Enhancing health benefits of cereal foods
Results, perspectives, challenges

Final HEALTHGRAIN Conference

5-7 May 2010
Scandic Star Hotel, Lund, Sweden
Foreword

Welcome to the HEALTHGRAIN conference! The five-year project is coming to an end, and we are pleased to host an event to share the results with all interested in tuning the grain chain towards healthier foods. It has also been delightful to see that network activities will continue to bridge scientists of different disciplines, as well as industries and government actors in order to exploit the cereal grains for promoting health and well-being.

The Integrated HEALTHGRAIN project, part of the European Commission Sixth Research Framework Programme, aims to improve health and wellness and reduce the risk of diseases related to metabolic syndrome by providing a scientific basis for increasing the intake of protective compounds in grains as part of processed foods. The research has ranged from the biological pathways and breeding potential of grains to human physiology in response to cereal foods, and from developing grain and grain biopolymer processing technologies to understanding consumer attitudes and perception of healthy cereal foods. HEALTHGRAIN also has a strong networking and dissemination element across the over hundred organisations involved and outside it.

HEALTHGRAIN has been an internationally unique platform to address the exploitation of the nutritional potential of grain raw material. Nutritionists, food chemists and technologists, plant breeders and consumer scientists have learnt to work with each other, and have so far published over hundred scientific articles, with many more to come. A HEALTHGRAIN methods handbook is available for characterization of the bioactivity potential of raw materials. Scientists and experts from the private sector have met in ten specific workshops. The HEALTHGRAIN definition of whole grain has been worked out. In many countries new healthier cereal foods already are available for the consumers.

On behalf of the HEALTHGRAIN board and the scientific and organising committees of the conference I wish you all a fruitful event in Lund. I hope that you will share our belief that the results obtained motivate to continue developing novel routes for healthier grain based foods and ingredients, and further studying the underlying physiological mechanisms.

Karlsruhe 18 April 2010, waiting for clearing of the sky of the ash from the volcanic eruption in Iceland

Kaisa Poutanen
HEALTHGRAIN Coordinator
Committees

Scientific Committee

Chair – Kaisa Poutanen, VTT, Finland
Per Aman, SLU, Sweden
Nils-Georg Asp, Swedish Nutrition Foundation, Sweden
Inger Björck, Lund University, Sweden
Jan Delcour, KU Leuven, Belgium
Roberto Ranieri, Barilla, Italy
Gabriele Riccardi, Federico II University of Naples, Italy
David Richardson, DPRNutrition, UK
Alan Schulman, University of Helsinki, Finland
Richard Shepherd, University of Surrey, UK
Peter Shewry, Rothamstead Research, UK
Jan-Willem van der Kamp, TNO, Netherlands

Organising Committee

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Anita Habershuber, ICC, Austria
Riitta Kervinen, VTT, Finland
Roland Poms, ICC, Austria
Elin Östman, Lund University, Sweden
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| 17.30–17.40 | Cereal foods and health – where are we now?  
Kaisa Poutanen, HEALTHGRAIN Coordinator, VTT, Finland |
| 17.40–18.00 | Food and Health as a research challenge in European Union  
Danièle Tissot, European Commission, Belgium |
| 18.00–18.30 | Public health nutrition - scenarios and health claims  
Hans Verhagen, RIVM, The Netherlands |
| 18.30–19.00 | Cereal grains and healthy foods - challenges for research and industry  
Baltasar Vallès-Pàmies, Nestlé Research Centre, Lausanne Switzerland |
| 19.00–19.30 | Epidemiological and clinical studies supporting health benefits of whole grain cereal products  
Gabriele Riccardi, University of Naples, Italy |
| 19.30–21.00 | Knowledge Plaza with ‘smørrebrød’ foods and drinks  
Coordination: Jan Willem van der Kamp and Roland Poms |

The Knowledge Plaza will provide a unique overview of cereals-health activities:
- A wide range of posters showing results of HEALTHGRAIN and related projects, and
- Table tops by research institutes, companies and organisations communicating to consumers, presenting activities, services and plans related to healthy cereal products and healthy eating.

### Thursday 6 May 2010

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Chairpersons Peter Shewry and Alan Schulman |

New approaches in grain production

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| 8.30–8.40 | Targeted and facilitated breeding for nutritional quality  
Peter Shewry, Rothamsted Research, United Kingdom |
| 8.40–9.00 | Variation in bioactive components in wheat and other cereals  
Jane Ward, Rothamsted Research, United Kingdom |
| 9.00–9.20 | Developing new wheat varieties with enhanced health benefits  
Zoltán Bedő, Agricultural Research Institute of the Hungarian Academy of Sciences, Hungary |
Exploiting genomics and transgenesis for enhanced health benefits of wheat
Gilles Charmet, INRA, France

The grain biotechnology toolkit
Clare Mills, Institute of Food Research, United Kingdom

9.40—10.00

Coffee break

10.00—10.30

Matching technological and nutritional benefits
Chairpersons Jan Delcour and Per Åman

10.30—10.40

Importance of processing: the issues at stake
Jan Delcour, Katholieke Universiteit Leuven, Leuven, Belgium

10.40—11.00

From classical to innovative milling technologies
Uwe Schill, Bühler, Switzerland

11.00—11.20

Novel dry fractionation technologies
Xavier Rouau, INRA, France

11.20—11.40

Matching Technological and Nutritional Benefits: The Arabinoxylan Case
Christophe Courtin, Katholieke Universiteit Leuven, Leuven, Belgium

11.40—12.00

Bioprocessing of bran for improved functionality
Kati Katina, VTT, Finland

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Lunch in Knowledge Plaza area

14.00—14.20

Impact of process conditions on selected nutritional and quality parameters of bread: outcomes from the EU-FRESHBAKE project
Alain Le Bail, ONIRIS, France

14.20—14.40

Advances in technologies for gluten free products
Elke Arendt, University College Cork, Ireland

14.40—15.00

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Roberto Ranieri, Barilla, Italy

15.00—17.30

Nutrition - Benefits of health promoting compounds and properties
Chairpersons Inger Björck and Gabriele Riccardi

15.00—15.20

Benefits of wheat processing on the bioavailability of phenolic acids in relation to potential health effects
Nuria Mateo Ansón, Maastricht University, The Netherlands

15.20—15.40

Colonic formation and absorption of short-chain fatty acids from whole grain cereal fractions
Knud Erik Bach Knudsen, University of Aarhus, Denmark

15.40—16.10

Coffee break

16.10—16.30

Acute and semi-acute effects on glucose regulation; studies of rye and barley
Elin Östman, Lund University, Sweden

16.30—16.50

Effects of wheat and barley diets on insulin sensitivity and beta-cell function in patients with type 2 diabetes
Anders Frid, Öresund Diabetes Team, Sweden
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| 16.50–17.10 | Effects of a “HEALTHGRAIN” diet on metabolic risk factors in subjects predisposed to type 2 diabetes and cardio-vascular disease - a two centre study  
Hannu Mykkänen, University of Eastern Finland, Finland |
| 17.10–17.30 | Potential of bioactive components in wheat grain fractions – results from human studies  
Ruth Price, University of Ulster, Northern Ireland |

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| 9.00–9.20 | Consumer attitudes to whole grain and functional grain products  
Richard Shepherd, University of Surrey, United Kingdom |
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Liisa Lähteenmäki, MAPP, Aarhus University, Denmark |
| 9.40–9.55 | Health statements and claims for cereal grain products in Europe: success factors and perspectives  
David Richardson, DPR Nutrition, United Kingdom |
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Jan Willem van der Kamp, TNO, The Netherlands |
| 10.10–10.30 | Shift towards healthy diets - impact on costs of healthcare and quality of life  
Bruce Traill, University of Reading, United Kingdom |
| 10.30–11.00 | Coffee break |

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| 11.00–11.15 | The HEALTHGRAIN 2010+ Forum – the best of the grain for consumer well being  
Kaisa Poutanen, HEALTHGRAIN Coordinator, VTT, Finland |
| 11.15–11.30 | Strengthening communication with a European basis to all stakeholders  
Jan Willem van der Kamp, TNO, The Netherlands |
| 11.30–11.45 | HEALTHGRAIN open innovation and HEALTHGRAIN kernel fractions availability for healthier cereal foods  
Roberto Ranieri, Barilla, Italy |
| 11.45–12.00 | Realising dietary shifts - can the Danish experience be transferred to Europe  
Morten Strunge Meyer, Danish Cancer Society, Denmark |
| 12.00–12.15 | Watch this! HG-TV. promoting cereals in a balanced diet opening new channels and forging alliances  
David Sutherland. Communications Director, Lycocard project, Caledonian Science Press Ltd, Spain |
| 12.15 | Final remarks  
Kaisa Poutanen, HEALTHGRAIN Coordinator, VTT, Finland |
Our vision: Make today delicious... helping people achieve health and well-being with the everyday foods they love

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Our commitments to Health and Wellness:

- **Providing better-for-you cereal-based foods to Consumers...** Whether it’s helping them manage their health and add fibre or whole grain to their daily diets, Kraft Foods Europe has the cereal food products that meet their needs. Kraft Foods Europe also continuously improves the nutrition composition of its biscuits (decreasing fat, saturates, and sugars year after year).

- **Listening to Experts:** a group of recognized health and wellness experts helps Kraft Foods make decisions about the products, research and communications.

- **Helping Consumers** make informed food choices by providing easy-to-understand nutritional information on packs.

- **Accompanying Consumers:** Kraft Foods Europe also supports healthy lifestyle programs. Helping children and their families make healthy food choices while encouraging physical activity has become part of how Kraft Foods gives back to communities.

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- Collaborative research in various nutrition, food science and engineering research programs.

- Partnerships in European nutrition and health research programs such as: Eurostarch, Diogenes, Eatwell, Healthgrain
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Health-Related Claims Promoting Healthy Choice

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The HEALTHGRAIN Whole Grain Definition

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The HEALTHGRAIN 2010+ Forum – The Best of The Grain for Consumer Well-Being

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“HEALTHGRAIN Open Innovation” and “HEALTHGRAIN Kernel Fractions” Availability for Healthier Cereal Foods

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Realising Dietary Shifts – Can the Danish Experience Be Transferred To Europe

M. Strunge Meyer

Watch This! HG-TV. Promoting Cereals in a Balanced Diet Opening New Channels and Forging Alliances

D. Sutherland
Opening Session

Chairpersons: Kaisa Poutanen and Roberto Ranieri

Wednesday 5 May 2010
17.30-19.30
The first ideas for the HEALTHGRAIN project were generated already in 2002, eight years ago. The health benefits of consuming grain fibre and the outer layers of the grains were already recognised, at the same time as the awareness of the role of healthy diet in health maintenance was gaining increasing interest. Different actors in the grain chain wanted to know more about their possibilities of contributing to healthier cereal foods. Timing was very suitable for a concentrated effort to learn more about cereal foods and health.

During these years the epidemiological evidence about the inverse association between intake of foods rich in whole grain and grain fibre and risk of type 2 diabetes and cardiovascular disease has further strengthened. However, also the number of intervention studies failing to show improvement in blood cholesterol and insulin sensitivity has increased. We still do not know the mechanisms through which the cereal foods could exert positive effects in the long run. In HEALTHGRAIN we are still waiting for more data and analysis of the intervention trials made. However, we have learnt about bioavailability and kinetics of absorption of many tentatively important compounds. The results also point out the importance of performance of the large intestine in mediating the effects.

In terms of knowing, analysing and modifying the grain raw material there is clear progress, as well as in being able to fractionate, classify and bioprocess the grains using enzymes and microorganisms. We have established a range of analysis methods for characterising of grains, and made them available in a form of a manual. We know that there is considerable variation in wheat and other grains, and that high levels of dietary fibres and other bio-active compounds can go together with good cultivation properties and high yield. The outer layers of grain have been studied with sensitive biochemical methods, and we ascertained that the outer pericarp layer may be removed without remarkable losses of the tentatively protective compounds, whereas the aleurone layer -situated between pericarp and endosperm and containing most bio-active components - contributes to a major extent to whole grain related health benefits. New insights into factors determining bread quality in products high in whole grain components or aleurone have been obtained and a range of bioprocessing methods have been developed to modify bran biopolymers so as to produce new types of indigestible ingredients.

Consumer studies, and also the global market, have shown that consumers are interested in health and wellbeing also in the context of cereal foods. High sensory quality remains a key, and new communication strategies must be developed for different countries for making healthy choices the favoured ones. It is obvious that we are on the right track, and that cereal food processing will gradually change to deliver more of the grain for human food. Close cooperation between the grain users and producers would allow choosing the raw materials suited for fibre-rich foods and tailored digestibility. It is important that the message about considering the health-protective power of grains will also be communicated to the rapidly developing countries, so that they will not adopt and develop a refined grain culture. Cross-cultural projects may in the future also diversify the types and varieties of cereal foods in the diet.

Keywords: grain, cereal, food, health
FOOD AND HEALTH AS A RESEARCH CHALLENGE IN EUROPEAN UNION

Danièle Tissot Boireau

Scientific Officer of HEALTGRAIN, European Commission, Belgium

Moving towards innovation-based sustainable growth is the core of the European Union's response to globalisation and the financial crisis within the framework of the EU2020 strategy. Generating and applying knowledge develops the economy and supports the quality of life. This presentation will give an overview of food and health research funded by the European Union via its Seventh Framework Programme. Its Theme “Food, Agriculture and Fisheries, and Biotechnology” contributes to building a Knowledge-Based Bio-Economy (KBBE) by funding research projects in the Activity “Fork to farm: Food (including seafood), health and well being”. The focus of this session will be on research policy and opportunities for funding research projects in the area of food and nutrition science.
Non-communicable diseases is the major cause of death. The WHO has issued nutrient-based dietary guidelines for optimal public health (1). WHO concluded that wholegrain cereals, fruits and vegetables are the preferred sources of “non-starch polysaccharides” and that the recommended intake of fruits and vegetables and consumption of wholegrain foods is likely to provide >20 g per day of NSP (>25 g per day of total dietary fibre). Recently, EFSA recommended dietary fibre intakes of 25 g/day to be adequate for normal laxation in adults (2). There are two ways to improve public health via diet: 1] consumer education and 2) product reformulation; these can go concomitantly. As concerns consumer education, the nutrient recommendations must be translated into food-based dietary guidelines. Reformulation of foods is considered a key option to achieve population nutrient goals. Scenario calculations show that the public health impact of improved diet is very significant in terms of life years spared, DALY’s spared, as well as euros saved. Moreover, the public health gain of improving diet and dietary behavior outweighs the public health gain by improving food safety issues by about two orders of magnitude (3).

