Whole grains, refined grains and fortified refined grains: What's the difference?

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Dietary guidance universally supports the importance of grains in the diet. The United States Department of Agriculture pyramid suggests that Americans consume from six to 11 servings of grains per day, with three of these servings being whole grain products. Whole grain contains the bran, germ and endosperm, while refined grain includes only endosperm. Both refined and whole grains can be fortified with nutrients to improve the nutrient profile of the product. Most grains consumed in developed countries are subjected to some type of processing to optimize flavor and provide shelf-stable products. Grains provide important sources of dietary fibre, plant protein, phytochemicals and needed vitamins and minerals. Additionally, in the United States grains have been chosen as the best vehicle to fortify our diets with vitamins and minerals that are typically in short supply. These nutrients include iron, thiamin, niacin, riboflavin and, more recently, folic acid and calcium. Grains contain antioxidants, including vitamins, trace minerals and non-nutrients such as phenolic acids, lignans and phytic acid, which are thought to protect against cardiovascular disease and cancer. Additionally, grains are our most dependable source of phytoestrogens, plant compounds known to protect against cancers such as breast and prostate. Grains are rich sources of oligosaccharides and resistant starch, carbohydrates that function like dietary fibre and enhance the intestinal environment and help improve immune function. Epidemiological studies find that whole grains are more protective than refined grains in the prevention of chronic disease, although instruments to define intake of refined, whole and fortified grains are limited. Nutritional guidance should support whole grain products over refined, with fortification of nutrients improving the nutrient profile of both refined and whole grain products.

Key words: whole grains, phytochemicals, anti-oxidants, dietary fibre, cancer, cardiovascular disease.

Introduction

Grains provide approximately two-thirds of the energy and protein intake in the world, especially in developing countries, and about one-quarter of energy intake in the United States.[1] The major cereal grains are wheat, rice and corn, while barley, sorghum, millet, oat and rye are minor grains worldwide. Oats are important because they are generally eaten whole and, therefore, constitute an important part of whole grain consumption in the United States. Whole rye is commonly consumed in northern Europe. Wheat accounts for one-third of total worldwide grain production, while rice accounts for one-quarter.

Most whole and refined grains consumed in developed countries are subjected to some type of processing to make a desirable product by optimizing flavour, colour, texture and appearance, as well as providing shelf-stable products. For breads and other baked goods, grains are milled, flour is prepared, and then the flour is subjected to treatment with water and heat. Commercial cereals may be extruded, puffed, flaked or altered to improve product quality. Processing in these ways may enhance the desirability and therefore consumption of whole grain products. Processing conditions the grain for digestion and absorption by the body. In most cases, the nutritive value of whole grain products is preserved during processing.

There is universal agreement that grain foods form the base of the pyramid, our accepted dietary guidance tool. Six to 11 servings from the grain group are recommended daily, with the higher number of servings needed for active men and women. At least 55% of our joules should come from carbohydrates, with higher levels (up to 70%) being recommended for athletes. Nutritionists support that this carbohydrate energy should be 'complex carbohydrate' rather than simple carbohydrates or sugars. We should consume no more than 10% of our energy as simple sugars, leaving a large amount of complex carbohydrate to be included in the daily diet.

The bread, cereal, rice and pasta group gives us a wide range of foods to select, foods that are appropriate at meals throughout the day. Breakfast can include cereals, breads, muffins, bagels or biscuits while many convenient snack foods are grain products. Breads are a mainstay of our lunch and dinner meals, and pasta and rice are favourite foods for consumers. Despite the universal acceptance of the importance of grains in our diet and high consumer acceptance, usual intake often is below recommended levels.

The nutrient rich grains

Grains provide more than just carbohydrate to our nutrient intake. Grains are the most important source of dietary fibre and resistant starch. Wheat is an important source of insoluble dietary fibre while oats and barley supply needed soluble

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fibre to our diets. Insoluble dietary fibre has been linked to protection against colon cancer and other bowel disorders while soluble fibre will lower blood cholesterol and help stabilize blood glucose levels. Diets in developed countries are low in dietary fibre. Nutritionists recommend we consume from 25 to 35 g of dietary fibre each day while usual intake in the United States is only 14 g per day. Many consumers turn to fibre supplements when the best solution is to choose whole grain breads and cereals daily. Even white bread supplies dietary fibre, although only about 1 g per slice. Yet studies find that for many North Americans white bread is an important contributor to dietary fibre in the diet.

