that may be involved in cardiovascular/hepatic protection, lipid metabolism and DNA methylation. Potential protective effects of bound phenolic acids within the colon, of the B-complex vitamins on nervous system and mental health, of oligosaccharides as prebiotics, of compounds associated with skeleton health (e.g. phosphorous, calcium, magnesium, manganese, copper and vitamin K), and of other compounds such as α-linolenic acid, policosanol, melatonin, phytosterols and para-aminobenzoic acid also deserve to be largely more studied. For example, it would be particularly interesting to study the effect of whole grain products on mental health issues like depression, insomnia and cognitive decline given that other bioactive compounds, such as choline, ferulic acid, magnesium, zinc, copper, inositols, policosanol and melatonin, are also potential candidates for mental health protection and equilibrium.

Optimizing the level of bioactive compounds

In addition to discussing the role of bioactive compounds in relation to health effects, Fardet outlines the main ways for improving cereal product nutritional quality (Figure 3). Thus, a good fertilization process may lead to a higher content of minerals such as selenium, magnesium, iron and zinc. Secondly, cereals with higher levels of bioactive substances may be obtained via genetics. Thirdly, the nutritional quality of cereal products may be increased via technological processes, notably through reducing the degree of refining and applying fermentation during processing. Indeed, if cereal fermentation is already largely used to produce alcoholic beverages, it may also have a positive effect on the bioavailability of bioactive substances and on their increased content in cereal products. More generally, one should search for increasing nutritional density of cereal products in bioactive compounds through germination, soaking and pre-fermentation of whole grain cereals and/or their fractions as already largely practiced in developing countries, notably in Africa and Asia.

The whole grain package

The contents of individual bioactive compounds in whole grain may seem too low for them to have any significant or lasting physiological effects. It is becoming more and more evident that the synergetic action of several bioactive compounds contributes to health protection and/or the maintenance of one physiological function, not just one compound. Figure 1 and 2 illustrate this concept of "whole grain package": therefore, obesity/body weight regulation, cardiovascular diseases, type 2 diabetes, cancers, gut, mental/nervous system and skeleton health might be potentially prevented by at least 10, 34, 17, 32, 10, 26 and 16 different bioactive compounds and/or groups of compounds respectively.

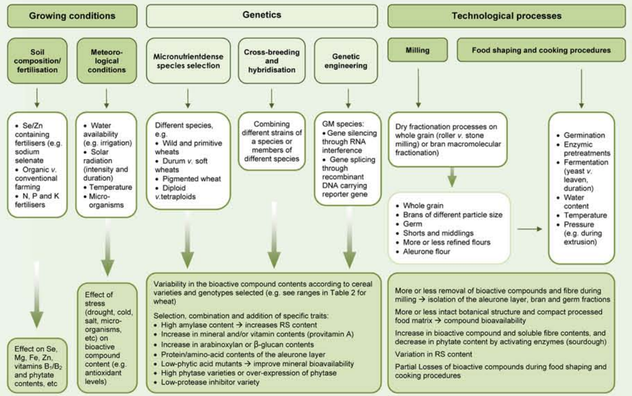


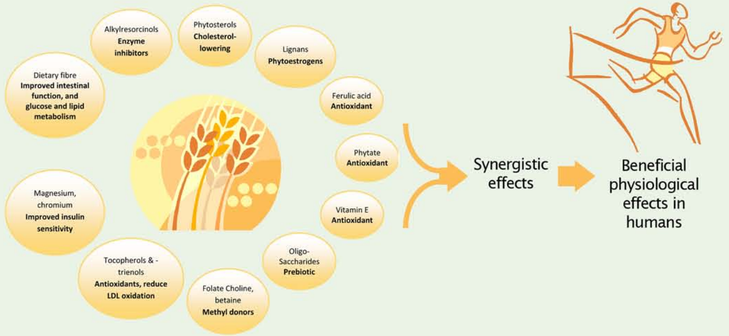
Figure 3. Ways for improving cereal product nutritional quality.

