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Beyond Whole Grain: The European HEALTHGRAIN Project Aims at Healthier Cereal Foods

KAISA POUTANEN,¹ RICHARD SHEPHERD,² PETER R. SHEWRY,³ JAN A. DELCOUR,⁴
INGER BJÖRCK,⁵ AND JAN-WILLEM VAN DER KAMP⁶

Cereal foods are an important source of carbohydrates and dietary fiber in our diet. Epidemiological evidence increasingly demonstrates that a diet rich in whole grain is protective against development of diet-related disorders such as cardiovascular disease and type 2 diabetes. The majority of cereal foods today, however, are made from refined wheat flour. The grain processing industry therefore faces challenges and opportunities to produce new ingredients and foods with added value for consumer health. Against this background, the European Community decided to support the HEALTHGRAIN project (www.healthgrain.org) over the 2005–2010 period as part of the 6th Framework Food Research Program. HEALTHGRAIN aims to improve the well-being of humankind and to reduce the risk of metabolic syndrome-related diseases in Europe by increasing the intake of protective compounds in whole grains or their fractions. It presents an integrated, multidisciplinary effort to determine the variation in composition, process-induced changes, and human metabolism of bioactive compounds in the major European bread grains wheat and rye and to reveal the physiological mechanisms underlying their role in the prevention of metabolic syndrome and related diseases. The target bioactive compounds are vitamins (folate, tocopherols, choline), phytochemicals (lignans, sterols, alkylresorcinols, phenolic acids), and indigestible carbohydrates (dietary fiber). Also, other product characteristics that may add to the metabolic benefits of whole grain products are promoted. The work is carried out in 17 work packages, distributed over five modules, and carried out by 43 organizations from 15 European countries.

Introduction

Cereal foods in general, and wheat in particular, are an important component of the daily diet throughout Europe and are a major

source of dietary carbohydrates. Usually only the inner part of the grains, i.e., the starchy endosperm that is milled to yield white flour, is used as raw material for baked goods, pasta, breakfast cereals, and other foods. Nutritional guidelines recommend that carbohydrates should provide about half of the recommended daily supply of energy. It would therefore be advantageous to simultaneously optimize the overall nutritional value and healthiness of the cereal foods.

In this context, it is important to mention that epidemiological findings over the past decade increasingly support the hypothesis of a protective role of whole grain foods against several diseases characteristic of Western societies, including the rapidly expanding epidemic of type 2 diabetes. Diabetes is a major disease of the present century, the global prevalence of which has been estimated to increase to 300 million in 2025. Risk factors for type 2 diabetes include obesity, physical inactivity, a high-fat diet rich in saturated fatty acids, and low intake of dietary fiber. With the aging population and current lifestyle, this is an alarming situation. Type 2 diabetes most often develops gradually and is preceded by impaired glucose tolerance. Numerous epidemiological studies have shown that intake of whole grains and cereal fiber protect against type 2 diabetes.

The scientific epidemiological data connecting the intake of whole grains with the reduced risk of other diseases is also exceptionally sound. Grain foods play an important role in gut health, and both wheat and rye brans have been shown to protect against colon cancer. Dietary fiber was long considered the major health protective component of grains. There is now increasing evidence also of the presence of other potentially protective compounds, which, together with dietary fiber, are concentrated in the outer layers of the grains.

However, the mechanisms for protection remain at a hypothetical level. Diabetes, heart disease, and cancers are multifactorial chronic diseases, and, thus, the diseases can only be used as endpoints in case-control or large-scale epidemiological studies. Most experimental studies on the relationship between chronic disease and dietary factors, however, use physiological biomarkers or risk factors as endpoints. The importance of various phytochemicals on the modulation of these factors has been suggested. However, insufficient data are available about their levels in cereal products or about the levels reached in people eating whole grains foods.

In parallel with the above, the food industry and health authorities over the past decade have also shown a growing interest in the health benefits of whole grain products. In the United States (1999), United Kingdom (2002), and Sweden (2003), this has resulted in the approval of whole grain health claims by the competent authorities. Industry has benefited economically by developing

¹ VTT Technical Research Centre of Finland, P.O. Box 1000, FI-02044 VTT, Finland; kaisa.poutanen@vtt.fi.

² University of Surrey, GU2 7XH Guildford, United Kingdom; r.shepherd@surrey.ac.uk.

³ Rothamsted Research Harpenden, Herts, AL5 2JQ, United Kingdom; peter.shewry@bbsrc.ac.uk.