Grains products are also an important source of resistant starch. Starch is the main carbohydrate in grains and is an important source of energy. Some starch does not get digested for energy and ends up in the large intestine as an energy source for the microflora. Thus, this resistant starch functions similarly to soluble fibre in the body and can help lower serum cholesterol and stabilize blood glucose. Whole grain products are an important source of resistant starch, although processed refined grains are also rich in resistant starch.[2]

Grains are rich in plant proteins. Although we often consider vegetable proteins to be lower in quality than animal proteins, they can easily be combined to form complete proteins. Grains are low in the amino acid lysine while legumes are low in the amino acid methionine. When grains and legumes are consumed together, they form a protein of higher quality. Grains are an important protein source for most of the world's population and have become an important source in the United States as we switch to a more vegetarian eating pattern. A recent study of protein intake from the Third National Health and Nutrition Examination Survey found that grains are our top vegetable supplier of protein.[3]

Grains have always been important sources of B vitamins in the diet. The nutritional deficiency disease Beriberi, a deficiency of the B vitamin thiamin, was linked to polishing rice, which removed the B vitamins. Some minerals are also concentrated in the outer layers of the grain. Grains are consistent sources of iron, magnesium, zinc and other minerals that are often in short supply in our diet.

Fortification of grain products

Because of the popularity of grain products, they often have been chosen as the vehicle for fortification of the diet. As nutrient deficiencies are discovered, public policy has often been directed to find successful strategies to improve nutrient intake. If nutrients are needed by the entire population, grains are often chosen because they are consumed universally and can deliver needed nutrients to a population. Breads were first fortified with riboflavin, niacin, thiamin and iron in the 1940s as a means to deliver these nutrients, which were in short supply in the American diet. This fortification policy helped eradicate the deficiency diseases associated with these B vitamins and helped improve iron intake in our population. Cereal products have also been fortified with these nutrients and additional nutrients that are known to be deficient in our diets. Thus, there are cereal products available that can contribute significantly to meeting the recommended dietary allowance (RDA) for a wide range of nutrients.

Folic acid, a B vitamin, has been in low supply in our diet as it is most concentrated in leafy green vegetables, which are not consumed as widely as recommended. The folic acid debate on fortification became more urgent after scientific research was published that low intake of folic acid was linked to higher incidence of neural tube defects in infants.[4] There was a need to deliver folic acid to women of childbearing age, as it became clear that folic acid intakes needed to be increased not just during pregnancy, but in the years leading up to pregnancy.

Again, grains were chosen as the vehicle for fortification with folic acid. In January 1998, grains in the United States were required to have folic acid added to the nutrients that were fortified. Recent research supports that grains fortified with folic acid are an important source of folic acid in low-income women. Knowledge of the link between folic acid intake and neural tube defects is not widespread, but because of fortification of grain products with folic acid even women who know nothing about this link are receiving folic acid when they consume grain products.[5] Because this fortification is included in all grain products, even women who choose inexpensive white bread as their grain source will be receiving this protection.

Grain-based cereals have recently been fortified with calcium. Rationale for this fortification is that calcium intakes are chronically low, especially for women and adolescent girls who consume few dairy products. As future research identifies nutrients in short supply in our diet, grains may be considered for additional fortification with nutrients.

Phytochemicals in grains

Grains supply a wide range of phytochemicals that have been found to be protective in models of chronic disease including cardiovascular disease, cancer and diabetes. Although the phytochemicals in grains are similar to phytochemicals in other plants, including fruits and vegetables, grains are unique sources of some phytochemicals, including potent antioxidants.[6]

Antioxidants

Oxidative stress results when the balance between the production of reactive oxygen species overrides the antioxidant capability of the target cell.[7] The accumulation of oxidative damage has been implicated in both acute and chronic cell injury including possible participation in the formation of cancer. Antioxidants are compounds that delay the onset or slow down the rate of oxidation of oxidizable substrates. Grains contain many antioxidants including vitamins and trace minerals; non-nutrients such as phenolic acids and lignans; and antinutrients such as phytic acid. Whole grains are concentrated sources of vitamin E, including tocotrienols. Trace minerals such as copper, zinc, selenium and manganese are also concentrated in the outer layer of grains.

Phenolic acids are located in the bran layer of grains, and grains are thought to be particularly rich sources of phenolic acids. The potentially anticarcinogenic mechanism of phenolic compounds involves the induction of detoxification systems, specifically the Phase II conjugation reactions. Wattenberg classified caffeic and ferulic acids, which are phenolic acids concentrated in grains, as inhibitors acting both by preventing the formation of carcinogens from

precursor compounds and by blocking the reaction of carcinogens with critical cellular macromolecules.[8] Phytic acid, which is concentrated in grains, is a known antioxidant. Phytic acid forms chelates with various metals, which suppress damaging iron-catalyzed redox reactions. Colonic bacteria produce oxygen radicals in appreciable amounts and dietary phytic acid may suppress oxidant damage to intestinal epithelium and neighbouring cells.