Until today, research has tended to focus on the study of isolated effects of individual bioactive compounds based on a reductionist approach. The combined physiological effects of the bioactive compounds would be now much more interesting to investigate based on a more integrative and holistic approach, but this is probably more difficult to apprehend. Today, the development of nutrigenomics offers new opportunity for studying further such combined and complex effects. With nutrigenomics, nutrition looks at the impact on the genes, protein synthesis and metabolic pathways in body biofluids and cells following diet or food consumption. In the end, due to the gap between observational studies and the elucidation of the causal physiological mechanisms involved, there is a real need for intervention studies with complex whole grain products in humans.

For more information see also:
EUFIC, Whole grain Fact Sheet (2009) http://www.eufic.org/article/en/expid/Whole-grain-Fact-Sheet

WHOLE GRAIN FOOD BIOACTIVITY

Whole meal vs. white flour: 2.5 - 5 x higher levels



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Source

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October 2011

Health-protective mechanisms of whole grain cereals - new hypotheses

Whole grain foods and health

Cereal foods are an essential part of the daily diet. Nutrition epidemiology research increasingly demonstrates that a diet rich in whole grain based foods assist in health maintenance and thus lowers the risk of non-communicable diseases.
An overview of all bioactive compounds in whole grains, their potential health effects and mechanisms involved is given in a major review paper with over 1000 references (Nutr Res Rev. 2010 23(1):65-134). In order to inform a wider audience, the author, Dr. A. Fardet has prepared for the Healthgrain Forum the summary presented in this leaflet.

Healthgrain Forum

The HEALTHGRAIN EU Project (2005-2010, www.healthgrain.eu) has substantially strengthened the scientific basis for a new generation of cereal based products with enhanced health benefits. The Healthgrain Forum (www.healthgrain.org) was initiated in 2010 for continuing HEALTHGRAIN's research, networking and communication activities. Already 55 member organisations joined, with an even balance between academia and industry. The Forum, based in Europe and with links worldwide, is formulating a Strategic Research Agenda and is developing a range of communication activities, with the overall aim of increasing consumers´ intake of protective components in whole grains.

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Health-protective mechanisms of whole grain cereals: what is beyond fibre?

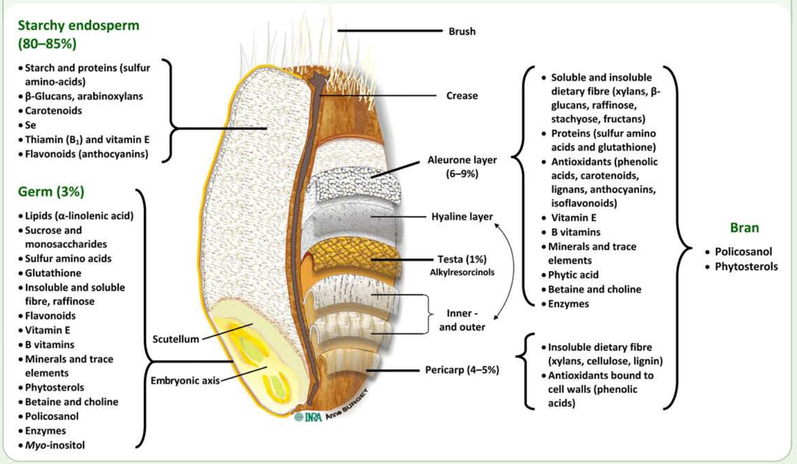
Introduction

Wheat, rice and corn are the most widely eaten whole grains, followed by oats, rye and barley. A wheat kernel consists of 80-85% endosperm, 10-14% bran and 2.5-3% germ (see Figure 1). Whole grains contain more than 26 bioactive substances such as fibre, vitamins, minerals, antioxidants and other phytochemicals such as betaine, choline, sulphur amino-acids or melatonin, which account for at least 15% of the whole grain by weight. Most bioactive substances are in the bran (about 52% by weight), and the germ (at least 24% by weight) fractions. In refined cereals, the levels of bioactive compounds are substantially reduced due to the complete or partial removal of the germ and bran fractions.