EU Regulation 1924/2006 states that health claims must be substantiated (4). EFSA is performing the scientific evaluation for the EC and has hitherto published several hundreds of opinions on health claims, including a few on fibre (5, 6, 7). As concerns normal blood cholesterol concentrations, EFSA considered that dietary fibre is not sufficiently characterised in relation to the claimed effect. Therefore there is insufficient evidence to establish a cause and effect relationship between the dietary intake of either total dietary fibre or “water-soluble fibre” and the maintenance of normal blood cholesterol concentrations. For beta-glucans, which are considered sufficiently characterised, negative EFSA opinions were given for the maintenance or achievement of a normal body weight and for maintenance or achievement of normal blood glucose concentrations, while a positive opinion was given in relation to the reduction of blood cholesterol concentrations. The current developments on nutrition and health claims are a very hot topic in Europe, leading to ample discussions among stakeholders (scientists, industry, government, consumers). As consumers understand nutrition and health claims different from scientists and regulators, innovation in industry can proceed via approved nutrition claims and approved health claims. The market and the shelves in the stores will not be empty; rather they will look different in the years to come.

Keywords: public health nutrition, scenarios, reformulation, consumer understanding, fibre, grain, health claims

References:
(4) Verhagen H. et al. (submitted). Status of nutrition and health claims in Europe.
The awareness of the relationship between diet and health, especially in the promotion of health and prevention of disease, is growing in the minds of consumers as more scientific evidence is being gathered. Therefore the demand for products facilitating a balanced diet or addressing specific health benefits is growing steadily. While different grains are consumed in different parts of the world, cereal foods in general, are an essential component of the diets across cultures. Offering healthy propositions to consumers in these product categories is an important opportunity for the food industry but also a great challenge to deliver excellent taste and high nutritional value. The ability for the food industry to offer healthy propositions to consumers in these product categories is an important opportunity. Since 2003, Nestlé has contributed to increase whole grain consumption with more than 2.7 billion additional servings of whole grains from different products categories. Further, whole grain is the main theme in the breakfast cereal category offered by Cereal Partners Worldwide, the joint venture between Nestlé and General Mills. For efficient new product development the technological aspects related to whole grain need to be mastered in order to guarantee the desired product attributes. The importance of consumer communication and consumer insight should not be overlooked.

The growing epidemiological evidence of the positive effects of whole grains was one of the foundations of the HEALTHGRAIN project. To continue gathering further evidence for these benefits, refining their understanding, and relating it them to cereal diversity will be key to continue enhancing the nutritional benefits further. In addition, it is well known that health attributes relate not only to composition, but to the supramolecular structure of the food. The influence of product structure and the effect of different processes currently used in the food industry on health benefits needs to be further extended. It is important to mention that while increasing whole grain is a clear path of development, a continuous enhancement of the overall nutrition profile of the product is key (e.g., reduction sugar and/or salt) and cannot be neglected.

The combination of all these elements together should provide a stronger framework for the development of cereal based healthier propositions for consumers. A clear definition and regulatory framework, including labeling guidelines, will be essential to reach the consumer.
EPIDEMIOLOGICAL AND CLINICAL STUDIES SUPPORTING HEALTH BENEFITS OF
WHOLE GRAIN CEREAL PRODUCTS

G. Riccardi

Federico II University, Naples, Italy

Whole grain intake – as a part of a healthy diet – has been promoted in the dietary guidelines in a number of countries and by WHO. As a matter of fact, there is strong evidence that regular consumption of whole-grain foods is associated with a substantially reduced risk of coronary heart disease (CHD); whether all parts of the grain are equally effective in this respect is not clearly established: fibre, magnesium, folate, vitamins and antioxidants may play a role in explaining this relationship.

The effects of whole grain foods or diets on CHD and its risk factors have been evaluated in randomised, controlled clinical trials. Lower total and LDL cholesterol levels were usually obtained with oatmeal foods; however the results with other wholegrain cereals have been less consistent. Our group has recently evaluated in healthy subjects the metabolic effects of a diet rich in whole grain wheat foods versus one based on the same products in refined form; after the whole grain wheat diet both total (-4.3%; p<0.03) and LDL (-4.9%; p<0.04) cholesterol levels were lower than after the refined wheat diet.

Observational studies evaluating the relationship between whole grain consumption and measures of body weight and adiposity have consistently shown that high consumers of whole grain have a lower BMI and a lower waist circumference than low consumers. However, this may not be regarded as an evidence for causality since people who consume more whole grains are likely to have healthier lifestyle: fewer of them smoke, they exercise more frequently and their diet has a lower fat and higher fibre content.

Regular consumption of whole grain foods is also associated in epidemiological studies with a reduced risk to develop type 2 diabetes; the acute metabolic advantage in relation to post-prandial glucose metabolism is at least in part due to the intact structure of the grain, although it seems also important the contribution of dietary fibre and other constituents of whole grain cereal foods. However, the association between whole grain food intake and reduced incidence of type 2 diabetes remains significant also after adjustment for fibre, magnesium and vitamin E intake.

In conclusion, a higher intake of whole grain cereals is associated with a lower incidence of coronary heart disease and diabetes; different biological mechanisms have been suggested as possible explanations of these associations and some of them have been explored within the framework of Healthgrain. Further studies are needed to evaluate the metabolic effects of wholegrain products derived from different cereal species; moreover the global impact on health of the regular consumption of wholegrain cereal foods requires long term controlled clinical studies with defined clinical end-points.
How to promote healthiness by processing and breeding

New approaches in grain production
Chairpersons: Peter Shewry and Alan Schulman

Matching technological and nutritional benefits
Chairpersons: Jan Delcour and Per Åman

Thursday 6 May 2010
8.30-15.00
TARGETED AND FACILITATED BREEDING FOR NUTRITIONAL QUALITY

P.R. Shewry

Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, UK

The development of new varieties of wheat with increased contents of bioactive components (phytochemicals and dietary fiber) is an important prerequisite for developing novel food products combining enhanced health benefits with high acceptability and affordability for consumers. Module 2 of the HEALTHGRAIN project has therefore used a range of approaches to identify sources of variation in grain composition which can be provided to plant breeders for incorporation into breeding programmes. Firstly, a diversity screen was carried out, with detailed analyses being carried out of 150 wheat lines (selected to represent a wide range of geographical origin and date of release) grown on a single site followed by similar analyses of 26 lines grown in multisite trials. Further variation in composition, in particular starch composition, was also sought by introgressing mutant genes from exotic germplasm and by screening a mutant population of wheat cv. Cadenza. Finally, variation in the content and composition of dietary fiber has been introduced by genetic engineering, by down-regulating and over-expressing candidate genes for enzymes catalysing β-glucan and arabininoxylan synthesis.

These studies aimed at identifying, generating and exploiting genetic variation in grain composition have been integrated with two further approaches aimed at providing tools for plant breeders. Firstly, detailed genetic and molecular studies have allowed loci controlling the content of arabininoxylan fiber to be identified and mapped, which will allow molecular markers to be developed for use in breeding programmes. Secondly, new analytical tools suitable for use in plant breeding and have been developed, including NIR calibrations for arabinoxylan.
VARIATION IN BIOACTIVE COMPONENTS IN WHEAT AND OTHER CEREALS

J. L Ward

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The benefits of wholegrain cereals are now widely accepted and have formed the basis for health claims in several countries. HEALTHGRAIN is an integrated project in the 6th Framework Programme of the European Union (2005-2010) and has provided the resources to carry out a detailed study on the phytochemical composition and variability across a large number of cereal lines. Data will be presented from a “diversity screen”, established in 2005, with 200 cereal varieties, spanning both old and modern varieties, sourced from different regions from Europe to New Zealand. 150 wheat lines and 10 rye lines were grown together with 20 other cereal lines (oats, barley, spelt, durum wheat and primitive diploid and tetraploid wheats) on a single site at Martonvásár in Hungary. Presented data will demonstrate a wide variation in phytochemical and fibre content, determined across a large number of classical analytical methods including phenolic acids, alkylresorcinols, sterols, folates and tocols. Additional studies on a subset of these lines has also allowed an assessment of the influence of the environment to be made with a full G x E study across six environmental conditions. The data has been collated into a comprehensive database allowing meaningful correlations to be drawn against classical agronomic trait data which has also been collected for each sample.
DEVELOPING NEW WHEAT VARIETIES WITH ENHANCED HEALTH BENEFITS

Z. Bedő1, L. Láng1, M. Rakszegi1, D. Lafiandra2, F. Sestili2, K. Gebruers3, G. Charmet4, J. Ward5, A. Phillips5, and P. R. Shewry5

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Increasing interest in human nutrition has focused plant breeders’ attention on the extent of variation and the genetic control of bioactive compounds in order to select new wheat varieties with improved nutritional values as the basis for a healthy cereal-based diet. The objectives of plant breeders are therefore to increase this variation using classical breeding and biotechnological tools, to combine existing germplasm rich in bioactive compounds with good agronomic and technological quality traits and to develop breeding methods for the selection of new genotypes combining high levels of bioactive compounds with good agronomic properties and technological quality in modern wheat varieties.

The HEALTHGRAIN diversity screen identified genotypes that combine high Zeleny sedimentation values and protein contents with high levels of water-extractable (WE-AX) and total arabinoxylans (TOT-AX). The exotic lines Yumai-34 (China) and Seu-Seun 27 (Korea) are outstanding for both traits. This combination of properties makes it possible to produce healthy food products containing high amounts of dietary fibre from wheat with good processing quality. Such new genetic resources are being used in breeding by crossing them with adaptive varieties with good agronomic performance and good technological quality properties.

The efficient introgression of genetic resources into elite varieties by backcross breeding requires the screening of the progeny with molecular markers to detect the presence of the selected trait. Lafiandra et al. (2008) developed lines with mutations in granule-bound starch synthase genes (Sgp-A1, Sgp-B1 and Sgp-D1), which contain starch with an increased proportion of amylose. This germplasm is now being backcrossed with commercial wheat varieties that are adapted to various growing regions of Europe and have good processing quality. Double and triple null mutant genotypes have been selected in the BC1 generation with molecular markers. They have similar amylose content as lines with mutation in granule-bound starch synthase genes and good agronomical characters as the elite wheat backcross parents. Pyramiding genes for nutritional quality improvement with molecular marker selection can accelerate the development of new wheat varieties and it can reduce the environmental effect during the selection.

key words: wheat, genetic resources, bioactive compounds, arabinoxylans, amylose, marker assisted selection

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Genomics and transgenesis approaches have been develop to exploit the large genetic variation observed in the wheat germplasm for most health promoting component through breeding enhanced varieties. Genomics aims at identifying key genes involved in the control of grain composition for macro and micro-nutrients. Then genetic markers derived from of closely linked to the genes can be used by breeders to optimise crossing, select progenies and cumulate the favourable alleles which improve the trait. Gene primers and sequencing can also be used to look for new alleles associated with improved trait value, either in natural variation of germplasm or in mutants collections.

A first target was dietary fibre, mostly represented in wheat by the soluble part of arabino-xylans. A “forward” quantitative genetic approach, using recombinant populations derived from crosses between parents with high and low contents of arabinoxylans, allowed three QTL regions, each explaining between 18 and 59% of phenotypic variation, to be identified and molecular markers were delivered to breeders. Further studies focused on key enzymes involved in the biosynthetic pathway of arabinoxylans. A total of 34 homoeologous candidate genes were sequenced in a set of 46 lines selected to represent worldwide diversity. 27 SNPs (in 13 candidate genes) were genotyped in the 156 lines of the HEALTHGRAIN diversity screen, and 8 associations were found, the most significant being between the COMT (cafeic acid O methyltransferase) gene on chromosome 7A the WE-AX fraction. Null alleles (deleted genes) were selected in a collection of irradiated mutants of cv Renan for each of the 3 genes (on A, B and D genomes) and crosses made to cumulate the 3 null alleles, with the hope to enhance the soluble part of AX by reducing ferrulic acid synthesis in endosperm. A similar approach was carried out on 6 genes involved in the biosynthesis of folates. 33 SNPs were identified of which 16 were tested and showed no significant associations with grain folate content. Surprisingly, SNPs in 2 genes showed associations with total tocols or the proportion of tocotrienols. These SNP markers can thus be used to “pyramidate” favourable alleles for various traits found in different lines, e.g. fibre with tocols and phenolics.

In addition, transgenesis was used in a reverse-genetic approach to modulate the expression of enzymes involved in cell wall biosynthesis. Using transcriptomics and bioinformatics, we identified several wheat gene candidates for glucan synthase, xylan synthase and arabinosyl transferase; three key enzymes in the synthesis of endosperm cell walls. Over 300 transgenic wheat lines were made with recombinant DNA constructs designed to either over-express or silence these genes. Endosperm-specific RNAi silencing of CLF6 in five independent transgenic lines of wheat resulted in a decrease of total beta-glucan content of between 36% - 53% as measured by HPAEC, confirming this gene encodes an active beta-glucan. We are currently analysing the arabinoxylan oligosaccharides in the endosperm of wheat lines possessing an RNAi cassette designed to silence a putative xylan synthase. Initial results from HPAEC indicate a significant reduction in arabinoxylan concentration in flour extracted from transgenic lines. Once validated, these GMO constructions can be used to develop wheat varieties with modified (improved) cell wall properties, or alternatively to explore the natural or induced genetic variation to develop non-GMO cultivars with enhanced fibre content.

References:

The primary processing of cereal grains has, in the past, largely relied on roller milling technologies. In milling wheat or rye, the flour, which contains starch as its major constituent, is physically separated from the cereal outer layers, which are most commonly known to the general public as bran. While wheat and, to a lesser extent, rye flour find their way into diverse food applications of which bread making is a major one, the cereal outer layers are insufficiently utilized in food systems. This has mainly to do with the fact that, in many cases, they impair the palatability of food systems containing them. However, this is especially regrettable as the calorie-poor outer layers of the grains contain great health potential which, with classical processing and food formulation, remain insufficiently unlocked. Indeed, the outer layers are especially rich in dietary fibre and accompanying health promoting constituents, which, hence, insufficiently reach the consumer. It is the merit of Healthgrain and its partners to have concentrated on innovative milling and dry fractionation technologies, as well as wet processing and fermentation technologies for extracting the best of the grain. By doing so, strategies have been developed for fully unlocking the health potential of cereal grains and providing foods of excellent organoleptic quality.
FROM CLASSICAL TO INNOVATIVE MILLING TECHNOLOGIES

Presenter(s): W. Eugster¹, U. Schill²
Script: W. von Reding³

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The milling industry is changing constantly on the globe. In emerging countries the industry is growing and supply of basic flour for the fast growing population is key. In other regions like Western Europe trends are moving towards healthier flour or grain fractions for specialty foods like whole grain or fiber enriched with high food safety requirements.

Buhler has its 150 years of anniversary. The presenter(s) will give a review about developments in the milling industry over the past 50 years and will give insights into the 21st century most modern milling technology to meet customer’s future needs.