Vitamin E, which is concentrated in grains, is an intracellular antioxidant that protects polyunsaturated fatty acids in cell membranes from oxidative damage. Another possible mechanism for vitamin E relates to its capacity to keep selenium in the reduced state. Vitamin E inhibits the formation of nitrosamines, especially at low pH. Wattenberg has characterized vitamin E as a cancer inhibitor that exerts its effect by preventing the formation of carcinogens from precursor compounds.[8] Selenium is also important in the prevention of oxidation. Its food composition is generally proportional to the selenium content of the soil in which the grain is grown. Selenium functions as a cofactor for glutathione peroxidase, an enzyme that protects against oxidative tissue damage. It has a suppressive action on cell proliferation at high levels. Wattenberg classifies selenium as a suppressing agent, an inhibitor that prevents the expression of neoplasia in cells that have been exposed previously to a carcinogen.[8]

Lignans and phytoestrogens

Phytoestrogens, which include isoflavones, coumestans and lignans, are compounds found in plants that have a structure similar to oestrogen.[9] Concentrated sources of lignans include whole grain wheat, whole grain oats and rye meal. Seeds are also concentrated in lignans, including flaxseed seeds (the most concentrated source), pumpkin seeds, caraway seeds and sunflower seeds. Whole grain breads and cereals are the most consistent source of lignans in the diet. Grain intake increases urinary lignan excretion, which is an indirect measure of lignan content in foods.

Estrogen metabolism is of interest because of its proposed role in breast cancer. Phytoestrogens are thought to alter serum hormones. Flax powder (10 g per day) increased average luteal phase length of the menstrual cycle in premenopausal women.[10] Any significant lengthening of the overall cycle length would be potentially beneficial in lowering risk for hormonally dependent cancers. Additionally, phytoestrogens improve menopausal symptoms, making them a popular dietary strategy for postmenopausal women.

Oligosaccharides

Grains contain significant amounts of oligosaccharides.[11] Oligosaccharides are defined as carbohydrates that are of a shorter chain length than polysaccharides. Oligosaccharides have been ignored until recently in human nutrition as the only property of note was their ability to generate intestinal gas. Common oligosaccharide names include oligofructose, fructans and inulin. Wheat flour contains from 1 to 4% fructan on a dry weight basis. Fructans have also been found in rye and barley with very young barley kernels containing 22% fructan. Wheat provides 78% of the North American intake of oligosaccharides.

Oligosaccharides have similar effects to soluble dietary fibre in the human gut. Additionally, oligosaccharides have consistently been shown to be able to alter the human faecal flora. Consumption of fructans increase bifidobacteria (good bacteria) in the gut while decreasing concentrations of *E. coli*, clostridia and bacteroides (pathogenic bacteria). Enhancement of the gut environment has been linked to improved immune function.

Others

Research on many phytochemicals in grains is just beginning, but they have wide-ranging effects in the body and play a role in the prevention of chronic disease.

Epidemiological support for the protective role of grains against chronic disease

Cardiovascular disease

Many studies support that grain products reduce the risk of cardiovascular disease independent of soluble fibre. Morris and co-workers followed 337 subjects for 10–20 years and concluded that a reduction in heart disease risk was attributable to a higher intake of cereal fibre, while indicating that soluble sources such as pectin and guar did not account for the lower coronary heart disease (CHD).[12] Brown *et al.* concluded that increasing soluble fibre can make only a small contribution to dietary therapy to lower cholesterol.[13] Other compounds in grains, including antioxidants, phytic acid, lectins, phenolic compounds, amylase inhibitors and saponins have all been shown to alter risk factors for CHD. It is likely that it is the combination of compounds in grains, rather than any one component, which explains its protective effects in CHD.

Large prospective epidemiological studies have found a moderately strong association between whole grain intake and decreased CHD risk. A total of 34 492 post-menopausal women, aged 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.[14] Whole grain intake was determined by seven 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 an adjustment for dietary fibre intake. This suggests that whole grain components other than dietary fibre may reduce risk for CHD.