The physiological mechanisms involved

Epidemiological research indicates that the consumption of whole grain products significantly protects against obesity, type 2 diabetes, cardiovascular disease and some cancers, especially within the digestive tract, the effect being the most conclusive against type 2 diabetes. How do whole grain foods offer protection against these chronic diseases? Human intervention studies have notably shown that increased whole grain product consumption may contribute to an improved intestinal health, a lower BMI (Body Mass Index), a healthier blood lipid profile, an improved blood glucose control, increased insulin sensitivity, lower homocysteine levels (a cardiovascular risk factor) and reduced inflammatory markers. The preservation of an intact food structure (i.e. more or less intact cereal kernels) may also lead to an increased feeling of satiety that is important in weight gain control. Whole grain products are also generally a rich source of fibre, antioxidants, anticarcinogens and magnesium that are all potentially

Figure 1. The three wheat fraction (bran, germ and endosperm) with their main bioactive compounds: whole grain wheat has a heterogeneous structure with bioactive compounds unevenly distributed within its different parts.



protective. In addition, whole grain products may lead to increased butyrate production (protective against tumour growth) within the colon due to resistant starch (the starch fraction that is not digested in the small intestine) and fibre fermentation. Some antinutrients like phytic acid, lectins, tannins, saponins and inhibitors of enzymes (e.g. proteases and α-amylases) may also positively affect starch hydrolysis rate and subsequent blood glucose levels. Finally, it is now well demonstrated that the consumption of low-GI (Glycaemic Index) whole-grain products either at dinner or at breakfast positively influence the glycaemia (or blood glucose control) at the following meal "the second-meal" effect, an effect which may contribute to the long-term metabolic benefits of low-GI diets.

Besides these quite well-known mechanisms, a whole grain also contains a multitude of other bioactive substances. The content of some bioactive substances may however seem too low for reaching a significant effect. But according to Fardet, it becomes increasingly obvious that the combination of all these bioactive substances might have positive synergistic health effects; not only within the intestine or towards cardiovascular diseases, glucose metabolism and weight regulation, but also in new areas such as bone health and mental health (see Figure 2). Let's now have a detailed look at the main physiological effects of whole grain bioactive compounds:

Whole grain cereals as a rich source of fibre

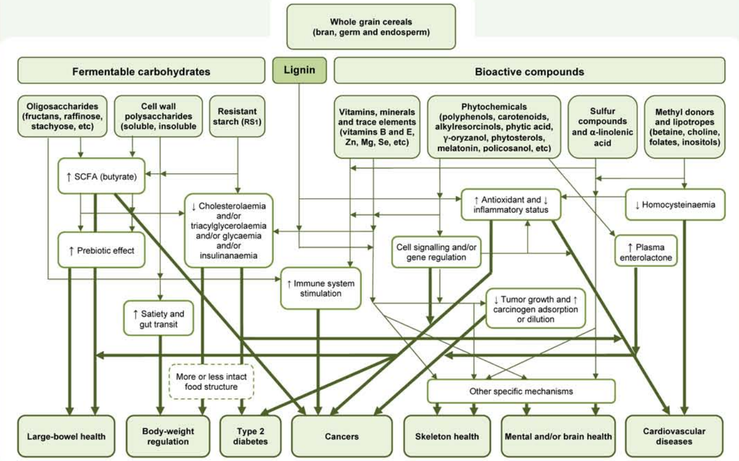
Whole grains are primarily a rich source of fibre. The fibre content of whole wheat varies between 9 and 17 grams per 100 grams. That is more than vegetables, which usually have up to 6 grams per 100 grams edible portion. Thus, consuming whole grain cereal products is undoubtedly a good way of increasing the fibre intake from the 10-15 g/day eaten by most Western populations to the recommended level of about 30-35 g/day.