Keywords: Roller mills, ash, yield, reliability, robustness, scale, Health, convenience, nutritional aspects, food safety, legal requirements, added value, ingredients, consumer Insights
NOVEL DRY FRACTIONATION TECHNOLOGIES

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Wheat bio-active compounds (fibres, minerals, vitamins, antioxidants) are concentrated in grain outer layers which constitute the bran fraction obtained after the milling process leading to the white flour. In order to improve the health value of the flours, whole grains can be processed or alternatively, bran fractions can be added to white flours. In the bran, bio-actives compounds are poorly bio-accessible as they are trapped in resistant cell-wall. Dry fractionation of wheat bran takes advantage from differences in compositional and mechanical properties between grain tissues. Both ultrafine milling and electrostatic separation can be used to prepare bran fractions with different degrees of micronization and/or enriched in compounds of interest. In vitro digestion studies of bran-enriched breads have shown that the bio-accessibility of phenolic acids and minerals improves with decreasing particle size and also with increasing concentration of micronized aleurone material.


References


MATCHING TECHNOLOGICAL AND NUTRITIONAL BENEFITS:
THE ARABINOXYLAN CASE

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The main quality determining dietary fibre in a number of cereals such as wheat and rye is arabinoxylan (AX). While the significant technological impact of AX on cereal based processes has been extensively researched over the past decades, reports on the nutritional benefits of these fibres and their degradation products are from a more recent date. Especially AX derived oligosaccharides, or AXOS, have raised particular interest by the bifidogenic effect they exert. As both soluble high molecular weight AX and AXOS are largely absent from most food products, supplementation of foods with these components or their in situ production in AX rich food products seem the two most straightforward ways of incorporating them in a human diet. Within the Healthgrain program, the possibility of in situ production in bread of sufficiently high levels of AX(OS) for physiological effects was evaluated.

Bread making trials combining supplementation of traditional bread recipes with AX rich cereal materials and a variety of commercial and experimental xylanases were set up and breads were analysed for their quality characteristics, AX(OS) content and degree of polymerisation. Results showed that AXOS levels of up to 2.4% on bread weight (dry matter) with an average degree of polymerisation of 20 to 30 can be obtained without compromising dough properties or final bread quality. This requires supplementation of the bread recipe with selected AX rich sources and the use of specific xylanases, mainly active during the baking phase of bread making. The latter appeared important in preventing loss of dough consistency and stickiness as a result of extensive AX degradation during the mixing and/or fermentation phase. Also in situ production of high molecular weight soluble AX material seemed feasible, given selection of the correct xylanases.
BIOPROCESSING OF BRAN FOR IMPROVED FUNCTIONALITY

K. Katina¹, E. Selinheimo¹, P. Lehtinen¹, P. , L. Flander¹, A. Laitila¹, R. Juvonen¹,
V. Piironen², M. Edelmann², S. Kariluoto² and K. Poutanen¹

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Bran is a rich source of dietary fibre and phytochemicals. ItHowever, it has only limited use in food products, especially in such amounts that health benefits can be expected, due to challenges in using of native bran with respect to sensory quality of the product. Fermentation of bran has been shown to improve the quality of subsequent products (Katina et al. 2006). The aim in HEALTHGRAIN was to study influence of peeling of grain, type of fermentation, use of enzymes and fermentation conditions on the properties of bran ferments. Furthermore, the effects of fermentation on the technological functionality of bran in bread baking (15-20 % addition level), as well as on in vitro bioavailability of ferulic acid in the subsequent high-fibre wheat bread were studied. The ultimate aim was find correlations between the properties of fermented bran and the texture, volume and nutritional quality of subsequent high fibre breads.

Fermentation was performed either spontaneously, with S. cerevisiae or by using S. cerevisiae and combination of cell-wall degrading enzymes (Veron CP, Depol 740L, Pentopan mono BG and Grindamyl). Structural modification of bran was studied by analysing amount and MW of arabinoxylans by GC and HPLC, acidity, activity of endogenous xylanases, and by detecting changes in cell wall structures by light microscopy. Bioactivity of fermented bran was studied by measuring amounts of folates and phenolic acids by HPLC. The quality of subsequent breads was studied by determining specific volume (Bread Vol Scan) and instrumental texture (Texture Analyser).

The most efficient tool to engineer the bran properties was the enzyme-aided yeast fermentation of bran from peeled kernels. Furthermore, peeling prior to bran separation clearly reduced the microbial load in wheat bran, which was also reflected in the microbial community during yeast fermentation. Tailored fermentation of bran increased the amount of soluble arabinoxylans four-fold and significant degradation of cell wall structures was observed. Yeast fermentation of bran also modified activity of endogenous xylanases and MW of arabinoxylans. These changes resulted in higher bread volume and softer bread texture in the subsequent breads. Tailored fermentation increased also level of folates nearly two-fold and free ferulic acid (FA) 17-fold, leading to improved bioavailability of FA (Mateo-Anson et al 2009). We conclude that bran fermentation is an efficient means to modify structure of the bran as well as levels of folates and FA, and results in the improved texture, increased folate content and bioavailability of FA of wheat bread supplemented with fermented bran.

Key words: bran, bioprocessing, bread, bioactivity

References:

Mateo Anson, Nuria; Selinheimo, Emilie; Havenaar, R.; Aura, Anna-Marja; Mattila, Ismo; Lehtinen, Pekka; Bast, A.; Poutanen, Kaisa; Haenen, G.R.M.M.. 2009. Bioprocessing of wheat bran improves in vitro bioaccessibility and colonic metabolism
IMPACT OF PROCESS CONDITIONS ON SELECTED NUTRITION AND QUALITY PARAMETERS OF BREAD; OUTCOMES FROM THE EU-FRESHBAKE PROJECT (FP6)

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EU-FRESHBAKE project (FP6 - Sept 2006 – Nov 2009 – 12 partners) has worked on the BAKE-OFF-TECHNOLOGY which allows the production and marketing of freshly baked breads and specialities made from industrial frozen (and non frozen) bakery preparations. EU-FRESHBAKE showed how important can be the processing condition on nutrition parameters; in particular, a significant reduction of the glycaemic index has been observed for part baked bread. EU-FRESHBAKE has also focussed on the impact of baking process on energy demand. Some innovation has been developed to reduce the energy but will not be presented in this presentation. Selected results from the European funded project “EU-FRESHBAKE” will be presented:
- Impact of baking (focus on part baked breads) conditions on the glycaemic index
- Impact of fibres and sourdough on glycaemic index and quality attributes
- Impact of dough freezing on phytase-phytates
- Sourdough and alternatives to yeast in the case of part baked bread
- Partial baking; impact on bread quality, staling rate, …
- Impact of freezing on bread aroma.

Note: Pr Le-BAIL has been coordinating the EU-FRESHBAKE project (http://eufreshbake.eu/eufreshbake/index.php) from the European Commission, FP6, Thematic Area “Food Quality and Safety”, FOOD-2006-36302 EU-FRESH BAKE. This presentation is done within the frame of the AGRIFOODRESULTS European project (FP7- Grant Agreement 226927) aiming at communicating the results of European projects toward the industry. It does not necessarily reflect the views of the European commission and in no way anticipates the Commission’s future policy in this area.
The incidences of celiac disease or other allergic reactions / intolerances to gluten are increasing largely due to improved diagnostic procedures and changes in eating habits. This creates a high demand for high quality gluten-free products. The majority of the gluten free cereal products currently on the market are lacking structure flavour and are very often of poor sensory quality. This presentation gives and overview on novel approaches taken during this project for the development of gluten free bread. The areas covered in the presentation are the detailed characterisation of gluten free cereals including oats and the assessment of these cereals as potential ingredients for gluten free breads. The characterisations ranges form a detailed chemical characterisation, to rheological evaluation of the resulting doughs, structural properties of the doughs and breads using advanced microscopical methods as well as pilot-scale baking trials and sensory evaluation. Methods to improve the quality of cereal products will also be introduced; one example being the use of specially selected Lactic acid bacteria with properties such as antifungal activity, exopolysaccharides production and enzyme production. A full characterisation of the selected strains is provided. The formation of structure is important for high quality gluten free products. The influence of a range of enzymes such as transglutaminase, glucose oxidase and protease on wide range of gluten free cereals will be shown. An in-depth understanding of the interactions of transglutaminase with the various proteins will be explained with the help of cereal proteomics. Novel processing such as high pressure processing will be introduced as a means to create ingredients for gluten free cereal products.
NEW CONSUMER PRODUCT PROTOTYPES

R. Ranieri, G. Tribuzio and M. Petronio

Barilla G. e R. Fratelli, Società per Azioni, Parma – Italy.

During 5 years of Healthgrain research many methods, processes and ingredients were developed. Barilla coordinated the work package composed also by Bühler, Syral and Raisio, that has the role to run the feasibility studies on the most promising processes, ingredients and/or a combination of both. Another objective of this work package was to deliver significant amounts of end products for the intervention studies.

The whole grain kernel (i.e. wheat or rye) can be considered as a source of an impressive list of nutrients and micronutrients that often, especially in Southern Europe, are only in small part, partially used to produce food; most of them go, embedded in bran, to feed. Within the Healthgrain research we demonstrated that it is possible to add value to the kernel fractions when separated and introduced to the end product according to the product concept the producer will choose.

The kernel can be slightly peeled (2-3% of the outer layer go to feed or to waste) to reduce the contaminant risk. Before to do it germ can be partially extracted to avoid it goes to feed. Then, the kernel can be pearled in different fractions until to reach the aleuron layer. Finally, it is possible with the traditional milling process to obtain a flour that at the end of the milling process can be enriched by different bran fractions which can vary based on the end product concept. Bran fractions can be further treated to extract, by physical treatment, the aleurone layer (i.e. Leuron from Bühler) or pure components like AXOS developed by xylanase activity/action on bran arabinoxylan.

The product design drivers are: nutrition, taste, texture (technological implications) and cost. To increase the consumption of grain-based end products it is important to keep in mind all four.

For example, if the product concept will lead to a whole grain product without the cardboard-like off notes, the flour could be enriched by the bran inner fractions obtained by the pearling and especially those closer to the aleuron layer, but not from those from the traditional milling. On the contrary, if the product concept will be to create an end product with lighter color and higher fiber the outer layers (avoiding the most external) will be the major components of this design. These fractions could be added to the flour keeping in account the respect of the original proportions of the kernel components if it is important to declare that the flour is a whole grain flour. Finally, being able to reintroduce all these fractions, or a portion of them, in the flour originated from the same kernel or from the same mill, will contribute to reduce the product costs.

“Healthyflour” is prototype flour generated by the Healthgrain project obtained mixing flour of the inmost bran layers fractions coming from the pearling (also called debranning) process, and the middlings coming from the regular milling process. The very external layers and the bran from the kernel crease separated by the regular milling process go to feed.

Using Healthyflour as a base and adding pure extract from bran or the different bran fraction it is possible to accomplish different end products that can satisfy different targets: mild whole grain, higher in Total Dietary Fiber (TDF), higher in TDF but with significant presence of soluble fiber, whole grain products lighter in color, product rich in betaine and other micronutrients with a significant impact on our wellbeing.

Therefore, we believe that we are moving from an offer that was only for whole grain lovers to a scenario, in the near future, were the shelves will be populated by grain-based end products which will be tailored-made to meet much better the consumer needs that will contain much more bran or bran derivatives than before. Healthgrain continuation (i.e. HG Forum) could play a role in this scenario stimulating fair competition in food innovation, helping in the definition of a clear regulatory framework and harmonizing it within the EU country members.
Nutrition – Benefits of health promoting compounds and properties

Chairpersons: Inger Björck and Gabriele Riccardi

Thursday 6 May 2010
15.00-17.30
Whole grain wheat is a potent source of bioactive compounds with antioxidant and anti-inflammatory potential (1). These bioactive compounds are likely implicated in the protective effect of whole-grain consumption against metabolic disorders. In an integrated and multidisciplinary approach, the process-induced changes and human metabolism of phenolic compounds in whole grain have been investigated with the objective to possibly optimize the health benefit of whole-grain products. The main findings can be summarized in the following study goals:

**Identification of the healthy fractions of a wheat grain.** Different fractions of the wheat grain were determined for antioxidant and anti-inflammatory effects *in vitro*. The outer-most fractions of the grain, the bran and within this one the aleurone layer, exerted the largest and most prolonged effects (2).

**Identification of the main bioactive compounds.** Ferulic acid appeared to be responsible for the most of the antioxidant capacity. This phenolic compound is the most abundant antioxidant in wheat grain and therefore it was chosen as a marker for antioxidants in wheat grain (3).

**Bioavailability studies.** The gastrointestinal release of bioactive compounds from cereal fractions and products was assessed *in vitro* using a multi-compartmental model simulating the dynamics of the gastrointestinal tract (TIM). The release of a compound from the food matrix to become available for absorption is defined by the term of “bioaccessibility”. The poor bioaccessibility of ferulic acid from the cereal matrix limits the bioavailability of this compound after whole-grain consumption, and this is likely applicable to other bioactive compounds as well.

**Effect of processing on the bioaccessibility.** The effect of several processing techniques of bran was investigated on the bioaccessibility of phenolic compounds, such as ultra-grinding, electrostatic separation, enzymatic treatment and fermentation. Bioprocessing of bran, consisting of yeast fermentation combined with enzymatic treatment, could increase the bioaccessibility of ferulic acid 5-fold from whole-meal wheat bread.

**Effect of processing on the colonic metabolism.** The colonic metabolism of the non bioaccessible ferulic acid into other compounds (mainly 3-hydroxyphenylpropionic acid and phenylpropionic acid) was also boosted by the bioprocessing. The bioprocessing also affected the colonic fermentation of fibre, which resulted in an increased production of butyrate.

**Effect of processing on the bioavailability and possible health effects.** An *in vivo* intervention in healthy subjects was conducted to confirm the above *in vitro* results. Bioprocessing of bran increased the bioavailability of ferulic acid among other phenolics by 3-fold from the whole-meal bran bread. There was no difference in the total antioxidant capacity in plasma between the breads. Before and after the bread consumption, blood was drawn from the volunteers, and subsequently an inflammatory response was induced *ex vivo*. The anti-inflammatory effect of consuming bioprocessed bran containing whole-meal bread versus the control, native bran containing whole-meal bread, was assessed by the decrease in the ratio of pro-inflammatory and anti-inflammatory cytokines. It was found that bioprocessing enhanced the anti-inflammatory effect of whole-meal bread.

Not only the high content of bioactive compounds plays a role in the health benefit of whole-grain products, also their actual bioavailability should not be overlooked. Processing can have a favorable impact on their bioavailability and subsequent biological activity, in that way the health benefit of whole-grain products can be optimized.