In a Finnish study, 21 930 male smokers (aged 50–69 years) were followed for 6.1 years.[15] Reduced risk of CHD death was associated with increased intake of rye products. Rimm *et al.* examined the association between cereal intake and risk for myocardial infarction (MI) in 43 757 US health professionals, aged 40–75 years.[16] Cereal fibre was most strongly associated with reduced risk for MI with a 0.71 decrease in risk for each 10 g increase in cereal fibre 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.[17] A total of 68 782 women, aged 37–64 years, without previously diagnosed angina, MI, stroke, cancer, hypercholesterolemia or diabetes at baseline were studied. Dietary data were collected with a validated semiquantitative food frequency questionnaire. After correcting for age,

cardiovascular risk factors, dietary factors and multivitamin supplement use, the relative risk was 0.77 (95% confidence interval (CI), 0.57–1.04). For a 10 g per day increase in total fibre intake (the difference between the lowest and highest quintiles), the multivariate relative risk (RR) of total CHD events was 0.81 (95% CI, 0.66–0.99). Of the different sources of dietary fibre (cereal, vegetable, fruit), only cereal fibre was strongly associated with a reduced risk of CHD (multivariate RR, 0.63; 95% CI, 0.49–0.81 for each 5 g per day increase in cereal fibre). The authors concluded that higher fibre intake, particularly from cereal sources, reduces the risk of CHD.

Cancer

There is substantial scientific evidence that whole grains, in the form commonly consumed in the United States and Europe, reduce risk of some cancers. Whole grain intake is difficult to assess in epidemiological studies because existing food frequency instruments were not designed to measure this dietary component. In epidemiological studies, various phrases identify whole grains including dark bread, brown bread, crisp bread, high-fibre cereal bread, whole grain bread and cereal, whole grain cereal, whole grain foods, whole grain pasta and wholemeal bread. Although these classification categories are not perfect, they do allow researchers to differentiate between participants who are infrequent versus habitual or frequent consumers of whole grain products.

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 six mentions with design/reporting flaws or low intake.[18] Odds ratios were < 1 in nine of 10 mentions of studies of colorectal cancers and polyps; seven of seven mentions of gastric and six of six mentions of other digestive tract cancers; seven of seven mentions of hormone-related cancers; four of four mentions of pancreatic cancer; and 10 of 11 mentions of eight other cancers. The pooled odds ratio was similar to studies that adjusted for few or many covariates.

A systematic review of case-control studies conducted using a common protocol in northern Italy between 1983 and 1996 indicated that a higher frequency of whole grain consumption is associated with a reduced risk for cancer.[19] Whole grain was consumed primarily as whole grain bread and some whole grain pasta in the Italian studies.

Other chronic diseases

Jacobs *et al.* determined the relationship between whole grain intake and all-cause mortality in the Iowa's Women's Health Study.[20] There were striking inverse associations of whole grain intake with risk of death. Unadjusted total mortality rates in the lowest to highest quintiles of whole grain intake were 13.4, 10.3, 9.0, 7.9 and 9.2 per 1000 person-years. Further analyses were conducted to determine whether the association of whole grain intake with total mortality could be attributed to dietary constituents of grain. After adjustment for fibre, vitamin E, folic acid, phytic acid, iron, zinc, magnesium and manganese intake from all sources (except supplements), the association of whole grain with risk of death was slightly attenuated.

Whole grains may also protect against diabetes. Salmeron *et al*. examined cereal fibre intake (high *vs* low quintile) and risk for non-insulin dependent diabetes mellitus (NIDDM) in 42 759 men followed over a 6-year period.[21] Cereal fibre intake was inversely associated with risk for NIDDM for 8.1 g per day compared with < 3.2 g per day. Salmeron and co-workers also examined cereal fibre intake and risk for NIDDM in 65 173 US women, aged 40–65 years, with a 6-year follow-up.[22] Cereal fibre intake was once again associated with a reduced risk for diabetes. This research supports the value of whole grains in the diets of people with diabetes to help reduce risk for CHD.

Clinical studies

Few feeding studies have been conducted on the biological effects of whole grains. Bruce *et al.* fed a diet high in whole and unrefined foods as compared to a refined diet to 12 hyperlipidemic subjects.[23] Subjects consumed the refined food diet for the first 4 weeks of the study and then switched to the phytochemical-rich diet for 4 weeks. The phytochemical-rich diet included dried fruits, nuts, tea, whole grain products and more than six servings per day of fruits and vegetables. The whole food diets significantly lowered serum cholesterol and low-density lipoprotein cholesterol, improved colon function, and increased measures of antioxidant defense, all biomarkers of decreased risk of chronic disease.

Conclusion

With the increased emphasis on consumption of whole grain products, more bakery and snack foods now include some whole grain flour. In July 1999 a health claim was approved for whole grains, which should encourage the development of whole grain products. A whole grain product is defined as one that contains 51% or more whole grain ingredients. Compliance criteria are based on the total dietary fibre content of such products. This health claim should lead to the development of more whole grain products for consumers and this should assist consumers in implementing dietary guidance on whole grain intake. Grains, through natural goodness and fortification, continue to be a significant nutrient source for American consumers and deserve their prominent place at the base of the pyramid.

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