⁴ Katholieke Universiteit Leuven, Kasteelpark Arenberg 20, BE-3001 Heverlee, Belgium; jan.delcour@biw.kuleuven.be.

⁵ Lund University, P.O. Box 124, SE-22100 Lund, Sweden; inger.bjorck@inl.lth.se.

⁶ TNO Quality of Life, P.O. Box 360, NL-3700 AJ ZEIST, The Netherlands; jan-willem.vanderkamp@tno.nl.

new foods and using the whole grain claim on cereals, resulting in increased sales. In this context, it is of note that in 2005, in Europe, the Confederation of the Food and Drink Industries of the European Union (CIAA) identified the key drivers for innovation to be pleasure (46%), health and well-being (28%), convenience (25%), and “ethics” (1%). The key growth areas in bakery and bread in Western Europe are health and wellness. From 2005 to 2010, the expected contributions of health and wellness products to overall growth are 67% in bread and 36% in bakery products.

The authors of this article represent the coordination committee of the scientific program of HEALTHGRAIN, ranging from consumer science to crop improvement, food technology, bioprocessing, and, finally, nutrition. HEALTHGRAIN also includes a comprehensive implementation program to interact with various stakeholders, including an industrial platform, nutrition information network, and consumer communication panel. We here discuss the objectives of the HEALTHGRAIN project, its structure, and work plan, and give a brief overview of the results obtained so far. More detailed accounts of the work carried out will be reported in the future.

Objectives

The strategic objective of HEALTHGRAIN is to improve the well-being and reduce the risk of metabolic diseases of European consumers by increasing the intake of protective grain factors through improved availability of health-promoting and safe cereal-based foods and ingredients.

To meet this strategic objective, state-of-the-art tools of plant biotechnology and bioprocessing, fractionation, and formulation technologies are being developed in order to increase the levels of protective grain compounds in cereal foods. It is a further aim to demonstrate the absorption and relevance of these compounds

in metabolic health, especially in control of blood sugar levels and insulin metabolism, and to provide effective technology transfer and dissemination about their health relevance to various stakeholders in the grain chain. In order to meet consumer demands for healthy cereal foods, consumer expectations and sensory quality of the bioactive cereal foods are studied as well. Thus, the following technical objectives can be discerned:

- To explore and understand consumer demands for healthy cereal-based food;
- To explore and extend variation in grain composition and to develop a biotechnology toolbox for accelerated breeding of improved cultivars;
- To develop technology and processing tools for nutritionally optimized cereal foods and new food ingredients from whole grains;
- To identify the physiological mechanisms of cereal foods related to human health or disease prevention; and
- To develop an interactive dissemination, training, and technology transfer program.

Research Program

HEALTHGRAIN is coordinated by Kaisa Poutanen. It has four research modules led by Richard Shepherd, Peter Shewry, Jan Delcour, and Inger Björck and one technology transfer and dissemination module led by Jan-Willem van der Kamp (Fig. 1). Taken together, they constitute an integrated interdisciplinary research, training, and communication program. Indeed, as outlined above, state of the art plant biotechnology, grain bioprocessing, and nutritional science are combined in an interactive manner to reveal the biological mechanisms behind the nutritional benefits of grains and to apply and disseminate the results to tailor cereal products for improved consumer health (Fig. 2).

