenopausal women with coronary artery disease. *Am Heart J* 2005;150:94-101.

**30.** Jensen MK, Loh-Banerjee P, Franz M, Sampson L, Gronbaek M, Rimm EB. Whole grains, bran, and germ in relation to homocysteine and markers of glycemic control, lipids, and inflammation. *Am J Clin Nutr* 2006;83:274-283.

**31.** Sahyoun NR, Jacques PF, Zhang XI, Juan W, McKeown NM. Whole-grain intake is inversely associated with the metabolic syndrome and mortality in older adults. *Am J Clin Nutr* 2006;83:124-131.

**32.** Murtaugh MA, Jacobs DR, Jacob B, Steffen LM, Marquart L. Epidemiological support for the protection of whole grains against diabetes. *Proceed Nutr Soc* 2003;62:143-149.

**33.** Salmeron J, Manson JE, Stampfer MJ, Colditz GA, Wing AL, Willett WC. Dietary fiber, glycemic load, and risk of non-insulin-dependent diabetes mellitus in women. *JAMA* 1997;277:472-477.

**34.** Salmeron J, Aserio A, Rimm EB, Colditz GA, Spiegelman D, Jenkins DJ, Stampfer MJ, Wing AL, Willett WC. Dietary fiber, glycemic load, and risk of NIDDM in men. *Diabetes Care* 1997; 20:545-550.

**35.** Montonen J, Neckt P, Jarvinen R, Aromaa A, Aeu-nanen A. Whole-grain and fiber intake and the incidence of type 2 diabetes. *Am J Clin Nutr* 2003;77:622-629.

**36.** Meyer KA, Kushi LH, Jacobs DR, Slavin J, Sellers TA, Folsom AR. Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. *Am J Clin Nutr* 2000;71: 921-930.

**37.** Liu S, Manson JE, Stampfer MJ, Hu FB, Giovannucci E, Colditz GA, Hennekens CH, Willett WC. A prospective study of whole grain intake and risk of type 2 diabetes mellitus in U.S. women. *Am J Public Health* 2000;90: 1409-1415.

**38.** Fung TT, Hu FB, Pereira MA, Liu S, Stampfer MJ, Colditz GA, Willett WC. Whole-grain intake and the risk of type 2 diabetes: a prospective study in men. *Am J Clin Nutr* 2002;76:535-540.

**39.** Liu S. Whole-grain foods, dietary fiber, and type 2 diabetes: searching for a kernel of truth. *Am J Clin Nutr* 2003;77:527-529.

**40.** Pereira MA, Jacobs DJ, Pins JJ, Raatz SK, Gross MD, Slavin JL, Seaquist ER. Effect of whole grains on insulin sensitivity in overweight hyperinsulinemic adults. *Am J Clin Nutr* 2002;75, 848-855.

**41.** Junatunen KS, Niskanen LK, Liukkonen KH, Poutanen KS, Holst JJ, Hykkanen HM. Postprandial glucose, insulin, and incretin responses to grain products in healthy subjects. *Am J Clin Nutr* 2002;75, 254-262.

**42.** McKeown NM, Meigs JB, Liu S, Wilson PWF, Jacques PF. Whole-grain intake is favorably associated with metabolic risk factors for type 2 diabetes and cardiovascular disease in the Framingham Offspring Study. *Am J Clin Nutr* 2002;76:390-398.

**43.** Juntunen KS, Laaksonen DE, Poutanen KS, Niskanen LK, Mykkanen HM. High-fiber rye bread and insulin secretion and sensitivity in healthy postmenopausal women. *Am J Clin Nutr* 2003;77:385-391.