**References:**

This research was financially supported by the European Commission in the Communities Sixth Framework Programme, Project HEALTHGRAIN (FOOD-CT-2005-514008). It reflects the author’s views, and the Community is not liable for any use that may be made of the information contained in this publication.
The main objective of the present investigation was to study the impact of cereal grain fractions varying in dietary fibre (DF) polysaccharide (β-glucan, arabinoxylans (AX), cellulose) composition. Two series of experiments were performed; a screening study with rats fed iso-DF diets based on 19 wheat and rye whole grain and fractions and a study with pigs fed four diets based on wheat flour with added purified wheat fibre, whole grain wheat, wheat aleurone flour and rye aleurone flour. In both series the colonic formation and absorption of short-chain fatty acids (SCFA: acetate, propionate, butyrate) was measured. The SCFA formation was primarily regulated by amount and composition of the dietary residues that escape digestion in the small intestine; DF polysaccharides; β-glucan, AX, and cellulose was quantitatively the most important. β-glucan and soluble AX was rapidly degraded in the caecum and proximal colon while the more insoluble polysaccharides, e.g. cellulose and insoluble AX, were degraded more slowly at more distal locations of the colon. Amount and rate of degradation of the individual polysaccharides had a profound influence not only on the total production of SCFA but also on the molar proportion of the produced acids. Thus, with both rats and pigs it was found that fermentation of AX rather than β-glucan stimulated the formation of butyrate and to a smaller extent propionate (absolute and relative) in a manner that was linked to the flux of AX to the large intestine.

**Key words:** Short-chain fatty acids; Butyrate, Arabinoxylans.
Frequent hyperglycaemic episodes over the course of the day are increasingly being associated with risk of cardio-vascular disease (CVD). In fact, post-prandial hyperglycaemia is a stronger predictor of CVD than elevated fasting blood glucose [1]. In accordance, treatment with Acarbose, an amyloglucosidase inhibitor which reduces the glycaemic impact of starchy foods, importantly delayed on-set of type 2 diabetes (T2D) and CVD in a prospective study in subjects with impaired glucose tolerance [2]. In fact, a subject may demonstrate high postprandial glycaemic excursions over a long period of time prior to elevations in fasting blood glucose. One mechanism for the detrimental effect of elevated postprandial glycaemic excursions is that it promote low grade systemic inflammation, which is increasingly being linked to insulin resistance and development of T2D and CVD.

A number of studies have shown that an increased intake of food with low glycaemic index (GI) may protect against development of CVD and T2D [3]. By definition, low GI foods result in an acute lowering of postprandial glycaemia after intake of a carbohydrate rich meal, compared to foods with high GI. Several studies have also linked a high intake of whole grain to reduced risk of T2D and CVD and it can be hypothesised that low GI characteristics of some whole grain foods is one feature contributing to the health value of whole grain diets. Another interesting feature of most low GI foods is their potential of improving glucose tolerance at a subsequent meal, the so called “second meal” effect. This has previously been described mainly in the perspective from breakfast to lunch [4, 5].

From studies performed within Healthgrain, it has been concluded that rye products, both kernel based and flour based, display favourably low acute insulin responses, compared with white wheat bread (WWB). On the contrary, for wheat products the maintenance of food structure was necessary to evoke low insulin responses. Another interesting feature of rye products was that both endosperm rye and whole grain rye lowered the insulin responses to a similar degree and this suggests that some component present in rye endosperm is the key to improved insulin economy. However, not all rye genotypes appear to share the insulin saving properties. In a Healthgrain study, the glucose and insulin responses to five different rye genotypes (Haute-Loire Pop, Nikita, Dankowski Zlote, Rekrut and Amilo) were evaluated and only bread made from Rekrut and Amilo displayed lowered insulin responses compared with WWB. Further comparisons between rye and wheat have revealed that a breakfast meal of boiled rye kernels were more satiating than wheat kernels, not only at the acute meal situation, but also at a standardised meal, served 4h later. Based on this finding we designed a study based on the hypothesis that energy intake at a voluntary lunch meal could be lowered if rye kernels were served for breakfast. The results confirmed the hypothesis and the rye kernel breakfast reduced the voluntary energy intake at lunch by 16%, compared with a WWB breakfast. Potential mechanisms behind the reduced energy intake after rye kernels are; improved glycaemic profile, lowered insulin and/or free fatty acid levels and increased fermentation of dietary fibres and associated components influencing gut hormones, production of short chain fatty acids etc.

In recent studies we have shown that cereal based foods with low GI and a high content of indigestible carbohydrates have the capacity to improve glucose tolerance in a longer time perspective during a whole day or over night [6-9]. Thus, food products containing specific mixtures of dietary fibre (DF) and resistant starch (RS) can improve the glucose tolerance in a perspective from an evening meal to a breakfast which is served after 10 hours. Intact rye and barley kernels, as well as bread containing high amounts of
barley kernels, are good examples of such foods. Furthermore, the beneficial effect in the 10 h perspective could be simulated by enriching a white wheat bread with RS and DF from barley in the ratios corresponding to the barley kernel bread. An improved overnight glucose tolerance was related to a higher degree of fermentation in the colon and higher concentrations of short chain fatty acids in plasma. In addition, the improved glucose tolerance was associated with lower levels of free fatty acids and higher levels of the incretin hormone GLP-1 (glucagon like peptide 1) in the blood. We also found a positive association between degree of colonic fermentation and subjective satiety and an inverse relation between colonic fermentation and rate of gastric emptying.

An evening meal with barley kernel bread resulted in a lowering of IL-6 and an increase in adiponectin at the subsequent breakfast. The latter suggest an anti-inflammatory effect of kernel based cereal products and this may be one mechanism behind the positive relation between whole grain and lowered risk of cardiovascular disease and type 2 diabetes seen in epidemiological studies [10].

To conclude, whole grain rye and barley products may not only improve acute glucose regulation but also have beneficial effects on glucose levels and metabolic risk markers in a longer term perspective. The semi-acute effects are suggested to be mediated though improved insulin economy and increased colonic fermentation. This offer a great potential for cereal based foods in the prevention of cardiovascular disease and type 2 diabetes.

References:
EFFECTS OF WHEAT AND BARLEY DIETS ON INSULIN SENSITIVITY AND BETA-CELL FUNCTION IN PATIENTS WITH TYPE 2 DIABETES

A. Frid
Öresund Diabetes Team, Sweden

Aim: to assess differences in glucose metabolism and laboratory parameters in patients with diabetes type 2 eating four diets differing regarding content of whole grain and glycemic index.

Intervention: Study period 4 weeks
1: Bread A. High GI, low whole grain white wheat bread
2: Bread B. High GI, high whole grain fine wheat bread,
3: Bread C. Low GI, high whole grain wheat kernel bread,
4: Bread D. Low GI, high whole grain barley bread

According to Swedish nutritional recommendations carbohydrates should cover 55-60% of the daily energy needs. Study breads gave 60% of the daily carbohydrate intake.

Individual weekly diet lists were made according to sex, medical history and weight

Patients: Male and female patients with diabetes type 2 according to standard WHO criteriae, treated with life-style intervention, no pharmacological treatment. Age 25-75, no drugs affecting insulin sensitivity i.e. cortison, other standard exclusion criteriae.

71 patients have entered the study
58 patients have completed the intervention
Bread A:13, B:16, C:12, D:16
Dropouts A:5, B:1, C:3, D:5
M:F ratio A:5/8, B: 7/9, C: 5/7 D:8/8
Mean BMI (kg/m²) A:28.2, B:27.8, C 25.9, D 28.6
Median weight (kg) A:76, B:83, C:75, D:84

Primary endpoint: Insulin first-phase response and insulin sensitivity measured by GITT (Glucagon-Insulin Tolerance Test)

Secondary endpoints: HbA1c, fasting plasma glucose, HDL, LDL, TG, ApoA, ApoB, PAI-1 and high sens CRP

All measurements beginning and end of study period.

Results: There were no statistically significant changes in insulin sensitivity from day 1 to day 28 for breads A, B and C. For bread D (whole grain low GI barley bread) there was a statistically significant increase in insulin sensitivity day 28 compared to day 1 (p=0.001) as measured by GITT, k-value 2.01±0.28 (mean±SEM) compared to 1.44±0.19.

There were no statistically significant differences regarding secondary endpoints.

Conclusion. A low GI, high whole grain barley kernel bread will improve insulin sensitivity over four weeks in a group of patients with diet-treated diabetes type 2.
EFFECTS OF A “HEALTHGRAIN” DIET ON METABOLIC RISK FACTORS IN SUBJECTS PREDISPOSED TO TYPE 2 DIABETES AND CARDIO-VASCULAR DISEASE – A TWO CENTRE STUDY

H. Mykkänen

University of Eastern Finland

Increased consumption of whole grain foods is associated with decreased risk of type 2 diabetes and improvement in metabolic risk factors predicting this risk. However, the results from controlled intervention studies evaluating the underlying mechanisms are not convincing. The objective of the present study was to determine the effects of a dietary intervention using whole grain products on glucose and lipid metabolism in subjects with the metabolic syndrome living in two European locations with different food cultures (Finland/Kuopio and Italy/Naples). Two-arm parallel group study design was used, and the diet period was 12 weeks. The test group received a “HEALTHGRAIN” diet containing cereal products with demonstrated positive effects on glucose metabolism, while the control group was offered a diet consisting mainly refined wheat cereals. The cereal products were bread, pasta, breakfast cereals and snacks, and they were included in the daily diets in amounts that reflect normal consumption patterns. Fasting blood samples were taken at the beginning of the study and at one-month intervals thereafter. The oral glucose tolerance (2h-OGTT, in Kuopio only) and intravenous glucose tolerance (FSIVGTT) tests were done at the beginning and end of the diet period. In Naples a test meal resembling the composition of the control diet was served at the end of the run-in period, and test meals resembling the control and test diets were served to the appropriate groups at the end of the intervention for the evaluation of postprandial glucose and lipid metabolism over a 3-h period. The subjects (n=69/Kuopio, n=54/Naples) in both locations were overweight and displayed abdominal obesity and high blood pressure, thereby filling the criteria of diagnosis of metabolic syndrome according to the National Cholesterol Education Program. Compared to the baseline, no change was seen in the anthropometric parameters (body weight, BMI and waist circumference) after 3 months on the “HEALTHGRAIN” diet or the control diet. Similarly, there were no significant changes in fasting plasma glucose, serum insulin and lipid levels during the intervention period in the two diet groups. The indicators of body glucose and insulin homeostasis derived from the FSIVGTT (first phase insulin secretion, insulin sensitivity, glucose effectiveness) were not changed during the intervention in either diet group. However, OGTT revealed a tendency towards improved glucose homeostasis during the “HEALTHGRAIN” diet in subjects at the Kuopio centre, and similarly in subjects at the Naples centre there was a reduced need for insulin during the test meal compared to the control meal. In the latter group also the triglyceride clearance was improved by the “HEALTHGRAIN” diet. This data indicates that dietary intervention using whole grain foods will influence primarily the postprandial events related to glucose homeostasis within the gut region.
There is now strong evidence that wholegrain foods protect against heart disease and certain cancers. The factor(s) responsible for these beneficial effects are currently unknown. Apart from being high in cereal fibre, wholegrain wheat products are also rich in bioactive components including antioxidants, such as tocols and ferulic acid, and the methyl donors, betaine, choline and folate, which are concentrated in the bran and particularly the aleurone layers of the grain. In order to evaluate the uptake of these components, and their potential to exert beneficial effects, we conducted three human intervention trials using wheat aleurone.

Two short-term cross-over studies evaluated the uptake of the above components from aleurone at two levels of processing. In the first study 14 healthy subjects consumed either 50g aleurone boiled in water or a control product balanced for fibre and macronutrients, after an overnight fast. In the second study, 13 healthy subjects consumed either aleurone-rich bread containing 50g aleurone or balanced control bread. In both studies blood samples were collected at baseline and at 30, 60, 120 and 180 minutes post-meal and were analysed for tocols, ferulic acid, folate, choline and betaine. Results showed that the consumption of both minimally-processed aleurone and aleurone processed into bread resulted in similar significant postprandial increases in plasma ferulic acid (P<0.001) and betaine (P<0.001).

The third study was a 4-week parallel, single-blinded intervention trial to evaluate the longer-term consumption of aleurone on markers of health. In this study, 79 healthy adults incorporated either aleurone-rich cereal products (providing 27g aleurone per day), or control products balanced for fibre and macronutrients, into their normal diets. Fasting blood samples from baseline and day 29 were analysed for the above components, and for associated functional markers of health. Results showed that, compared to the control, consumption of an aleurone-rich diet for 4-weeks resulted in significantly higher fasting plasma betaine (P<0.001), the betaine metabolite, dimethylglycine (DMG) (P<0.001), and lower plasma homocysteine (P=0.010), an independent risk factor for stroke. Results also showed significantly lower concentrations of C-reactive protein (P=0.035), a marker of inflammation, LDL-cholesterol (P=0.037), and a higher concentration of insulin (P=0.049) in the aleurone group. Plasma total SCFA concentrations were similar in each group, but the aleurone group had a greater proportion of butyric acid (P=0.001).

In conclusion, these human intervention trials emphasise the importance of aleurone in the provision of dietary ferulic acid and betaine, and also support the multi-factorial nature of the protection exerted by wholegrains. Further work is needed to establish if these effects can be maintained by the habitual consumption of aleurone-rich foods or achieved by a wholegrain-rich diet.
Consumer attitudes, regulatory issues and communication strategies

Chairpersons: David Richardson and Richard Shepherd

Friday 7 May 2010
9.00-11.00
CONSUMER ATTITUDES TO WHOLEGRAIN AND FUNCTIONAL GRAIN PRODUCTS

R. Shepherd

University of Surrey, Guildford, UK

There has been little research on consumer perceptions of wholegrain products or consumer views on functional cereal products. As part of the European HEALTHGRAIN project (www.healthgrain.org), consumer research has been carried out in the UK, Finland, Germany and Italy. Initial focus groups were followed up by quantitative surveys in each of the countries. Two thousand and ninety four (50.4% women, 49.5% men) members of the public from the four countries completed the questionnaire. The participants were over 18 years of age and were solely or jointly responsible for the family’s grocery shopping. The questionnaire included questions on perceived attributes of wholegrain and refined grain products, along with a series of questions based on three different types of base grain products (bread, pasta and biscuits) with two forms of modification to make them healthier (cholesterol lowering and fibre added). These latter questions included perceived healthiness, benefits and willingness to use. Wholegrain products were rated more positively than refined grain products in terms of healthiness, naturalness, being nutritionally balanced, filling and offering slow energy release. Differences in ratings of digestibility, taste and inexpensiveness were much smaller than for the other attributes, although still statistically significant. The differences in ratings were more pronounced for the Finnish sample but less so for consumers from the UK and Italy; in particular this was due to lower ratings of refined grain products by the Finnish consumers. Women were found to be more aware of the benefits of cereal based foods than men, to be more health conscious and to expect less illness in later life caused by their eating habits. Women were also more willing to use bread containing added fibre and pasta containing added fibre. Older people were also more willing to use all of the examples of bread, pasta and biscuits modified to have added fibre or to lower cholesterol.