PROJECT STRUCTURE

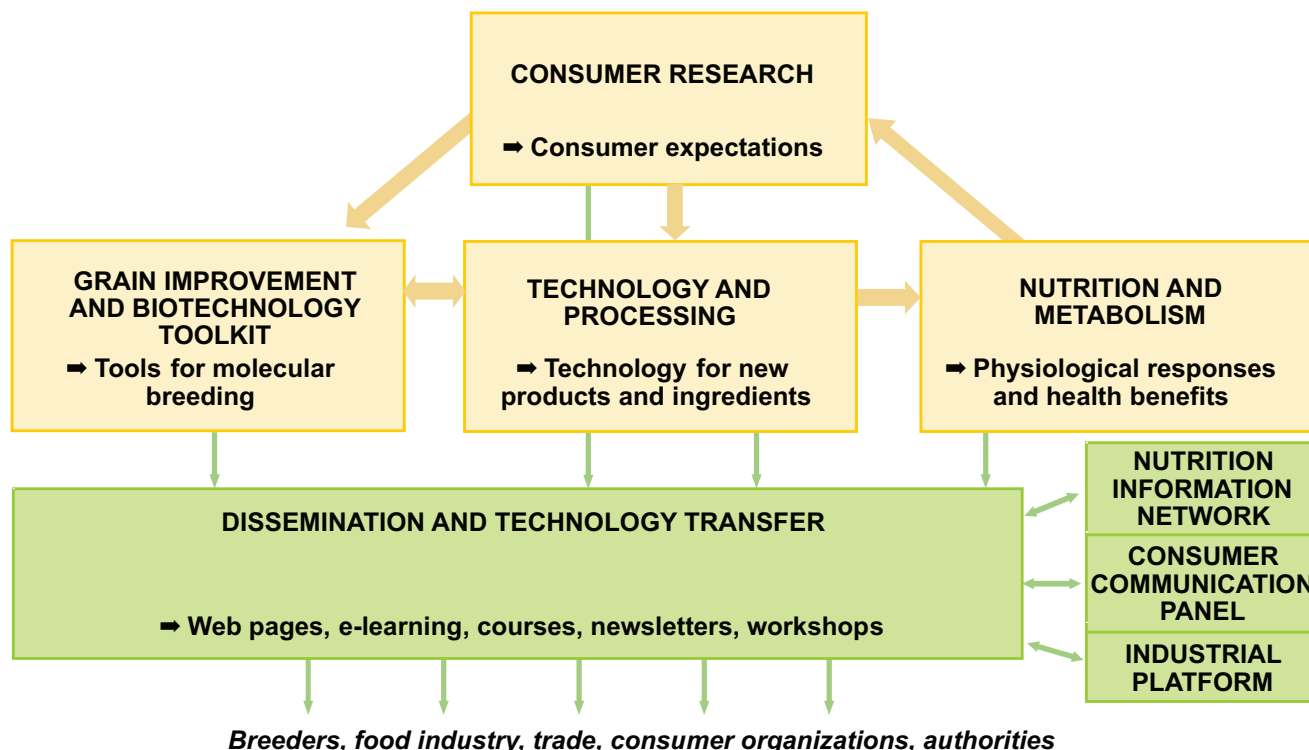


Fig. 1. Scheme of the HEALTHGRAIN project structure.

Module 1—Consumer Expectations and Attitudes on Healthy Cereal Foods

Good taste, health, convenience, and price are typical reasons for food choices among European consumers. Although taste and healthiness are often considered as opposite factors for food choice, consumers today can make healthy choices from pleasant tasting options. Food products also carry health images that may be underlying factors in the way we judge foods and make our choices. Cereal-based products form a wide selection of alternatives that play various roles in food culture in different parts of Europe. Also, their health image varies.

The consumer research module, led by Richard Shepherd, studies consumer expectations of cereal-based products that have been modified to contain more health promoting components, compares the appeal of different health promoting aspects of cereal-based foods among European consumers, and studies how these aspects fit with the existing health image of various grain foods.

The first consumer study in four countries has been completed, showing that whole grain foods are generally considered beneficial, although there were differences between the countries included in the study. Sensory quality was important as a product quality criterion even for healthy foods.

Module 2—New Sources of High Quality Raw Material for Use in Plant Breeding and Tools to Facilitate Selection of Cultivars

The development of cultivars with increased concentrations of nutrients is essential for the delivery of benefits to consumers, particularly in white flour products, which currently contain low levels of such components. It is, therefore, necessary to determine the distribution of components within the grain as well as the total amounts present in the whole grain and, in particular, to focus on the starchy endosperm tissue, which is isolated as white flour upon milling.

The plant breeding and biotechnology module, led by Peter Shewry,

- Identifies sources of variation in the total amounts and compositions of bioactive compounds in whole grain and milling fractions of wheat and rye, and variation in the spatial distribution of these components within the grain;
- Extends the range of variation in key components using chemical mutagenesis followed by screening using biochemical and molecular approaches. Transgenic approaches are also being used to identify novel genes for targeting by mutagenesis, focusing on the pathway of arabinoxylan synthesis; and

- Develops tools (markers, kits, analytical procedures) to allow plant breeders to exploit this variation in their breeding programs to develop improved cultivars for European production.