**44.** McIntosh GH, Noakes M, Royle PJ, Foster PR. Whole-grain rye and wheat foods and markers of bowel



- health in overweight middle-aged men. *Am J Clin Nutr* 2003;77:967-974.
- 45.** Qi L, van Dam RM, Liu S, Franz M, Mantzoros C, Hu FB. Whole-grain, bran, and cereal fiber intakes and markers of systemic inflammation in diabetic women. *Diabetes Care* 2006;29:207-211.
- 46.** Slavin JL. Dietary fiber and body weight. *Nutrition* 2005;21:411-418.
- 47.** Pereira MA, Jacobs DR, Slattery ML, Ruth KJ, Van Horn L, Hilner JE, Kushi LH. The association of whole grain intake and fasting insulin in a biracial cohort of young adults: The CARDIA study. *CVD Prevention* 1998 1:231-242.
- 48.** Ludwig DS, Pereira MA, Kroenke CH, Hilner JE, Van Horn L, Slattery ML, Jacobs DR. Dietary fiber, weight gain, and cardiovascular disease risk factors in young adults. *JAMA* 1999;282: 1539-46.
- 49.** Liu S, Willett WC, Manson JE, Hu BF, Rosner B, Colditz G. Relation between changes in intakes of dietary fiber and grain products and changes in weight and development of obesity among middle-aged women. *Am J Clin Nutr* 2003;78:920-927.
- 50.** Koh-Banerjee P, Franz M, Sampson L, Liu S, Jacobs DR, Spiegelman D, Willett W, Rimm E. Changes in whole-grain, bran, and cereal fiber consumption in relation to 8-y weight gain among men. *Am J Clin Nutr* 2004;80:1237-1245.
- 51.** Jacobs DR, Marquart L, Slavin JL, Kushi LH. Whole-grain intake and cancer: An expanded review and meta-analysis. *Nutr Cancer* 1998;30:85-96.
- 52.** Chatenoud L, Tavani A, La Vecchia C, Jacobs DR, Negri E, Levi F, Franceschi S. Whole-grain food intake and cancer risk. *Int J Cancer* 1998;77:24-28.
- 53.** Larsson SC, Giovannucci E, Bergkvist L, Wolk A. Whole grain consumption and risk of colorectal cancer: a population-based cohort of 60,000 women. *Br J Cancer* 2005;92:1803-1807.
- 54.** Terry P, Lagergren J, Ye W, Wolk A, Nyren O. Inverse association between intake of cereal fiber and risk of gastric cardia cancer. *Gastroenterology* 2001;120: 387-391.
- 55.** Kasum CM, Jacobs DR, Nicodemus K, Folsom AR. Dietary risk factors for upper aerodigestive tract cancers. *Int J Cancer* 2002;99: 267-272.
- 56.** Kasum CM, Nicodemus K, Harnack LJ, Jacobs DR, Folsom AR. Whole grain intake and incident endometrial cancer: The Iowa Women's Health Study. *Nutr Cancer* 2001;39:180-186.
- 57.** Borriello SP, Setchell KD, Axelson M, Lawson AM. Production and metabolism of lignans by the human faecal flora. *J Applied Bact* 1985;58:37-43.
- 58.** Adlercreutz H, Fotsis T, Bannwart C, Hamalainen E, Bloigu A, Ollus A. Urinary estrogen profile determination in young Finnish vegetarian and omnivorous women. *J Steroid Bioch* 1986;24:289-296.
- 59.** Kilkkinen A, Valsta LM, Virtamo J, Stumpf K, Adlercreutz H, Pietinen P. Intake of lignans is associated with serum enterolactone concentration in Finnish men and women. *J Nutr* 2003;133:1830-1833.
- 60.** Kilkkinen A, Stumpf K, Pietinen P, Valsta LM, Tapanainen H, Adlercreutz H. Determinants of serum enterolactone concentration. *Am J Clin Nutr* 2001;73:1094-1100.
- 61.** Jacobs DR, Pereira MA, Stumpf K, Pins JJ, Adlercreutz H. Whole grain food intake elevates serum enterolactone. *Br J Nutr* 2002;88:111-116.
- 62.** Vanharanta M, Voutilainen S, Rissanen TH, Adlercreutz H, Salonen JT. Risk of cardiovascular disease-related and all-cause death according to serum concentrations of enterolactone. Kuopio Ischaemic Heart Disease Risk Factor Study. *Arch Inter Med* 2003;163:1099-1104.
- 63.** Jacobs DR, Pereira MA, Meyer KA, Kushi LH. Fiber from whole grains, but not refined grains, is inversely associated with all cause mortality in older women: The Iowa Women's Health Study. *J Amer Coll Nutr* 2000;19: 326S-330S.
- 64.** Jacobs DR, Meyer KA, Kushi LH, Folsom AR. Is whole-grain intake associated with reduced total and cause-specific death rates in older women? The Iowa Women's Health Study. *Amer J Public Health* 1999;89:322-329.
- 65.** Jacobs DR, Meyer HE, Solvoll K. Reduced mortality among whole grain bread eaters in men and women in the Norwegian County Study. *Eur J Clin Nutr* 2000;55: 137-143.



**66.** Liu S, Sesso HD, Manson JE, Willett WC, Buring JE. Is intake of breakfast cereals related to total and cause specific mortality in men? *Amer J Clin Nutr* 2003;77:594-599.

**67.** <http://www.wholegrainscouncil.org/WholeGrain-Stamp.html>

**68.** Richardson DP. Whole grain health claims in Europe. *Proc Nutr Soc* 2003;62:161- 169.

