The HEALTHGRAIN Integrated Project (www.healthgrain.org) is funded for a five-year period beginning in 2005 as part of the European Commission Sixth Framework Program for food research. It aims to improve health and wellness and reduce the risk of metabolic syndrome-related diseases by providing a scientific basis for increasing the intake of protective compounds in grains or their fractions as part of processed foods. As outlined (7), HEALTHGRAIN is an integrated, multidisciplinary effort establishing the variation, process-induced changes, and human metabolism of bioactive compounds in the major European bread grains wheat and rye. The project reveals physiological mechanisms by which cereal foods may contribute to the prevention of metabolic syndrome-related diseases. The work includes studies on consumer expectations and attitudes, grain improvement, technology and processing, and nutrition. HEALTHGRAIN has a strong dissemination and technology transfer component that is evident from its large network of about 120 different organizations.

All authors of this article are members of the HEALTHGRAIN Board of Directors. They are responsible for the scientific program that ranges from consumer science and crop improvement to food technology, bioprocessing, and finally, nutrition. HEALTHGRAIN also includes a comprehensive implementation program to promote the interaction of various stakeholders, including an industrial platform, nutrition information network, and a consumer communication panel. In this article, some of the results obtained during the first years of the project by 44 partners in 15 European countries are presented.

Research Program

The project, coordinated by Kaisa Poutanen, has four research modules led by Richard Shepherd, Peter R. Shewry, Jan A. Delcour, and Inger Björck, respectively, and one technology transfer and dissemination module, led by Jan Willem van der Kamp. In addition, Roberto Ranieri chairs the industrial panel. Taken together, they constitute an integrated interdisciplinary research, training, and communication program. 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 in order to apply and disseminate the results to tailor cereal products for improved consumer health. To date, more than 100 original scientific papers have been published and the list is available on the project’s website (www.healthgrain.org).

Module One

Module One—consumer expectations and attitudes on healthy cereal foods—is led by Richard Shepherd and studies consumers’ expectations for cereal-based products that have been modified to contain more health-promoting components, comparing the appeal of different kinds of health-promoting aspects of cereal-based foods among European consumers. This module also studies how these modified products fit in with the existing health image of various grain foods.

The objective of the first consumer study was to understand product-related expectations that may influence the willingness to use whole grain foods. Consumers’ beliefs about whole grain and refined grain product categories were measured and compared and consumers were segmented based on these beliefs. Data were collected with self-completion questionnaires in the United Kingdom (N = 552), Italy (N = 504), and Finland (N = 513). On average, consumers in the United Kingdom, Finland, and Italy were aware that whole grain products are healthier than refined grain products as the whole grain product category was rated as more nutritionally balanced, healthier, more natural, more filling, release energy more slowly, and are slightly more digestible than the refined-grain product category. However, certain consumer segments did not perceive much difference between the health-related characteristics of whole and refined-grain products, suggesting a lack of motivation for increasing whole

1 VTT Technical Research Centre of Finland, Espoo, Finland, kaisa.poutanen@vtt.fi.
2 University of Surrey, Guildford, United Kingdom, r.shepherd@surrey.ac.uk.
3 Rothamsted Research Harpenden, Herts, United Kingdom, peter.shewry@bbsrc.ac.uk.
4 Katholieke Universiteit Leuven, Heverlee, Belgium, jan.delcour@biw.kuleuven.be.
5 Lund University, Lund, Sweden, inger.bjorck@intl.lth.se.
6 TNO Quality of Life, Al Zeist, the Netherlands, jan-willem.vanderkamp@tno.nl.
7 Barilla G.E.R. Fratelli S.p.A., Parma, Italy, r.ranieri@barilla.it.

doi:10.1094/CFW-55-2-0079
© 2010 AACC International, Inc.
grain consumption (2). This sets a challenge for promoting whole grain products, especially in Italy and the United Kingdom, where the respondents were less likely than the Finnish respondents to differentiate between the healthiness of whole and refined-grain products.

The Health Belief Model (HBM) (11) was used to predict the willingness to use functional breads in the United Kingdom, Italy, Finland, and Germany. The behavioral evaluation components of the HBM (perceived healthiness and pleasantness) and the health motivation component were good predictors of the willingness to use functional breads. In contrast, threat perception components (perceived susceptibility and perceived anticipated severity of disease) were poor predictors. This result was common in all four countries and across products. The role of “cue to action” was marginal. The importance of health motivation in the willingness to use products with health claims implies that there is an opening for developing better models for explaining health-promoting food choices that take into account both food- and health-related factors without making a reference to a disease-related outcome (13).