Wheat fibre is mainly insoluble fibre and resistant starch. Fibres from whole grain foods are beneficial for gut health. Insoluble fibre, which is poorly fermented in the colon, favours an increased transit time and greater faecal bulking, two parameters that probably prevent colon cancer by diluting carcinogens and reducing their time in contact with epithelial cells. Cereal fibres also increase satiety and help control body weight. Fibre fermentation is also associated with a high production of short chain fatty acids (e.g. butyrate) that are associated with a lower risk of cancer, favouring the development of a healthy colonic microbiota (i.e. a prebiotic effect). However, the way fibres may be beneficial for human health is multi-factorial and it involves other physiological mechanisms e.g. hormonal effects or decreased gastric emptying rate (due to viscous fibre).

Whole grain cereals as rich sources of anti-carcinogenic compounds

This anti-carcinogenic effect is mainly attributed to the anti-oxidant and anti-inflammatory properties of several bioactive compounds, as increased oxidative stress and inflammation are involved in cancer aetiology. Phenolic acids, flavonoids, carotenoids, vitamin E, n-3 fatty acids, lignan phytoestrogens, steroid saponins (found mainly in oats), phytic acid and selenium are all potential suppressors of tumour growth, but human, animal and/or in vitro cell studies indicate that their mechanisms of action may differ. To summarize, it is possible to distinguish between the anti-carcinogenic effects of insoluble fibre (including lignin) and phytochemicals. Insoluble fibre may act directly by absorbing or diluting carcinogens (through increased faecal bulk by water absorption), or indirectly by decreasing colon pH (through Short Chain Fatty Acids production) and increasing butyrate production. The role of phytochemicals is complex and multi-factorial, and notably involves their antioxidant properties.

Figure 2. Current and new proposed physiological mechanisms involved in protection by whole grain cereals. The dotted thin arrows (⟶) indicate the link between whole-grain bioactive compounds and protective physiological mechanisms, while the coloured plain arrows (⟶) indicate the relationship between physiological mechanisms and health outcomes.



Whole grain cereals as a rich source of magnesium and anti-oxidants

Not only do whole grains contain fibre, but also relevant amounts of magnesium and antioxidants. The high magnesium content may partly explain the beneficial effect of whole grain foods on insulin sensitivity and risk of type 2 diabetes. Magnesium increases insulin secretion and it is known that diabetes is often associated with a lack of magnesium. In a whole grain there are also different substances that contribute directly or indirectly to protect the body from increased oxidative stress. At least 30 bioactive compounds might be involved: Think of polyphenols, carotenoids, vitamin E and minerals like selenium, iron, copper and zinc, which act as a cofactor in antioxidant enzymes; sulphur-containing amino acids, methionine and cystine that are precursors of glutathione, an endogenous antioxidant. Even lignin, generally considered as biologically inactive, has been shown to exert a potential antioxidant effect in animals. Antioxidants found in whole grains may also protect the intestinal epithelium against damage by free radicals, such as those produced within the colon through bacteria metabolism. The antioxidants in whole^grain cereals may therefore act via different, complex, and synergetic mechanisms in vivo. However, the antioxidant action of whole grain cereals has not yet been convincingly validated in humans and requires further exploration.

Other bioactive compounds and potential health effects

Recent findings, the exhaustive listing of bioactive compounds found in whole grain wheat, their content in whole grain, bran and germ fractions and their estimated bioavailability, have led to new hypotheses. The involvement of polyphenols in cell signalling and gene regulation, and of sulphur compounds, lignin and phytic acid should be considered in antioxidant protection. Whole grain wheat is also a rich source of methyl donors/lipotropes (methionine, betaine, choline, inositol and folates)