So far, 150 wheat varieties and 50 other cereals (including 17 rye varieties) of diverse origins and ancestry have been grown on the same site in Hungary and analyzed for variation in phytochemicals (tocols, sterols, folates, phenolic acids, alkylresorcinols) and dietary fiber components (total and water soluble arabinoxylans, beta-glucans, and total dietary fiber). The variation in most components in bread wheats was twofold to threefold, but was wider in some cases (approaching tenfold in free phenolic acids). Twenty-six selected lines of wheat and five of rye were grown for a second year on the same site and on four sites in different parts of Europe (Hungary, Poland, France, UK) for a third year to determine the impacts of the environment on composition. A mutant population of 4,200 lines of the UK breadmaking wheat variety Cadenza has been developed and is being screened to identify mutations leading to changes in grain composition. This includes the identification of mutations in genes expected to confer a high amylose (resistant starch) phenotype.

Module 3—Technologies and Processing Methods for Nutritionally Optimized Cereal Foods and New Food Ingredients from Whole Grains

In spite of strong evidence that whole grain foods can protect against many common Western diseases, the large majority of cereal-based food products in Europe are produced from refined cereal flours (i.e., cereal endosperm tissue), rather than whole grain meals. The levels, and also bioavailability, of carbohydrates and various bioactive compounds can remarkably be controlled by knowledge-based processing. The bran, rich in nutritionally important and health-implicated components such as antioxidants, phenolics, and fibers, is often only valorized as feed ingredient. In those cases where miller's bran is incorporated in human foodstuffs, its health relevant components are often insufficiently accessible. Incorporation of bran, either isolated or as part of the grain, therefore often results in lower-quality products (in terms of microbial safety and mechanical and/or sensory properties). It follows that the full nutritional potential of cereals is certainly not used in modern day cereal food production.

The food processing module, led by Jan Delcour,

- Monitors microbiological safety during cereal grain processing;

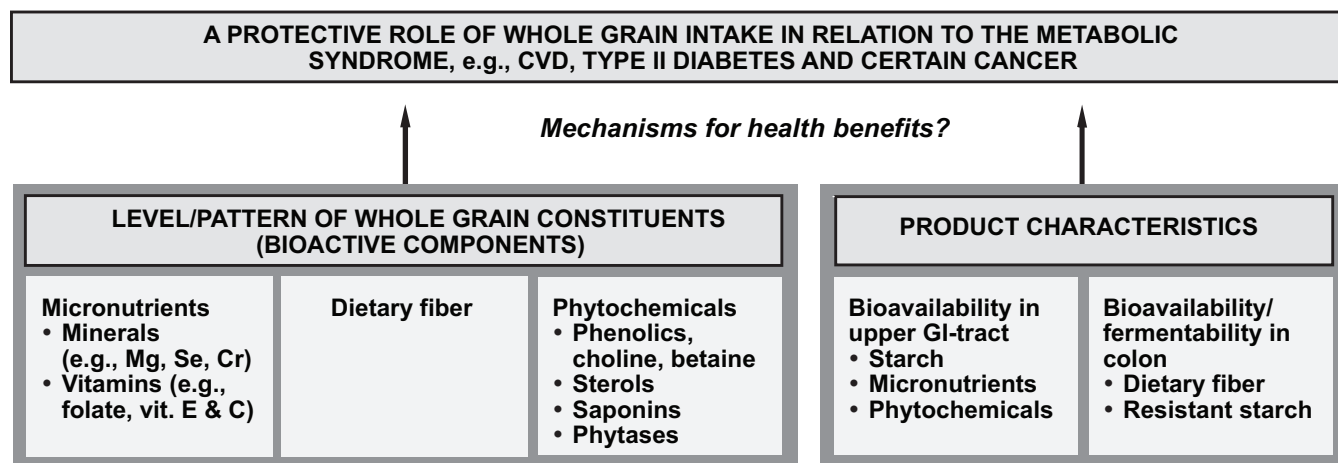


Fig. 2. The HEALTHGRAIN approach to understanding health benefits of whole grain components. GI—gastrointestinal.

- Develops new food ingredients of high nutritional impact by isolation and/or processing of new cereal fractions using economically viable technologies;
- Develops cereal foods of high nutritional impact (including foods for individuals sensitive to particular cereal constituents) based on economically viable technologies;
- Studies process-induced changes of bioactive compounds in European grains; and
- Evaluates and demonstrates the feasibility of the developed technologies in terms of industrial scale processing.