The second part of the consumer research study aimed to assess how consumers perceive the healthiness of whole grain in cereal products compared to precise physiological benefits that are based on specific components of grains. Two pilot studies were carried out in December 2007 and January 2008 on two separate samples of consumers from Finland, the United Kingdom, Germany, and Italy. Based on pilot studies, several attitude measures and other background variables were finalized for the main survey. A base version of the questionnaire was developed in English and then translated to Finnish, German, and Italian. The data collection for the main survey was carried out on 2,395 subjects from April through June 2008. The questionnaire was self-administered. The sample of subjects consisted of people more than 35 years old; about half were 35–50 years old and about half were more than 50 years old, with an even balance of males and females. The survey was based on the conjoint design and the elaboration likelihood model (ELM). Different profiles of cereal-based products (bread or cake) or products with added cereals (yogurt) with no claim, a weak health-related claim, or measures and other background variables were finalized for the main survey. A base version of the questionnaire was developed in English and then translated to Finnish, German, and Italian. The data collection for the main survey was carried out on 2,395 subjects from April through June 2008. The questionnaire was self-administered. The sample of subjects consisted of people more than 35 years old; about half were 35–50 years old and about half were more than 50 years old, with an even balance of males and females. The survey was based on the conjoint design and the elaboration likelihood model (ELM). Different profiles of cereal-based products (bread or cake) or products with added cereals (yogurt) with no claim, a weak health-related claim, or strong health-related claim with other cues were shown to the consumers. Health claims were related to type II diabetes. Perceived healthiness, benefits, attractiveness, and the intention to buy products were measured. General health interest, natural product interest, self-defined expertise, and attitude toward food as medicine were measured as attitudinal background variables. The need for cognition, faith in intuition, need for accuracy, and previous use of products with health claims were assessed according to the ELM. The ELM basically states that people can make use of two different strategies when they process information: they can either process the information quickly and superficially (heuristic processing/peripheral route) or think about it thoroughly (systematic processing/central route). The relevance of type II diabetes for respondents was measured in order to examine whether the relevance influences the likeliness of using systematic processing.

Module Two

The development of nutritionally enhanced wheat varieties depends on the availability of variation in the amounts and compositions of key components in wheat and related species, and plant breeders’ ability to utilize this in their breeding programs. Module two—new sources of high-quality raw material for use in plant breeding and tools to facilitate selection of cultivars—is led by Peter R. Shewry. Module two aims to facilitate the improvement of the health benefits of wheat and other cereal grains by providing sources of variation in content and composition of bioactive components and the tools to facilitate their selection in breeding programs. To this end, it 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 (12). It also 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. Finally, Module Two 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.

Variation in Bioactive Components

Three field experiments have been carried out with 150 wheat lines, 10 rye lines, and 40 other cereals initially grown in unreplicated plots on a single site in Hungary from 2004 to 2005. Analyses of these lines showed a wide variation in the content and composition of phytochemicals (sterols, tocols, folicates, phenolics, alkylresorcinols) and fiber components (arabinoxylan, β-glucan). The full data are reported in a series of refereed papers, included in a special section of the Journal of Agricultural and Food Chemistry (Volume 56, No. 21, published on November 12, 2008), while the analyses of the wheat lines are given here (Fig. 1). Substantial variation in the contents of all groups of bioactive components was observed, ranging in 1.4 fold for tocols in whole meal wheat to 3.6 fold for phenolic acids and up to 4.7 fold for water-extractable arabinoxylan in white wheat flour (14). It is unlikely that such variation was due entirely to environmental impacts since the lines were grown on adjacent plots on the same site. To determine the relative contributions of genotype, environment, and genotype-environment interactions on the amounts and compositions of bioactive components, a selected series of 26 wheat lines and five rye lines were grown on the same site for two further years (2005–2006 and 2006–2007) and on an additional three sites selected to give a wide range of environmental conditions (in the United Kingdom, France, Hungary, and Poland) in 2006–2007 only. The same series of analyses were carried out on the material from the first field experiment, allowing the heritability of the different groups of components to be calculated as ranging up to 70% of the total variance.