An analysis of the perceived benefits of the three types of products (bread, pasta and biscuits) modified to have added fibre or to be cholesterol lowering showed that greater benefits were expected in the products with added fibre than the cholesterol lowering products. In addition, the modified bread was seen to have more benefits than were the pasta, with biscuits having the least benefit.

Perceptions of grain products differ between countries, with Finnish consumers seeing refined grain products more negatively. Women and older people were found to be more positive about functional grain products modified to have added fibre or to lower cholesterol and more willing to use such products.

**Keywords:** attitudes, consumers, wholegrain, functional foods

**References:**
Health-related claims offer consumers information about the benefits products can provide them. Adding a health claim into cereal products increases the perceived benefit\textsuperscript{1,5}, but this increase depends on the type of the product, type of benefit, target population and perceived relevance.

Health-related messages in products can vary in their content and form. Claims that contain the ingredient, its function and the health outcome (benefit) provide more information than claims that provide only information about the outcome benefit. When asked about convincingness of the claims, consumers in the Nordic countries could be divided into two groups: those who found the long claims with the whole chain of information most convincing and those who thought that short claims with just the outcome benefit were most convincing\textsuperscript{2}. There are cultural differences in the perception of claims: In UK respondents were most positive towards claims that promised increased well-being, whereas in Finland and Germany consumers preferred risk reduction claims, but in Italy all health-related claims were perceived negatively and they reduced ratings for likelihood to buy\textsuperscript{4}. Regardless of the cultural differences, those who recognise themselves at risk of a disease find claims that are relevant to them as more beneficial than those with a low perceived risk\textsuperscript{1}.

Having a claim in the product can increase the perceived healthiness, but the increase is modest and a health claim can even have a negative impact on product perception if it based on compounds and benefits that people are not familiar with. Especially perceived naturalness of the products can be affected by health claims and consumer may also infer lower expected taste quality and overall attractiveness from health claims\textsuperscript{3}.

Since the consumer responses to health claims differ from one application to another, it is always important to study the consumer perception of claims in relation to the carrier product and target population. The research on health claims suggest that claims can add value to the product, but the benefit tends to be limited and has to be adjusted against other reasons for product choices.

**Keywords:** health claims, consumers, food choice

**References:**

HEALTH STATEMENTS AND CLAIMS FOR CEREAL GRAIN PRODUCTS IN EUROPE: SUCCESS FACTORS AND PERSPECTIVES

D. P. Richardson

DPR Nutrition Ltd

Nutrition and health (NH) claims are potentially powerful tools in consumer communication as they convey information on food characteristics (e.g. ‘a source of fibre’) and health benefits (e.g. ‘regular consumption of oat beta-glucan contributes to maintenance of normal blood cholesterol concentrations’) that might otherwise remain unknown to the consumer. As such, NH claims may influence consumer preferences and facilitate well informed food choices. The use of NH claims has become widespread, and applied correctly, it has the potential to improve consumers’ nutritional knowledge and healthy eating patterns, as well as to contribute to public health more generally. NH claims also have the potential to misdirect consumers towards inappropriate food choices and to undermine fair competition. Not surprisingly, scientific substantiation and consumer understanding constitute the cornerstones of the European legislation on NH claims.

From a consumer protection point of view, the issue of consumer understanding is an important milestone in nutrition and health communication at the European level. The present paper will review (1) opportunities for communicating the benefits of cereal grain products outside the scope of the EU legislation (e.g. dietary recommendations and goals, scientific reviews and articles in the press); (2) the processes for the scientific substantiation of NH claims, and in particular, the assessment of the totality of the available data and the weighing of the strength and consistency of the evidence; and (3) the type of data and information that may be needed to provide evidence that the average consumer adequately understands a particular NH claim. The paper will include case studies on oat beta-glucan and maintenance of normal blood cholesterol levels, benefits of whole grain cereals and learnings from a claim based on newly developed scientific data (IPR protected) on water-soluble tomato concentrate and maintenance of normal platelet aggregation (contributes to healthy blood flow).

Ultimately, the proof of the pudding is in the eating, and this saying also holds for cereal grain products with health claims authorised under the new regulation, for dietary goals for whole grain consumption and for media activity on any beneficial effects of cereals and cereal constituents. Future research should include evaluations of the true effect of the NH labelling regulation to see if it has increased the share of healthy food choices among consumers, whether it has stimulated healthy food innovations and, through changes in food choices, it has had a significant impact on public health.

References


THE HEALTHGRAIN WHOLE GRAIN DEFINITION

J.W. van der Kamp

TNO Quality of Life, Zeist, The Netherlands

Cereal grain kernels consist of three main parts: endosperm, bran and germ. In Europe and world-wide: most cereal products are based on kernels or flour after removal of bran and germ, the two parts containing most of the dietary fibre and other bio-active components. In the past decade consumers are (re-)discovering whole grain based products, and food producers have substantially increased their efforts in developing and introducing such products. As a result consumption of whole grain products is growing, both in countries such as in Northern and Central Europe with a whole grain tradition, and in countries and regions where whole grain was hardly known.

In a number of countries short definitions of whole grain exist stating, for example: “Whole grain products include the entire germ, endosperm and bran. Grains that have been subjected to processing such as milling are also included.” Recently more comprehensive definitions have been developed in the USA, Canada, UK and Denmark. These definitions include items such as a positive list of the grains included and specifications of allowed processes.

The HEALTHGRAIN consortium felt the need for developing a definition of whole grain with the following scope:

- More comprehensive than current definitions in most EU countries
- One definition for Europe – when possible equal to definitions outside Europe
- Reflecting current industrial practices
- Useful in the context of nutritional guidelines and nutrition claims.

The definition was developed in a set of discussion meetings and e-mail discussions.


Paris, 4 November 2008 Open discussion meeting.
Newcastle, 24 March 2009 Discussion meeting at Whole Grain Global Summit
La Grande Motte, 11 June 2009 4th HEALTHGRAIN Annual Meeting
  1st draft definition, followed by e-mail discussions
Frankfurt, 17 November 2009 Open discussion meeting
  2nd draft definition + e-mail discussions

A committee with Nils-Georg Asp (SNF, Sweden), David Richardson (DPRNutrition, UK), Kaisa Poutanen (VTT and University of Eastern Finland) and Jan Willem van der Kamp (TNO, Netherlands) took care of guiding the discussions and formulating the definition.

The discussed items included:

1) Inclusion of pseudocereals. In accordance with the definitions in the USA and the UK the pseudocereals amaranth, buckwheat and quinoa are included.

2) The option for recombining endosperm, bran and germ of the same grain but from different batches, and for recombining by producers of consumer products. This was agreed since a) In current flour milling ‘milling streams are recombined where endosperm, bran and germ may originate from different batches and b) as shown in HEALTHGRAIN, the composition of cultivars of a grain shows large variations; by using milling streams where batches are mixed more constant flours for further processing will be obtained

3) Removal of the very outer layer of the kernel, in order to reduce the level of contaminants

4) Criteria for further processing (e.g. can a malted whole grain still be mentioned whole grain?) and for labelling (% of whole grain on dry matter basis?).

Broad consensus was obtained for the decisions regarding 1), 2) and 3). The HEALTHGRAIN Forum will continue with discussions on item 4).

The development of the definition, with active involvement of industry, academia and organisations communicating to consumers resulted in widely increased understanding among all participants what whole grain means in industrial practice since a number of decades.

The current definition - defining whole grain as a raw material - will be widely communicated in and outside Europe.

Note: The definition and relevant references are included in this Book of Abstracts.
SHIFT TOWARDS HEALTHY DIETS – IMPACT ON COSTS OF HEALTHCARE AND QUALITY OF LIFE

B. Traill

*University of Reading, United Kingdom*
Final session

Chairpersons: Jan Willem van der Kamp and Roland Poms

Friday 7 May 2010
11.00-12.15
THE HEALTHGRAIN 2010+ FORUM - THE BEST OF THE GRAIN FOR CONSUMER WELL-BEING

K. Poutanen¹, P. Lehtinen¹ and J.W. van der Kamp²

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²TNO Quality of Life, Zeist, The Netherlands

The 5-year HEALTHGRAIN project has, in addition to the scientific research and development of technology, created an active network of stakeholders interested in making healthier cereal foods as part of the everyday life of consumers. This attempt necessitates an active dialogue of scientists, industrialists and government officers. The HEALTHGRAIN 2010+ Forum will continue the activities and work of the HEALTHGRAIN project. It is also evident that even though HEALTHGRAIN has been a large integrated project with a lot of resources, the research volume in this field already in progress at national level only in Europe is even more substantial. HEALTHGRAIN has already served as a network pulling together national research themes and ideas, and the wish is now to continue this joint approach by defining a strategic research agenda to be jointly worked out.

The HEALTHGRAIN Forum will be the future platform to support the work for healthy cereals in (European) diet. The aim is to continue the HEALTHGRAIN networking to disseminate about the many results still arising from the work already done, and further to stimulate research, facilitate international cooperation and organise dissemination of national research activities. The Mission of the Forum is to promote science based concepts fully unlocking the health promoting potential in the entire grain food production chain to obtain healthy, convenient and appealing foods. The vision of the Forum is that grain based foods assist consumers in health maintenance worldwide, help reduce health care costs and provide added value for companies in the production chain.

The new Forum will

- Continue knowledge and technology sharing between academia, industry and public bodies.
- Stimulate and initiate research facilitating the development, processing and marketing of healthy cereal foods, including new research projects, continuing and expanding the scientific themes of HEALTHGRAIN.
- Exploit and expand the expertise created in the HEALTHGRAIN project to increase the awareness, availability and acceptability of healthy cereal foods by actively communicating about cereal grain based products and health and using advanced web-based communication tools
- Be the platform for the creation of a broader grain alliance for better health

The activities of the Forum will be divided to communication and networking activities of the stakeholders, and on defining and implementing the strategic research agenda. The Forum is open for all actors interested in contributing to the mission and vision, thus also thinking that the forum will assist them in their own work. Please contact one of the authors for more information.

Keywords: grain, cereal, food, health, collaboration, international, communication
STRENGTHENING COMMUNICATION WITH A EUROPEAN BASIS TO ALL
STAKEHOLDERS

J.W. van der Kamp

TNO Quality of Life, Zeist, The Netherlands

The HEALTHGRAIN project and the HEALTHGRAIN Forum aim to increase the intake by consumers of cereals, cereal products and beneficial components of cereal grains. To achieve this objective, R&D has to be complemented with effective communication, addressing consumers as well as all other stakeholders: all those involved in cereal grain-related production chains, nutritionists, medical professionals, dieticians, legislators and organisations communicating the benefits of healthy eating to consumers.

Communication of results and conclusions of research in this field form the basis of all further communication efforts. HEALTHGRAIN has already delivered about 100 peer-reviewed papers and will deliver another 50, including a set of reviews. In addition, results have been and will be presented in several hundred presentations, at international scientific conferences and in a wide range of other ways: workshops for members, training courses, national meetings and on www.healthgrain.org with a public area and login facilities both for Forum and for HEALTHGRAIN members (research organisations, Industrial Platform, NIN and CCP).

Communication with Forum members will focus on

- Scientific information and discussions about results of national projects in Europe
- Member issues, e.g. forthcoming meetings for members, reports and powerpoint presentations of meetings,
- Information about availability of well characterised materials for R&D (e.g. aleurone concentrates and ‘HEALTHFLOUR’ - such materials will be made available to members at preferential rates
- Communication of new developments in the areas of health claims (and EFSA opinions), nutrition claims and national nutritional guidelines.
- Further development of the definition of whole grain and related labelling issues.
- Implication of the new EU definition of dietary fibre. The current method (AOAC985.29) used for fibre levels in food composition databases does not measure/partially measures levels of oligosaccharides/resistant starch - compounds included in the EU definition. The Forum can support the introduction of correct and higher fibre levels for bread, pasta and other grain-based products without a huge amount of analytical work.
- Upcoming issues, to be determined by Forum members

When required - as is the case now with the HEALTHGRAIN Whole Grain Definition - results of actions of HEALTHGRAIN and the Forum will be communicated to all relevant stakeholders.

Communication to the ‘general public’ will focus on health benefits of whole grain, high grain fibre and related products and will be addressed to non-specialists: managers, medical professionals, dieticians and consumers of all ages. With the limited possibilities for communicating health benefits via EFSA approved health claims, other ways of communication should be explored.

An important new activity of the Forum will be interactive web-based communication for non-experts, including consumers of all ages, about cereal grain-based products and health. The newly created website www.cerealsandhealth.com will operate in a similar way to www.tomatoandhealth.com the successful website associated with the 6th Framework project LYCOCARD. The site will display information on cereal products and health, and a set of features making the site attractive such as games for children, a video section and healthy recipes.

The website will provide information in English - with additional funding other languages may also be used. The site will aim at a realistic presentation of cereal products and processes, and will not suggest that ‘old-time technologies’ are still the state-of-the-art.

With sufficient financial support, also other activities may be considered, e.g. the Danish model for increasing availability and consumption of whole grain products can be applied in a range of countries.
“HEALTHGRAIN OPEN INNOVATION” AND “HEALTHGRAIN KERNEL FRACTIONS”
AVAILABILITY FOR HEALTHIER CEREAL FOODS

R. Ranieri and G. Tribuzio

Barilla G. e R. Fratelli, Società per Azioni, Parma – Italy.

Which kind of products could Healthgrain2010+Forum (HG2010) sell after this end meeting? This is the question on which we started working on, since HG2010 will need to compete on the market with other organizations, institutions and private companies. Selling knowledge, know how, precious information and developing tailor-made projects with member countries will probably be the majority of the future activities.

What else could we sell? We started making a list of the Healthgrain project (HG) outcomes and we focused on three groups: more than 100 international scientific papers (within one year this number will double); many bran fractions or their derivatives are very well characterized in terms of chemical and physical characteristics as well in contaminants presence; powerful HG websites, but clearly underutilized. What can we do more?

What is Open Innovation? It is a powerful tool for technology transfer. There are already many networks supplying this kind of services, that allows to address questions (scientific, technical...), sometimes very difficult questions, to an audience consisting not only of experts in the specific fields, but also of people that may find solutions thanks to their different scientific, technical or even cultural perspective, thus generating incremental or breakthrough innovation. Companies and food companies too, are using more and more this tool (or process) which works sometimes quiet well especially when questions are clear. By the use of internet services, this approach is dramatically empowered in its “real time”, world-wide, multidisciplinary features. For the selected answer there is often a reward and/or the possibility for the researcher to develop a further project with the company. Who proposes the question generally has to pay a fee to the network. There is an open innovation network proposed by the European Commission (Enterprise Europe Network) which has the mission to help small companies, to match questions with answers for free.