To date, specific emphasis has been put on producing flour containing the majority of the grain bioactivity but with enhanced processability in terms of sensory quality. Cryogenic milling has been developed for separation of the grain in new types of fractions, and various nutritionally enhanced flours have been prepared by mixing the fractions. Markers and rapid methods have been developed to detect different anatomic parts of the kernel. Development of enzyme technology in general and xylanase technology in particular, has allowed modifying biopolymer functionality and tailoring arabinoxylan modification. Yeast fermentation has been shown to improve the processability of both bran and whole grain wheat flour in bread baking and to increase the levels of folate and soluble arabinoxylan. *Lactobacillus plantarum* was identified as a useful starter culture in the baking of gluten-free breads, where enzyme technologies also are applied.

Module 4—Identification of the Mechanisms for the Health Benefits of Whole Grain Foods

In order to best tailor the benefits of cereal products toward the risk factors of metabolic syndrome, the mechanisms for the health benefits of whole grain foods need to be elucidated. In this respect, it is encouraging that significant reductions of disease risk are already evident at a comparatively modest increase in whole grain intake. Thus, in the epidemiological studies, whole grain products are frequently defined as cereal products containing more than 25% whole grain, and the majority of cereal products are produced from refined grain. Currently consumed cereal products frequently have high rather than low glycemic indices. This suggests that important health benefits of the European population can be achieved by extending the list of cereal products on the market which, in addition to being high in fiber and other whole grain constituents, are characterized by low glycemic index features.

This module, led by Inger Björck,

- Determines the relevant food characteristics, e.g., release features of phytochemicals and starch, with potential influence on metabolic variables using in vitro experimental models;
- Evaluates mechanisms for the metabolic effects of whole grains/whole grain fractions on risk parameters for metabolic syndrome using animal experimental models;
- Assesses the bioavailability of certain bioactive components and studies the acute or semi-acute metabolic effects of such components and of other relevant product characteristics on risk factors for the metabolic syndrome in “at risk” subjects and in healthy subjects; and
- Studies the influence of whole grain fractions and/or product characteristics on risk factors for metabolic syndrome, including effects on weight regulation in at risk subjects and type 2 diabetics.

In the work done thus far, the physiological mechanisms behind the nutritional benefits observed with a diet rich in whole grain and cereal fiber have been studied in vitro, in animal experiments, and in acute human studies. In vitro antioxidant ac-

tivity was shown to be high in aleurone and bran fractions, which also consistently increased plasma levels of betaine. Experiments studying bioavailability and metabolism of phenolics and other substances have been made in pigs. In humans, boiled wheat kernels showed lower glucose and insulin responses than porridge, indicating the importance of food structure for physiological responses. The earlier findings that rye products are beneficial in terms of acute insulin economy have been confirmed. Rye kernels were also shown to be more satiating than wheat kernels.

Module 5—Interactive Dissemination, Training, and Technology Transfer Program

In order for the research program to impact the European consumer, HEALTHGRAIN also includes an education, training, and dissemination element in order to transfer the technology and know-how about healthy grain foods to the European grain processing industry and health professionals. The awareness of the benefits of consuming cereal grains rich in micronutrients and other protective substances as part of an enjoyable and healthy diet in Europe will thus be increased, leading to their increased consumption and improved health status.

The dissemination module, led by Jan-Willem van der Kamp,

- Develops a comprehensive intellectual property rights, technology transfer, and dissemination program with dedicated workshops and contributions to conferences and publications at international, national, and regional levels;
- Is responsible for an industrial platform of companies of different sizes and representing all parts of the cereal production chain as a core target group for technology transfer, dissemination, and training;
- Is responsible for a nutrition information network of nutrition and health professionals throughout Europe for the dissemination, training, and exchange of views;
- Maintains a highly interactive web page (www.healthgrain.org) with e-learning functions; and
- Facilitates training possibilities at the Ph.D. and postdoc levels as well as for industrial researchers.

The dissemination, training, and technology transfer program has been very active both within the consortium of more than one hundred researchers as well as towards the industrial platform of more than 50 companies, the nutrition information network of 26 opinion leading nutritionists of 17 European countries, and the consumer communication panel. Altogether, five workshops have been organized in addition to the biannual project meetings. HEALTHGRAIN has also sponsored an array of international congresses and supported scientific exchange of young scientists between partners. The project also provides a discussion forum for scientific evidence and current practices with respect to the adaptation of the new EC Nutrition and Health Claim Regulation. The HEALTHGRAIN project has thus already become a central platform and actor in the cereal R&D field, and companies realizing the value of participation in the industrial platform activities are increasingly becoming members.

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