Selected samples were also analyzed for choline and betaine, showing strong environmental impacts in both cases. The data from the HEALTHGRAIN diversity screen was also used to select lines to determine the distributions of arabinoxylans and phenolic acids within the grain using novel fourier transform infrared (FT-IR) and FT-Raman imaging methods. These showed differences in spatial distribution within the grain that could be exploited by milling.

Generating New Variation in Bioactive Components

New approaches are also being used to generate a wider range of variation in grain composition than is currently available to plant breeders. The Sgp-1 I genes encode a form of granule-bound starch synthase involved in the synthesis of amyllopectin, one of the two polymers comprising starch. Mutations that inactivate these genes or the enzymes that they encode may therefore increase the proportion of amylose. Amylose is less readily digested than amyllopectin, and the mutations, therefore, lead to “resistant starch,” which has a lower glycemic index (GI) than normal starch. However, it is necessary to combine mutations in all three genomes of hexaploid bread wheat to have a significant
Fig. 1. Ranges of bioactive components in wholemeal (tocols, sterols, alkylresorcinols, phenolic acids, folate, and β-glucan) and white flour (total and soluble arabinoxylans) from 150 wheat lines grown in Martonvásár (Hungary) in 2005.
impact on the grain’s amylose content. Naturally occurring muta-
tions at the Sgp-A1, Sgp-B1, and Sgp-D1 loci have therefore been
crossed to generate a triple mutant line that has been crossed with
five modern cultivars and backcrossed once. Further backcrosses
will be carried out to generate lines suitable for use in breeding
programs.

Mutagenesis can be used to generate novel sources of variation
for exploitation in breeding. A population of approximately 4,000
lines of the breadmaking wheat cultivar, Cadenza, has therefore
been developed, after treating the seeds with the chemical muta-
gen ethyl methane sulphonate and grown to the M6 generation
(i.e., homozygosity) in the glasshouse and field. Biochemical and
molecular analyses of the M3 and M4 generations have identified
new allelic forms at the Sgp-1, as well as new mutations in other
genes, which may affect the proportion of amylose in the starch.
These new mutations will be combined to generate double and
triple mutants and then transferred into commercially relevant
germplasm as discussed above.

Bioinformatics has been used to identify candidate genes for
enzymes controlling the major types of dietary fiber in the grain,
arabinoxylan, and β-glucan. Transgenesis is therefore being used
to confirm the functions of these genes by using RNAi technology
to suppress mRNA levels. This has clearly demonstrated that the
Cslf6 gene encodes the major form of β-glucan synthase ex-
pressed in the developing grain. Further series of transgenic lines
have been made to confirm the functions of putative xylan syn-
thase and arabinoxyl transferase and feruolyl transferase genes.
This work will identify key genes that can then be targeted to
identify variation in natural and mutant populations.

Tools for Breeders

A rapid method for determining choline and betaine in aqueous
extracts of flour, bran, and whole meal has been developed using
1H-nuclear magnetic resonance (NMR) spectroscopy. The values
for betaine determined by this method have also been validated
by comparing analyses of the same series of samples using a clas-
sical high performance liquid chromatography (HPLC)-based
approach.

A complete proteomic map of the albumin and globulin frac-
tion from mature grain of the Chinese spring cultivar has been
constructed, with more than 350 components having been identi-
fied by mass spectrometry, and selected components mapped to
chromosomes by the analysis of deletion lines. Similarly, more
than 300 proteins from the aleurone layer have been analyzed by
mass spectrometry.

A new strategy has been developed to identify loci and markers
for soluble fiber, exploiting expression profiling and information
from the related regions of the rice genome. The identification of
new single nucleotide polymorphism (SNP) markers for dietary
fiber has focused on an epimerase gene that encodes an enzyme
involved in arabinoxylan synthesis. Sequence analysis of this
gene from a number of cultivars has led to the identification of
more than 50 mutations in their sequences.

The availability of detailed analyses of lines from the diversity
screen provides an ideal opportunity to develop new analytical
approaches and evaluate currently available methods for their
applicability to plant breeding programs. In particular, near in-
frared (NIR) has been used to develop robust calibrations for
arabinoxylans that may be exploited by NIR instrumentation
manufacturers.