We propose to carefully consider to set up an analogous system within the HG2010 that simply gives the opportunity to the companies to address scientific and technical questions to the research institutions. The reward could be just a lump sum of money or a more relevant research project. Our web site could be the nest for this kind of activity. In this case the research institutions could be easily engaged in innovation and technology transfer and companies will get more advantage of this scientific community. There are risks too: questions may not enough frequent to keep alive the HG open innovation service; answers may not arrive on time or may not arrive at all. But we have the questions (branded companies have always scientific and technical questions), the competencies (200 papers are the evidences) and the tool (web site) to try to set up a “HG Open Innovation” system.

Many studies in the HG scope were successfully done with a limited set of well characterised raw materials such as flours, aleurone enriched flours and flour fractions. The supplying of such materials could be organized for HG2010 members and/or for everybody wants to try. More precisely Healthyflour, Whole grain flours coming from each species, Each bran fraction used for Healthyflour, Durum and common wheat germ, Durum bran fraction enriched with aleuron layer, Leuron (if the company agrees), AXOS (if the company agrees), Other fractions/flour could be provided according with new researches needs could be standardized and sent to the clients in small amounts (few kilos) or for pilot trials (few hundred kilos). All the samples could be quoted including shipping. The “fraction producer” will work on behalf of HG2010 and will receive the compensation for its work. Again, the base for orders will be the HG web site. Each kind of sample will have a standard composition and the ‘provider’ will be able to produce it every time it will be asked. Samples of derived ingredients from the HG research, but further developed by companies could be included in HG2010 sample offer. There are risks in setting up this activity: nobody, with few exceptions, is interested in using all these set of samples sampling and shipping are too expensive to afford for companies.

If we believe that in the future more and more whole grain products will be present in our diet, allowing and facilitating companies to run trials with this fractions and or new ingredients, it will be a very concrete way for HG2010 to contribute.
REALISING DIETARY SHIFTS – CAN THE DANISH EXPERIENCE BE TRANSFERRED TO EUROPE

M. Strunge Meyer

Danish Whole Grains Campaign, Danish Cancer Society and European Cancer Leagues (ECL)

A Public-Private Partnership was founded in January of 2009 after 2 years of preparation. The aim of the partnership is to increase public health by getting Danes to eat more whole grains. The partners include government, health NGOs for heart, diabetes and cancer. Also major players from relevant industry sectors including millers, industrial bakeries, retail bakeries, retailers, multinational food companies, fast food restaurants and growers are actively participating in the Danish Whole Grains Campaign.

The benefits associated with mobilizing such a broad and strong alliance will be exemplified, and some of the strategies for building and maintaining a strong partnership and consensus will be discussed.

The Danish campaign is successful in creating an important dietary shift because the campaign is not limited to being a campaign based on communication only. Especially three strategies will be highlighted during the presentation in Lund:

- New products are being developed and marketed
  A new logo was developed in order to allow consumers to quickly identify the products that are healthy and contain a substantial amount of whole grain. The logo has more importantly motivated millers, bakeries and retailers to develop and market a substantial number of new products containing much more whole grain than before. This is an example of how the interests of the industry, public health are able to complement each other and create new synergies and results.

- Adding whole grains to existing products
  The Danish Whole Grains Campaign hope to be able to make a substantial contribution to the average intake of whole grain by adding a small fraction of finely grinded whole grains to existing white products without jeopardizing quality and appearance. By doing so we might even be able to increase the taste quality of many products.

- Creating new social norms
  Some vocational schools in Denmark are challenged by low student attending rates. A pilot study has shown that a whole grain breakfast for students and teachers can contribute effectively to the reduction or elimination of problems with students not showing up or dropping out. This is one example of how a broad partnership can induce other and perhaps more effective changes than traditional marketing and communication campaigns.

Some of the Danish experiences from mobilizing and maintain a strong partnership including industry, health NGOs and authorities should be evaluated and applied when creating a powerful European HEALTHGRAIN Forum. This is of particular interests to the European industry partners.

Given that the upcoming and new HEALTHGRAIN Forum should play a role in increasing European consumption of healthy grains to the benefit of the involved industries and public health, the following needs careful consideration:

1) Is there a need for a common European Whole Grain Stamp?
2) How can industry be rewarded for developing new products a higher content of whole grains?
3) How can industry be motivated to add some whole grains to popular existing white products?
4) How can the new Forum coordinate pan European initiatives for changing social norms?
5) How can the new Forum play an active role in changing relevant European regulations and policies?
It has been said that becoming obese is a normal response to the current environment. Left unchecked, obesity may become apparent in the vast majority of the population by 2040, the most dangerous issue being chronic obesity and rising levels of diabetes in children. The genesis of many chronic diseases, most notably cardiovascular disease and many cancers is thought to be predominantly diet related. Cereals and cereal products form a broad foundation of the western diet. Showing industry and the public how to process or consume foods made from grains in a way that promotes a healthy balanced diet has become an urgent and fundamental need.

In order to ‘reach and teach’ both industry and consumers, new channels must be opened and developed that harness the communications revolution created by the advent of the Internet. Many conditions apply to creating a successful, acceptable, accessible, trustworthy set of resources that both industry and the public can turn to, be drawn to, be directed to – in order to discover how to include cereal and grain based foods in their diet in a way that improves their quality of living.

What will these new channels look like?
This was the challenge we faced as the central dissemination partner within the LYOCARD project - to evolve new ways to firstly, provide easily accessible resources and secondly, to drive those resources to multiple target groups from a common source.
We created a multi-channel web platform called Tomato & Health along the lines of a health magazine mixed with a video cooking show and the news, with games for kids, a teaching package for the classroom and all of it free access, free download and all of it free of advertising or product placement. The website has worked well and is now being cloned into stand-alone websites in 7 countries.
We designed the individual online resources to act like ‘honey pots’ attracting interest from busy people, who are generally already distracted by everything else in the World that competes for their attentions. The resources attract niche interest groups and hopefully gain recognition for their quality and are in turn recommended person to person as being of value.
This is now the most viable way to reach people in a meaningful way. You don’t reach them – they reach out for you – if they feel like it.
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HEALTH GRAIN
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Poster Section 1
Cereal crops, breeding and biotechnology

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Tritordeum - A Novel Cereal Species With Potential For Use in Functional Food Applications 83
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Reserve starch constitutes about 70-80% of the dried wheat kernel and is formed by two distinct glucan polymers, amylose and amyllopectin. They are synthesized from a common substrate (ADP-glucose), but with two different pathways. A granule bound starch synthase (better known as waxy protein) catalyzes the amylose biosynthesis whereas the amyllopectin is produced by the concerted action of different starch synthases (SSs), branching (SBEs) and debranching enzymes (DBEs) (Stone and Morell, 2009). The modulation of amylose/amyllopectin ratio greatly affects wheat flour nutritional and processing properties. Recently low and high amylose wheats have been produced through the identification of natural lines lacking waxy and Sgp-1 proteins, respectively (Miura et al., 1994; Yamamori et al., 2000). Currently many efforts are focusing on the objective of varying the amylose/amyllopectin ratio as both high and low amylose starches can result in many food and non food applications. The combination of chemical mutagenesis with molecular tools has resulted in a high throughput novel non GM approach (Targeting Induced Local Lesions IN Genomes) for generation and detection of novel genetic variation overcoming limits associated with transgenic issues.

In this work an EMS mutagenised population of the bread wheat cultivar Cadenza has been analyzed for the identification of new alleles in the three homoeoalleles of waxy, SSIIa (Starch Granule Protein 1, Sgp-1) and SBEIIa genes. Extensive electrophoretic analyses (SDS-PAGE) have led to the identification of partial waxy and Sgp-1 mutant lines, characterised by the lack of one waxy or Sgp-1 protein. Furthermore a TILLING strategy has allowed the identification of novel variants for Sgp-1 and SBEIIa genes, including mutations responsible for the loss of gene function. Crossing of these materials is currently being carried out in order to obtain the complete null genotypes in the three target genes. This will result in the production of materials with a wide variation in amylose content in the same genetic background and in an elite bread wheat cultivar.

**Keywords:** mutagenesis, TILLING, starch, low-high amylose

**References:**


WHEAT BREEDING FOR HIGH AMYLOSE CONTENT

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The relative amounts of amylose and amyllopectin in starch are known to influence both nutritional and technological properties such as susceptibility to enzymatic hydrolysis, gelling and pasting behavior, which could be of biotechnological importance. High amylose starches are widely used as thickeners and strong gelling agents but they also have a positive effect on dietary fibre content of the flour by increasing the level of starch resistant to human enzymatic digestion after consumption.

In order to produce wheat genotypes with high amylose content and good agronomical properties, a triple mutant line (Sgp-A1, Sgp-B1, Sgp-D1) has been created in an advanced breeding line of wheat called N11 (Uni-Tus). This line was multiplied and crossed with five current commercial mainly EU varieties of breadwheat (Solstice, Lona, Koreli, Ukrainka, Yumai-34) to introgress the three mutations. The BC2 generation was produced this year after backcrosses. The amylose contents of the possible triple mutant lines was determined in BC1 generation and lines with high amylose content were identified (approximately 40%).

Twelve seeds from each of the triple heterogeneous BC1 plants (13 crosses, 3-8 plant/cross in BC1) were sown and marker assisted selection (MAS) was carried out in BC1F2 generation in order to select mutant or heterogeneous plants for the three alleles to be used for backcrossing. From the 388 studied lines, three were found to be complete Sgp-1nulls and 128 were either partial nulls or parental type. Backcrossing of these lines resulted in 1098 seeds which will be used for further backcrossing and multiplication. Double mutants were also identified in BC1F2, the ratio of these were found to be 36.85%.

A preliminary study of amylose content was carried out in BC1 population with the Megazyme enzymatic kit. According to the results the amylose content of the triple heterogeneous breeding lines changed from 26 to 42%, with five genotypes showing similar amylose content to the mutant control line (41%).

The phenotypic properties of the breeding lines were mainly similar to the commercial wheat varieties in BC1F2, only a few (22) lines were rather similar to the mutant lines.
DECREASED (1,3;1,4)-β-D-GLUCAN IN ENDOSPERM OF WHEAT
BY RNAI INHIBITION OF THE CSLF6 GENE

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The cell walls of cereal endosperms are major components of the dietary fibre consumed by humans. In the starchy endosperm of wheat (Triticum aestivum L.) (1,3;1,4)-β-D-glucan (β-glucan) accounts for 20% of the total cell walls. In order to manipulate the fibre composition of wheat flour, the CSLF6 gene was identified as putatively encoding an enzyme involved in β-glucan biosynthesis and used as target for RNAi suppression to determine the effects on endosperm cell wall composition (1).

Vectors for RNAi were constructed and transformed into the spring wheat variety Cadenza using particle bombardment, delivered under the control of the starchy endosperm-specific HMW subunit 1Dx5 promoter from wheat. Stable transgenic lines were obtained and measurements of β-glucan content of T3 grain of homozygous transgenic RNAi lines, by enzyme fingerprinting and total β-glucan assay, showed that down-regulation of the CSLF6 candidate gene is sufficient to reduce the amount of β-glucan in the starchy endosperm of wheat to less than half of that in control lines (2). Enzyme fingerprinting results on developing caryopses were consistent with the expression pattern of the HMW subunit promoter, with no differences being observed at 10 dpa but with significant decreases in β-glucan content in the transgenic line at 14 dpa and 21 dpa. Immunolabelling showed a clear reduction of β-glucan throughout the starchy endosperm of mature and developing transgenic caryopses.

The results confirm that the CSLF6 gene of wheat encodes a β-glucan synthase and hence a key target for manipulation in order to increase or decrease total β-glucan.

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MANIPULATION OF ARABINOXYLAN COMPOSITION IN T. AESTIVUM VAR. CADENZA

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The cell walls of wheat grain affect the behaviour during milling and food processing and are an important source of dietary fibre for human health. Arabinoxylan (AX) polysaccharides are the major cell wall components of wheat endosperm, comprising 70% of total cell wall polysaccharides. Other components include (1→3) (1→4) β-glucans (20%), glucomannans (2-7%), cellulose (2-4%). The AX fraction from cereals also contains ferulic acid, linked at the 0-5 of some arabinose units, and this can result in cross-linking between adjacent AX polymers. An increased consumption of dietary fibre could help reduce (1) Type 2 diabetes, (2) Serum cholesterol, (3) Bowel cancer, (4) Coronary heart disease (5) Obesity by increasing post-meal fullness and decreasing hunger. We are therefore studying the biosynthesis of AX in the developing wheat grain in order to manipulate the amount and composition in order to optimise benefits for human health.

We have used a combination of bioinformatics and expression profiling to identify several candidate genes for enzymes that play key roles in AX biosynthesis (xylan synthase and arabinosyl transferase). These genes (from the GT43, GT47 and GT61 families) have been cloned and sequenced and have been used in over-expression and RNAi constructs for functional characterisation in transgenic wheat. Transgenic lines for both over-expression and RNAi have now been produced and flour from T1 seeds has been analysed using enzymatic fingerprinting using HPAEC. Results from lines transformed with RNAi constructs for the GT43 and GT47 candidate genes show severe reductions in AX content, indicating that these genes may encode enzymes involved in the synthesis of the xylan backbone. Analyses of lines transformed with RNAi constructs for a GT61 candidate gene, have decreased arabinose substitution at the O3 position on the xylan backbone, indicating that they may encode forms of arabinosyl transferase.
SOME POSSIBILITIES OFFERED BY ACHIEVEMENTS IN PROTEOMICS ANALYSIS OF WHEAT GRAIN PERFORMED IN THE FRAMEWORK OF THE HEALTHGRAIN PROGRAMME

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Proteome analysis of cv. Chinese Spring was performed on aleurone layer (AL) and endosperm. The protocol of 2-dimensional electrophoresis (2-DE) of the albumins-globulins present in the aleurone layer is described in Laubin et al., 2008. The protocol used for the endosperm proteins is based on the protocol described by Merlino et al., 2009 with some modifications. The following major achievements were made possible thanks to the support of the HealthGrain programme:

1. The albumin–globulin proteome (corresponding to enzymes and structural cell proteins) of the mature endosperm of Chinese Spring was studied and proteins in 415 spots corresponding to albumins-globulins were identified.
2. Chromosome assignment of albumins-globulins was undertaken by analysing these proteins in mature endosperm of 71 DLs of Chinese Spring. The Chinese Spring line was used for the reference gel, giving a total of 1107 Coomassie stained spots. Among the 1107 spots analyzed, 239 were assigned to one or more chromosome bin.
3. The proteins present in the isolated aleurone layer of mature grain were extracted and then revealed by 2-DE as from 650 to 750 Coomassie-stained AL proteins detected on the gel. These spots were subjected to mass spectrometry and a first set of 343 proteins were identified at the Danish Technical University.
4. Chromosome assignment of these proteins in AL was performed. The 300 2-DE images were analysed, allowing spots that were absent in the different DLs to be assigned to chromosome bins. This work revealed that some new proteins were expressed while others were up-regulated or down-regulated in response to the bin deletion.

These results should enable further progress:

1. Identification of the proteins present in the isolated tissue (endosperm and AL) should enable the establishment a proteome database for the comparison of varieties. A brief comparison already showed that 10% and 30% of the endosperm proteins and AL proteins respectively differed between cultivars.
2. The proteins identified in this study provide a valuable basis for understanding the composition and properties of varieties with specific uses. The present proteome database, made using the international standard hexaploid cultivar Chinese Spring, will greatly help future studies on associations between proteome and grain composition.
3. The AL is a living layer of the caryopses where the majority of minerals and vitamins are located. The experiences acquired in proteomics analysis as well as in the genetic assignment of genes encoding several hundred proteins are real advances that pave the way for future important developments such as deciphering the genetic factors involved in pathways of nutritional and health compounds occurring in the AL.
4. Significant effects of genetic and environmental factors were revealed in numerous nutritional compounds in the HG biodiversity screening programme. The present study provides tools to understand the genetic responses to both abiotic and biotic stresses. (such as heat stress and fungi attacks) that influence the nutritional and health value of the wheat grain.

Key words: proteome, aleurone layer, endosperm

References:


COMBINED META-GENOMICS ANALYSES UNRAVEL CANDIDATE GENES FOR THE GRAIN DIETARY FIBER CONTENT IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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The flour viscosity associated with grain dietary fibre content has important digestive and metabolic effects on monogastric animals. Viscous soluble fibre from oat and barley products are known to lower plasma cholesterol level and postprandial glucose and similar health benefits are expected from bread wheat grain dietary fibres.

Based either on a diversity panel (association genetic approach) or on bi-parental populations (meta-QTL approach), we clearly identified the chromosomal regions driving the grain fibre content in bread wheat. Moreover, integration of association genetics (seven detected loci on chromosomes 1B, 3A, 3D, 5B, 6B, 7A, 7B) and meta-QTL (three consensus QTL on chromosomes 1B, 3D and 6B) data allowed the identification of seven chromosomal regions underlying grain dietary fibre content in bread wheat. In parallel, we identified 73 genes differentially expressed during the grain development and between genotypes with contrasting grain fibre contents. Microarray hybridization experiments were performed to identify genes that are differentially expressed between 200 and 400 degree days (physiological phase of cell wall synthesis in wheat endosperm) as well as between five high fibre and five low fibre tails of a recombinant population. We observed 5383 and 6596 genes differentially expressed between 200 and 400 degree days and for the five low fibre and five high fiber lines, respectively but more interestingly a subset of 73 genes that are associated with distinct expression pattern between the five low fibre vs five high fibre lines.

Finally, integration of quantitative genetics and transcriptomic data allowed us to propose a short list of four candidate genes (membrane protein OMP85 family coding gene, a tubby-related protein coding gene, a gamma-glutamyl hydrolase precursor and an alpha-trehalose-phosphate synthase) that are conserved in the rice, sorghum and Brachypodium chromosome regions orthologous to the seven wheat grain fibre content QTL and that can be considered as major candidate genes for the future improvement of grain dietary fiber content in bread wheat selection programs.

Molecular markers linked to the MetaQTL regions can already be used in breeding programmes to help pyramiding high fibre alleles into elite germplasm. Moreover, these results provide the opportunity to accelerate the map-based cloning of genes controlling dietary fibre content for further functional validation or at least as a source of accurate (perfect) molecular markers for bread wheat selection programs.
GENETICS OF FOLATE CONTENT IN BREAD WHEAT

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The consumption of cereal whole grain or whole grain products is believed to have a protective role as it reduces the incidence of chronic diseases related to the metabolic syndrome and cardiovascular disease. These health benefits have been attributed in part to the unique phytochemical content of cereal grains, such as phenolic compounds, phytosterols, tocols and folates (vitamins B9).

Folates are tripartite molecules constituted by a pterin moiety, a p-aminobenzoate unit (pABA), and a glutamate chain. In plants, their synthesis has been reviewed by Rébeillé et al (2006). The maintenance of cellular activities in all organisms requires the continual availability of folates. An incomplete biosynthesis pathway in animals has resulted in a dependence on dietary folate sources.

Cereal products, in particular wheat due to its importance in human diet, are regarded as an important source of folates. Folate level presents variability in wheat (Piironen et al, 2008). Breeder may hope to exploit this natural diversity to improve folate content. In accordance with HealthGrain (HG) objectives, we performed a genetic analysis to develop tools for breeding varieties with enhanced folate contents and we develop markers in key genes for folate synthesis.

This study relied on HG collection for bread wheat: 156 accessions, grown at Martonvasar (Hungary) in 2004-2005, harvested, milled and analyzed for a range of phytochemicals including folates (Ward et al 2007). For all these accessions, DArT markers fingerprinting was performed at the Diversity Arrays Technology Pty Limited (Canberra, Australia, http://triticarte.com.au). This provided a set of 494 polymorphic markers, which were successfully positioned on a consensus genetic map. We also examined genes coding for GCH1, HPPK, DHPA and DHFS to discover sequence polymorphisms.

Identification of chromosomes regions that control folate variation was performed by genome-wide association analysis using this approach. This was completed by a candidate gene approach based on polymorphisms discovered. Significant associations were found with two DArTs, wPt-4300 and wPt–5652, mapped at 108.4 cM on 7BL and 26.5cM on 6AS, respectively. We detected four other markers located in the region including wPt-5652 that showed a P-value slightly over 0.001. Thus these two regions may contain QTLs for folate level. None of the 32 sequence polymorphisms discovered in the eight genes under study and typed in HG collection was associated with folate content.

In folate biosynthesis, the pterin and pABA biosynthesis converge. As shown by transgenesis, both branches have to be enhanced simultaneously to increase the level of folate. This may explain the lack of association between polymorphisms in a given gene coding for a key enzyme and folate content. Additionally, we showed recently a low heritability for folate contents in wheat. Thus improving folate content by exploiting its natural variation by classical breeding method may be difficult. However the two associated DArT markers, once converted into PCR markers, could be used to facilitate and accelerate transfer of chromosome regions enhancing folates in elite wheat varieties through breeding.

References


NEW POSSIBILITIES FOR MEASURING OF BIOACTIVE COMPONENTS IN GRAINS AND PRODUCTS WITH NIR

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The bioactive compounds of cereals and their milling fractions have different nutritional benefits covering a broad spectrum of physiological, immunoprotective, immunostimulatory or disease preventive effects. The various morphological layers of cereal seeds or fortified fractions prepared by mixing could have dedicated compositions from bioactive components point of view. The different commodities, plant tissues and fractions are showing a broad spectrum of lyophilic (tocols, phenolic compounds, alkylresorcinols, sterols, lignans) and hydrophyllic (folic acid, tannins, lignins, arabinoxylans, glucans, other non-starch polysaccharides) bioactive components varying in a concentration range between some mg/kg and 25 % (w/w). The quantitative measurements of bioactive compounds mentioned above need complicated wet chemical methods including laborious (extraction, saponification, purification, derivatization separation, detection etc.) steps which are time consuming and expensive.

In HEALTHGRAIN 150 wheat varieties and 50 other varieties of rye, barley and oats, grown on one location and analysed for a range of dietary fibres and phytochemicals followed by growing and analysing 31 varieties at 4 locations. This included both wet chemical analysis and non-destructive NIR analysis. The investigated big sample sets covered commodities (winter wheat, spring wheat, rye, oat, barley), crop year (three years), GxE (4 growing locations, 31 varieties) and instrument variations in order to maximise the robustness of calibration models.

Effects of commodity, variety, crop year, and instruments were sensitively detected both in NIR and NIT spectra. Milling fractions show significant differences in both the 1700-1800 and 2260-2400 nm regions indicating the possible presence of hydrophobic and hydrophilic minor components, especially in bran fractions.

Results confirmed that the morphological distribution of some bioactive components may be assessed from near infrared spectra directly and the spectra are a useful source of information for modification of milling and separation technologies.

Combined calibration models (including all commodities) for total arabinoxylans (TOTAX), water extractable arabinoxylans (WEAX), alkylresorcinols and sterols resulted fast and reliable routine screening methods, providing either quantitative or semi-quantitative results.

The dedicated models (including wheat samples only) have poorer R-square values (compared to general combined models) due to reduced total variance of spectroscopic data file and narrower ranges of reference values. The standard error of cross-validation (SECV) values were smaller (the accuracy increased) compared to general models because the avoiding of commodity effects. The optimal number of latent variables was also slightly decreased.

Fully independent validation of calibrations for 5 sets of samples was used to confirm the reliability of equations.

The quality of calibration models were checked also with using repeatability files for all parameters.

The validated models are transferable between different instruments but the conditions of transfer and the quality of transferred models need further evaluation.
LOCALIZATION OF FOLATE AND PLANT STEROLS IN GRAIN FRACTIONS OF WHEAT

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The HEALTHGRAIN Integrated Project aims to improve well-being of consumers by increasing the intake of protective compounds in whole grains or their fractions. The aim is to produce health promoting and safe cereal foods and ingredients of high quality which are attractive to consumers (www.healthgrain.org).

In this presentation, an overview of the localization of folate, plant sterols, and steryl ferulates in various dry process fractions of whole wheat grains and bran is made.

Samples from Tiger variety were obtained from other partners of the project (1). Total folate was determined with a microbiological assay, plant sterols by gas chromatography and steryl ferulates by high performance liquid chromatography (2-4).

White flour contained only 147 ng/g fw total folate and 269 µg/g fw plant sterols, while the respective contents in whole grains were 414 ng/g and 563 µg/g. During a peeling and pearling process, where 3.5% and 3% of the outer layers were removed, the highest total folate, plant sterol and steryl ferulate contents were 1350 ng/g (brans after peeling and pearling), 1860 µg/g (pearling fraction), and 539 µg/g (bran after peeling), respectively. Very high levels of folate and plant sterols were also found in aleurone fractions (up to 1820 ng/g and 1850 µg/g). Further characterization of the peeling base representing the pericarp, pearling base representing the intermediate layer and aleurone fractions by electrostatic separation further supported the uneven distribution of the bioactive compounds and showed a possible means to concentrate them.

Folate, plant sterol and steryl ferulate compounds were concentrated in the peripheral layers of the wheat grain. Total folate was the highest in the aleurone layers. Total sterols were the highest in both the intermediate and aleurone layers, while the steryl ferulates were especially rich in the intermediate layers. Thus the bioactive compounds studied showed differences in the localization in the wheat grains.

Keywords: folate, plant sterols, steryl ferulates, milling, pearling, peeling

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VARIATION OF PLANT STEROLS AND TOCOLS IN WHEAT AND RYE GRAINS

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The aim of this presentation is to give an overview of plant sterol and tocopherol and tocotrienol (i.e. tocols) composition of wheat and rye grains. The focus is on the natural variation that occurs among genotypes grown in one location and of selected genotypes grown under various environments.

Plant sterols and tocols were included in a diversity screen study (www.healthgrain.org) where 150 bread wheat genotypes and 50 other cereals including 10 rye genotypes were analyzed for bioactive compounds (1-4). There were differences in plant sterol composition among species, and the highest contents were found in rye (1098-1420 µg/g dm) whereas the contents in wheat lines ranged from 670 to 959 µg/g dm. The most abundant plant sterol was sitosterol followed by campesterol and stanols. The range of total tocols in bread wheat grains was very large ranging from 27.6 to 79.7 µg/g dm. Tocol contents in rye grains were comparable to those in wheat being 43.6-67.2 µg/g dm. In both of the species, the major tocols were α- and β-tocopherols and –trienols. There was a statistically significant positive correlation between total sterols and tocols in bread wheat genotypes indicating a positive relationship between these two lipid-soluble compounds. Moreover, total sterol and tocol concentrations were smaller in large wheat grains than in small grains. Such trends could not be found in the rye grains.

A further study on the effects of environmental factors was conducted in three years on one location (Hungary) and also on three other locations (UK, France and Poland) in one of the years using 26 bread wheat genotypes and 5 rye genotypes. The wheat lines included lines with both high and low contents of these bioactive compounds, while the rye lines were more stable. Total sterol contents in wheat lines varied among the four locations, but not among the growing years, while both environmental factors had a significant effect on total tocols. Growing location and year also had an effect on total sterol and tocol contents of rye grains.

In conclusion, these experiments generated valuable knowledge on the levels and variability of bioactive compounds in wheat and rye grains, which enables selection of potential candidates for the breeding of cultivars.

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FLAVONOID CONTENT IN BARLEY, OAT, RYE AND WHEAT CULTIVARS

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Cereals, such as barley, oats, rye and wheat, contain a selection of very interesting minor components, which are assumed to have a vital role in the plant’s defence system against biotic and abiotic stress. Many of these compounds have been found to have antioxidative or anticarcinogenic activities or have some other specific physiological activity. As cereals are used for food, the same compounds can act as health promoting components in the diet.

Previously we have reported the contents of some selected phytochemicals, namely alk(en)ylresorcinols in barley, rye and wheat, benzoxazinoids (DIBOA and DIMBOA and their conjugates) in rye and wheat, catechins and hordatines in barley, avenanthramides and avenalumins in oats (Pihlava et al. 2009). In a later study we learned that in addition to these compounds, especially rye contains a large variation of flavonoid conjugates (up to 16). Also wheat, oats and barley contained a variation of flavonoid conjugates even though their numbers were much lower (usually less than 5, excluding the number of catechins in barley).

Our study showed that the average amount of flavonoids in four studied rye cultivars was 22 mg/kg d.w. on average, quantitated as quercetin. In the three wheat cultivars and in the four oat cultivars the average amount of flavonoids was 19 and 10 mg/kg d.w. respectively. In the three barley cultivars the average total amount of catechins (flavan-3-ols) was 333 mg/kg d.w. and the other flavonoids 5 mg/kg d.w.

From the nutritional point of view, the amount of flavonoids in cereals is quite low. However, it can be expected that these compounds have their contribution in the antioxidant potential of the cereals and through that can have an impact on health promoting properties of cereals.