Module Three

The production of healthier cereal foods relies on new ingredi-
ents, new processing tools, and knowledge on process-induced
to changes in cereal matrices. Against this background, the work
in module three—technologies and processing methods for
nutritionally optimized cereal foods and new food ingredients
from whole grains—revisits dry milling and wet fractionation
processes. It also develops new enzymes, enzymatic processing,
and fermentation in order to produce food ingredients and foods
with increased levels of grain aleurone components and structural
features delivering good sensory properties. Particularly, module
three, led by Jan A. Delcour, monitors microbiological safety
during cereal-grain processing and develops new food ingredient-
s of high nutritional impact by isolation and/or processing of
new cereal fractions using economically viable technologies. The
module also develops cereal foods with high nutritional impact
based on economically viable technologies. Finally, the module
studies process-induced changes of bioactive compounds in Eu-
ropean grains and evaluates and demonstrates the feasibility of
the developed technologies in terms of industrial-scale process-
ing.

Novel Technologies for Whole Grain Dry Fractionation

Tools were developed for monitoring cereal fractionation pro-
cesses. The emphasis was on whole grain fractionation to produce
functionally and nutritionally improved flours and bran fine frac-
tionation using cryogenic and electrostatic technologies (3). Spec-
cific marker technologies were developed for quantifying the
relative proportions of wheat tissues in fractions from unknown
wheat cultivars (4). A Ph.D. thesis was completed in INRA,
Montpellier, France, on the new fractionation technologies. Laser
ablation techniques were also used for the first time to selectively
remove outer grain layers (6). Whole grain fractionation efforts
focused on debranning/milling combinations for producing flours
that can serve as an alternative to whole grain flours.

Novel Wet Processing Technologies for Producing
Bioactive Compounds or Fractions

Xylanases suited for the production of soluble (prebiotic) ara-
boxylin (oligosaccharides) were developed. Xylanase technol-
ologies also improved the properties of breads high in fiber. The
addition of amylose-lipid complexes to starch gels resulted in
gels with significantly higher resistant starch content, showing
their possible health-improving potential (8,9). It was also shown
that bran fermentation followed by drying results in stable modi-
fied brans with improved properties in breadmaking applications.
The fermentation process in combination with added enzymes
also released phenolic acids from the bran matrix (1).

Novel Technologies to Produce Nutritionally
Optimized Grain-Based Foods

Progress was made in applications of both enzyme and fer-
mentation technology in baking. A new psychrotolerant xylanase
had
a strong bread-improving effect, especially when using arabinoxyl-
yan-rich fiber sources. Fermentation improved the structure and
retarded glycemic response of breads very rich in outer grain lay-
ers and grain fiber. Laccase and sourdough improved the volume
and bread crumb of 100% oat breads suitable for celiac patients
(10).

**Pilot/Industrial/Demonstration Activities**

The Healthflour concept was brought to larger scale trials. Sev-
eral wheat-milling fractions were tested in pastamaking and
large-scale baking experiments. Bread and biscuit prototypes
with high contents of whole grain or grain outer layers, or with
retarded glycemic response, were developed and produced in
quantities needed for intervention trials. The samples were sup-
plied to long-term nutrition studies.

**Module Four**

When it comes to exploiting the preventive merits of a whole
grain diet, a major disadvantage is that the mechanisms for health
benefits remain largely unknown. The objective of the work
within the nutrition module is to identify mechanisms for poten-
tial benefits of whole grain products on risk markers for cardio-
vascular diseases, type 2 diabetes, and obesity. Module four—identification of mechanisms for the health benefits of
whole grain foods—is coordinated by Inger Börck; the overall
ambition of the work is to provide mechanistic knowledge for the
tailoring of innovative cereal products with magnified health ben-
efits. The focus is on wheat, and to some extent, rye and barley.
The work is performed in animal experimental models, in vitro
models simulating events in the upper and lower parts of the
gastro-intestinal tract, cell-bioassays, and in acute or semi-acute
meal studies in healthy or at-risk subjects. Based on this mecha-
nistic work, long-term dietary interventions are performed in at-
risk and type 2 diabetic subjects. The longer term dietary
interventions also have a mechanistic approach, addressing key
hypotheses related to whole grain wheat, as well as potential synergy
between the whole grain concept and the GI and/or insu-
linemic index concept, respectively.

**In Vitro Prediction of Bioavailability and Fermentability
of Grain Components**

In vitro studies have been performed on wheat fractions and
bread products using models indicative of small intestinal bio-
availability and colonic fermentability and metabolism, respec-
tively. Ferulic acid was shown to be a major antioxidant in the
outer layers of the grain. The antioxidant capacity of wheat frac-
tions was highly correlated with the amount of aleurone in the
fraction. The bio-accessibility of ferulic acid from aleurone and
bran, as well as from aleurone-enriched bread, was low (1–2%) in
a simulated upper-gut in vitro model (1). Innovative processing
and pretreatment of bran (lactic acid fermentation, enzymes), in-
creased the bioaccessibility of ferulic acid, and other phenolic
acids (coumaric and sinapic acids) in the model. Most of the phe-
nolic compounds passed the small intestine and entered the colon
under simulated in vitro conditions, where they can be released
and further metabolized by the colonic microbiota. Metabolites
formed from phenolic compounds have been identified. Studies
have further shown that the pretreatment of bran (lactic acid fer-
mentation and/or enzymes) increases in vitro butyric acid forma-
tion in wheat bran.

**Bioavailability and Metabolic Effects of Bioactive
Compounds**

Screening experiments with wheat or rye fractions fed to hy-
percholesterolemic rats showed that aleurone and rye flour with a
high ash content give rise to the high hind-gut production of bu-
yric acid. The formation of butyrate also correlated with the di-
etary content of arabinoxylans. Bread was prepared from whole
grain and standard flours to study the degradation of carbohy-
drates and phenolics in the gut and their uptake by the body using
cannulated and catheterized pigs (5). A rye diet gave rise to
higher ileal viscosity than the wheat-based diets and resulted in a
significantly lower digestibility of starch in the small intestine.
Thus, more resistant starch was delivered for fermentation.

The plasma concentration of enterolactone, derived from the
colonic metabolism of plant lignans, was generally higher when
feeding the rye rather than wheat fractions. The degradation of
carbohydrates and phenolics in the gut and the uptake to the body
is being further studied using cannulated and catheterized pigs.

A 12-week feeding experiment with seven wheat fractions, in-
cluding the germ, has been performed in mice predisposed for the
metabolic syndrome. There were modest differences in the meta-
biotic impact between the fractions. A diet with whole grain wheat
resulted in a higher body weight gain than a diet with only the
intermediate or pericarp fraction. This was probably due to higher
energy intake. A diet with whole wheat resulted in higher levels
of antiinflammatory markers (adiponectin) and increased the in-
sulin secretory capacity in a model using islets of Langerhans
rather than a diet with the pericarp fraction. The different wheat
fractions did not differ with respect to their effects on whole body
glucose tolerance or adipocyte insulin sensitivity.

**Bioavailability and Acute Metabolic Effects**

New data have been generated regarding the effects of rye on
glucose metabolism and satiety. The evidence suggests a better
insulin economy with rye than with wheat products. Interestingly,
the improved insulin economy with rye products was observed
also with rye products made from endosperm rye.

From two series of acute meal studies regarding the bioavail-
bility of methyl donors and ferulic acid in healthy subjects, it
was concluded that the ingestion of raw bran and aleurone meals
induced significant post-meal increases in plasma betaine and
ferulic acid. A second series of experiments with aleurone-rich
bread rolls confirmed the above results and demonstrated signifi-
cant post-meal increases in plasma ferulic acid and betaine. Ef-
fects on plasma choline and folate were small and nonsignificant,
and no significant effects on plasma tocopherols and carotenoids
were observed in either of the meal studies. The studies provide
the first evidence that wheat products impact betaine status and
wheat products favorably impact plasma ferulic acid levels.

**Long-Term Effects of Whole Grain on Metabolic Risk
Factors and Weight Regulation**

Four longer term intervention trials in at-risk subjects are cur-
rently ongoing, or have recently been terminated and are cur-
rently under evaluation. The aim of a first study was to determine
whether inclusion of wheat-based whole grain foods in a hypoca-
loric diet enhances weight loss and improves CVD risk factors.
The study examines the impact of whole grain wheat or refined
wheat on weight loss in overweight women, involving a total of
72 women. Body weight, waist circumference, and percentage
of body fat decreased significantly in both groups over the study
period, but there was a significantly greater decrease in percent-
age of body fat (–3%) in the whole grain group than in the refined
grain group (–2.1%). Total and LDL cholesterol changes differed
significantly between groups—they increased by 5% in the re-
fined group, but remained unchanged in the whole grain group.
Insulin, glucose, and C-reactive protein levels did not change in
either group. It could be concluded that both hypocaloric diets are
effective in inducing weight loss, but whole grain foods had a
more beneficial effect on body fat percentage and cholesterol levels than refined grains.

The main focus of the second study was to examine whether alleurone-rich products, selected based on their potential index to increase plasma levels of betaine and ferulic acid, positively affect blood lipids and other metabolic parameters. A four-week intervention trial in overweight subjects with an alleurone-rich test diet versus a refined control diet was performed in 80 healthy subjects (45–70 years old with a body mass index of greater than 25). The statistical evaluation is ongoing and correlations will be made as to the content of potentially bioactive compounds in the experimental diets.

The third intervention study, focusing on type 2 diabetics, is ongoing. The study, performed over 28 days, uses four parallel and matched groups. Twenty subjects were included for each diet. Insulin sensitivity will be used as a critical endpoint. The diets vary with respect to the features of the bread products. The control diet includes high GI/white wheat bread; whereas the three different test diets contain either high GI/whole grain wheat flour bread, low GI/whole grain wheat kernel bread, or a low GI/whole grain barley kernel bread, respectively. The fourth study is a joint two-center study. It determines the effects of a diet with multiple beneficial characteristics of whole grains on glucose and insulin metabolism in subjects with metabolic syndrome in two different dietary settings. Sixty subjects fulfilling the National Cholesterol Education Program (NCEP) criteria for metabolic syndrome have been included, with 30 on each treatment arm using a parallel design.

**Module Five**

In order for the research program to impact the European consumer, HEALTHGRAIN includes education, training, and dissemination elements in order to transfer the technology about healthy grain foods to the European grain-processing industry and health professionals. Increased awareness of the benefits of ingesting cereal grains rich in micronutrients and other protective substances as part of an enjoyable and healthy diet in Europe will hopefully lead to increased consumption and improved health perception. Thus, Module Five, the dissemination module, led by Jan Willem van der Kamp, manages comprehensive intellectual property rights, a technology transfer and dissemination program with dedicated workshops, and contributions to conferences and publications at international and national/regional levels. The module is also responsible for an industrial platform of companies of different sizes, representing all parts of the cereal-production chain, as a core target group for technology transfer, dissemination, and training.

Roberto Ranieri, as chair of the industrial panel, has contributed to revealing the industrial needs in this respect. Furthermore, Module Five manages a nutrition information network of nutritionists of 17 European countries, and the consumer communication panel. Altogether, more than 10 workshops have been organized both separately and jointly for members of the industrial platform, the Nutrition Information Network, and the consumer communication panel, in addition to the biannual project meetings. In 2010, an open congress, “Enhancing health benefits of cereal foods—Results, perspectives, and challenges” will be organized in Lund, Sweden, May 5–7 (www.healthgrain.org). HEALTHGRAIN has also sponsored an array of international congresses and supported the scientific exchange of young scientists between partners. The project has also provided a discussion forum for scientific evidence and current practices with respect to the new European Commission on Nutrition and Health Claim Regulation and for developing a European definition of whole grain. Here, close collaboration has been established with the AACC Intl. Whole Grain Taskforce. The HEALTHGRAIN project has thus developed into a central platform and actor in the cereal research and development field. Stimulated by the feedback from the network, the HEALTHGRAIN Board is now developing a strategic research and communication agenda with an adequate structure to facilitate joint efforts after the European Union-funded project ends.

**Acknowledgments**

This publication is financially supported by the European Commission 6th Framework Program, Project HEALTHGRAIN (FOOD-CT-2005-514008). It reflects the authors’ views and the community is not liable for any use that may be made of the information contained in this publication. Rothamsted Research receives grant-aided support from the Biotecnology and Biological Sciences Research Council of the United Kingdom. The authors thank Jane Ward (Rothamsted) for preparing Figure 1.

**References**