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EFFECT OF ENVIRONMENT AND GENOTYPE ON THE CONTENT OF DIETARY FIBER AND ITS COMPONENTS IN WHEAT IN THE HEALTHGRAIN DIVERSITY SCREEN

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Within the HEALTHGRAIN diversity screening program, the variability of the contents of dietary fiber (DF) and components thereof, i.e. non-starch polysaccharides (NSP), arabinoxylan (AX), lignin and β-glucan, was studied in wheat. Furthermore, the contribution of genotype, environment and their interaction to this variability was estimated. To this end, an elaborate field experiment [26 varieties, 3 growing seasons (1 location) and 4 locations (1 year)] was conducted. The total DF (TDF), total NSP (TOTNSP) and total AX (TOTAX) levels in whole meal varied approx. 1.5-fold. The water extractable NSP (WENSP), lignin and β-glucan levels in whole meal varied approx. 2.0-fold. Compared to whole meal, the variability of TOTAX level in wheat flour and bran was somewhat higher, i.e. approx 2.0-fold. The highest variability was observed for water extractable AX (WEAX) level in flour and bran, i.e. 3.4- to 4.0-fold, which is probably due to the cold wet weather in the United Kingdom in 2007 favoring pre-harvest sprouting and microbial growth leading towards increased xylanolytic activities in wheat grain. Genotype and environment contributed to a similar extent to the total variability in TDF, TOTNSP and TOTAX content in wheat. The observed relatively high impact of genotype – environment interaction suggests that the levels of these constituents are weak breeders parameters. WENSP level is a more stable breeding parameter as the effect of the interaction term was much less than the impact of genotype. For TOTAX and WEAX in flour, WEAX in bran, β-glucan in whole meal and extract viscosity, wheat genotype determined about 50 % or higher of the variation observed, while the impact of the interaction between genotype and environment was relatively low. These findings suggest that the health-related and technological functionality of wheat can be directed to a certain extent by selection of appropriate wheat varieties.
SIMPLIFIED METHODS FOR DETERMINATION OF DIETARY FIBRE AND ITS COMPONENTS IN CEREALS

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Dietary fibre is one of the most important components in cereals of the health-promoting properties. Definition of dietary fiber (DF) has been evolved from the time since it was developed. Recently, in the EU countries definition of DF has been established on the basis of the properties it exhibits and the positive effects on health status with its increasing consumption (2008/100/EG). This fact is very important since new rules on health and nutrition claims made on food products entered into force within the EU countries, also with reference to content of DF. A claim that a food is a source of DF may be made when the product contains at least 3 g of fibre per 100 g, or is high in fibre when contains at least 6 g of fibre per 100 g (1). Precision of fibre determination is therefore crucial in this respect. There are few methods for analyzing DF content, with both direct and indirect approaches. The first approach is used for consumer purposes and allows characterizing individual fractions of DF. The second approach as more simple is proposed for screening purposes to select varieties with high amount of this component. For rapid indication of varieties with high amount of soluble polymers of DF, the use of rapid viscosity test is recommended (2). The aim of the study was validation of an indirect approach for determination of dietary fiber in cereals, based on calculation from the difference between the contents of dry matter and major grain components, such as: protein, ash, lipids, digestible starch and free sugars by comparison the results with a standard direct procedure.

Material for the study comprised of wholemeal cereal samples represented by 24 winter, 2 spring wheat varieties and 5 rye varieties produced in 2007 harvest year at four distinct locations: Hungary, United Kingdom, France and Poland. The varieties were selected from the wide range of cereal genotypes evaluated within the HEALTHGRAIN diversity screen (2, 3). Directly, total dietary fibre (TDF) was determined with the standard Uppsala method (AACC 32-25), as a sum of nonstarch polysaccharides, uronic acids and Klason lignin. Under the indirect approach DF in cereals was established on the basis of the chemical definition. In this approach EDF was calculated as the residue between the sum of the basic grain components, analyzed with approved standard procedures (AACC 2003) and dry matter content. The viscosity of aqueous extracts of wholemeal samples (WEV) was measured on Brookfield Cone/Plate Digital Viscometer as described earlier (2). All analyses were carried out in duplicate and the results expressed on dry matter basis. Analysis of variance (ANOVA) and Tukey – Kramer multiple range test were applied using SAS® System.

The results obtained by the direct standard Uppsala procedure of TDF were on average nearly 28 % lower than that of EDF by an indirect approach either for wheat or rye samples. Nevertheless, in wheat and rye samples the fibre content measured with EDF was highly correlated (r= 0.95) with the data based on direct (TDF) Uppsala procedure. The same correlation for wheat samples only was r=0.71. As such, it might be concluded, that the indirect approach may be useful for rapid selection of grain with higher amounts of dietary fibre when protein, ash and starch content are determined as indicators of the processing quality of wheat and rye. The content of water soluble arabinoxylans (WS-AX) was in the range between 0.57 and 1.12% in wheat samples, and 2.5 – 2.7% in rye. The WS-AX made up 15 and 25% of TDF content and 53% and 65% of soluble fractions of TDF in wheat and rye varieties, respectively. The significant correlation (0.95) between WS-AX and WEV in wheat samples confirmed the suitability of the simple viscosity test for selecting wheat samples reach in soluble arabinoxylans, thus with greater functional properties.

Keywords: dietary fibre, water-extractable arabinoxylans, viscosity, Healthgrain
References:


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BIOACTIVE MOLECULES IN CEREALS AND THEIR ANTIOXIDANT CAPACITY

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Recent epidemiological studies have shown that the consumption of whole grains and wholemeal cereal products appears to reduce the risk of developing diseases such as cardiovascular diseases, cancer, diabetes, etc. However, the scientific base of the above mentioned positive effect is currently under investigation.

In this work, we tried to investigate and describe a profile of the most important bioactive substances in cereals such as phenolic acids, carotenoids and lignans and to evaluate the total antioxidant capacity of whole grains usually cultivated and consumed in Italy by means of two different assays, TEAC (Trolox Equivalent Antioxidant Capacity) and FRAP (Ferric Reducing-Antioxidant Power).

As regards the bioactive substances, grain samples of soft and durum wheat, barley, oat, emmer, spelt, triticale, rye, rice and maize were analyzed by HPLC methods. For each species, two or more representative cvs were analyzed to have an idea about the in species variation. The results showed a large variation in the kind and amount of bioactive substances present, both at the specific and at the varietal level. For example, taking the lignans measured in our study, oat and barley as a species could be considered a good source of these compounds but in rice the cv Vialone Nano gave values which were comparable with those of oat.

In this regard and in attempt to correlate the results of the FRAP and TEAC tests with the contents of the measured molecules, we could say that barley as a species also gave high FRAP and TEAC values within the examined group of cereals.

Our data on phytochemicals in grains could provide a scientific basis for cereals breeding but also for the development of functional whole grain cereal foods.

Key words: cereal grains, carotenoids, lignans, phenolic acids, antioxidant capacity.

References:


FOLATE IN OAT AND BARLEY FRACTIONS

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Folates are a group of water soluble B vitamins being essential nutrients for human beings. They play an important role in a wide range of biochemical pathways, for instance in amino acid biosynthesis, cell replication and growth. Adequate intake of folate is associated with prevention of megaloblastic anaemia and neural tube defects, protection against certain cancers, and decreasing the risk for cardiovascular diseases. In many countries folate intakes fall below recommendations. Especially in countries where mandatory folic acid fortification has not been introduced it is important to study folate sources - such as whole grain foods - in the diet and the possibilities for folate enhancement. Folate is unevenly distributed in the grain. In rye, folate contents in milling fractions may vary 10-fold (1), and in wheat high folate concentrations have been found in bran (2) and particularly in aleurone layer (3), but less in known about folate in oats and barley. The aim of this study was to examine folate contents of oat and barley fractions. Oat fractions included native grain, hulls, bran, endosperm flour, flakes, flour from cutting, and residual flour from flaking. Barley fractions were native grain, 5, 10 and 20% dehulled grains and corresponding hulls, fine and coarse barley flours, and fine and coarse barley granules. Millings were performed twice, and samples were analysed as duplicates for their total folate contents using microbiological assay (4). In addition, the ash contents were determined.

In oat the highest folate concentrations were determined in the oat bran that had 30 to 40% higher folate contents than the native oat grain. In endosperm flour and oat flakes folate retention was approximately 80%. Folate contents in the flour from cutting and especially in the residual flour from flaking were significantly higher than in the native grain. In barley hulls folate contents were significantly higher than folate content in the native barley grain. Folate contents in the dehulled grains decreased respectively: in 5% dehulled grain folate retention was approximately 75% compared to the native grain, whereas in 20% dehulled grain the retention was only around 30%. Folate contents in the coarse barley flour and coarse barley granules were higher than in fine barley granules and fine barley flour. Folate content in coarse barley granule was even slightly higher than in the native grain, but in fine barley flour the folate content was only half of the folate content of the native grain. Folate contents of barley fractions increased with increasing ash contents. In oat fractions this positive correlation was less pronounced.

Utilization of folate-rich fractions as a food ingredient or as a starting material for other processes could offer a feasible method for natural folate enhancement. The nutritional characteristics of cereal products could thus be further improved.

Keywords: Folate, oat, barley

References:
(2) Arcot et al. 2002. Food Aust. 54: 18-20
QUALITY CHARACTERISTICS OF DOMESTIC TRITICALE CULTIVARS IN REGARD TO THE NUTRITIONAL AND TECHNOLOGICAL IMPORTANCE

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The first triticale (Triticosecale sp.) cultivars in our country which has been bred by crossing between wheat and rye, have been registered in 1988. But, because of the low resistance to lodging down, as well as of the poor kernel quality, these cultivars did not have a larger application in the past period. Triticale has an excellent biological adaptability for various soil and climate growing conditions (Pena, 1996). Comparing with the other bread cereals, it has stronger root mass, due to what it uses more of the soil nutritive materials. That’s the reason why this cereal has been also successfully grown on poor, acid and salted soils. The great is the part of the arable land in our country on which triticale could be successfully grown (30%).

By now, the triticale has been insufficiently used in the human nutrition in our country, and it has been mainly used in the animal nutrition. Triticale has higher percentage of protein and lysine in regard to the parental species and lower energetic value in regard to the wheat and maize (Mosse et al., 1988; Barneveld and Cooper, 2002). But, by breeding of new triticale cultivars with the intention their kernel quality to be improved, the interest for triticale production has been raised.

The aim of this study was to investigate the nutritive and technological quality of new domestic triticale varieties in order to evaluate their potential and importance for the human nutrition and to give a better information to the consumers about the usage of the bread and other baked goods produced from triticale flour.

ICC approved methods were used in the investigation of the technological quality of five domestic triticale cultivars, grown in Skopje region. Investigations on the kernel flour quality have shown that the value of the crude protein content varied among the investigated cultivars from 12.3% to 15.1%, and its average value was 13.7%, which was higher than that of the standard wheat cultivar of 12.3%. The sedimentation value ranged from 15ml-30 ml, and was lower than the average value of the standard wheat of 33.5 ml. The wet gluten content of the triticale cultivars was also lower than that of standard wheat (38.5 %) and ranged from 5%-26%. The triticale cultivars have also shown lower flour yield than the wheat standard (60%-70%), and it ranged from 40%-56%. Investigations on triticale flour quality have shown lower quality number (in the range 27-51) comparing with the standard wheat (65-73), lower quality subgroup number (B2-C1) than the standard wheat (A2-B1), and lower dough energy (0-35 sm²) than the standard wheat had (42-57 sm²).

As conclusions from our investigations can been stated that because the new domestic triticale cultivars possess higher crude protein content and lower wet gluten content than the wheat standard used, they might have a potential for nutrition of the population having celiac desease and they can be recommended to the consumers for use in the nutrition. Regarding to their technological quality, because of the lower quality obtained than the wheat standard, the triticale cultivars can be used for producing of special baked products.

Key words: triticale, cultivars, quality, nutrition

References:

OAT GENETIC RESOURCES IN KAZAKHSTAN

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Oat (Avena sativa L.) and oat bran have beneficial effects as human food and animal feed. In Kazakhstan 11 cultivars of oat are grown, including 6 cvs of local breeding. Thus the main goal for Kazakhstan is to form oat gene fund and to establish an adequate cultivars selection on the steps of their planning, breeding, trials, and registration. The main goal of our investigation was to study the biochemical content of oat cvs grain of Kazakhstan and to reveal the most perspective cvs for utilization.

The plant material: 1) 11 commercial and 22 perspective cvs of oat grown in 2000-2008 in 20 locations of Kazakhstan; 2) 64 accessions of competitive trials on breeding program of Kazakh Research Institute of Farming (2007-2008 yield). Genetic oat resource was analyzed on following parameters: the contents of protein and its fractions (albumin + globulin, avenine, gluteline), contents of starch, amylose, oil, β-glucan iron and zink, hullness, hardness, 1000 kernel weight and yield.

Results and discussion.

Protein content varied in the range 6.3-21.1 percents, oil – 3.1-5.9% yield – 0.3-5.7 t/h, albumine + globuline 24-40%; avenine 5-13%. The content of starch varies in cvs range in dependence of grown conditions from 47.0 to 52.3 percent. The highest range of variability was in cvs Skakun (52.4%) and Tarmanskii (52.3%). Commercial cvs oat β-glucane content range 29-47 g/kg⁻¹; for perspective breeding lines – from 34 to 52 g/kg⁻¹. Significant difference were found for the main effects of genotype and location and their interaction. The variance ratio for the interaction was much smaller than those for the main effects and, except for one location, the rank order of the cultivars was generally similar. The β-glucan, iron and zink concentration was not correlated with 1000 kernel weight. It was concluded that selection for high β-glucan in a single environment should be representative of relative performance in other environments.
TRITORDEUM – A NOVEL CEREAL SPECIES WITH POTENTIAL FOR USE IN FUNCTIONAL FOOD APPLICATIONS.

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Tritordeum is a novel cereal species, created by hybridisation between durum wheat and a wild barley species, Hordeum chilense. It is a hexaploid cereal, which is morphologically and agronomically similar to wheat, although it has a series of traits of interest derived from its barley parent. Tritordeum was first synthesized by Dr Antonio Martin of the Institute for Sustainable Agriculture (IAS) in Córdoba, Spain in the 1980s. Over the past 30 years a breeding programme at the IAS has resulted in a series of elite tritordeum lines with yields comparable to wheat. In 2005 the company Agrasys SL (www.agrasys.es) acquired the commercial rights to tritordeum and has continued the development of the crop in collaboration with the IAS. The first variety of tritordeum, JB1, was registered with the EU CPVO in November 2009.

At the agronomic level, tritordeum resembles bread wheat, but it shows better resistance to drought and temperature stress, suiting it to production in southern European regions. Tritordeum also shows elevated resistance to a number of diseases, particularly fungal pathogens, derived from Hordeum chilense.

At the quality and nutritional level, tritordeum has a number of characters making it of interest for the development of functional foods. It has similar protein and starch composition to wheat, but typically shows higher protein levels. In addition, tritordeum has exceptionally high levels of the carotenoid antioxidant lutein, up to 20 times the level found in bread wheat, it has elevated levels of polyphenolic antioxidants and high levels of some mineral micronutrients. Within the tritordeum breeding programme there exists great variability for a number of other traits of functional food interest which are being selected for in new lines. Food products made with tritordeum have a good flavour and an attractive golden-yellow colour.

Agrasys is developing tritordeum food products in collaboration with selected European cereal food companies, including the Swedish multinational Lantmännen. These products will be marketed under the trade mark Vivagran® (www.vivagran.es). Data from compositional and functional analyses and food product development will be presented.

Keywords: Tritordeum, novel cereal, functional food, plant breeding

References:

### Poster Section 2
Technology and processing

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MICROORGANISM AND MYCOTOXIN REDUCTION OF NATURALLY CONTAMINATED GRAINS USING PEELING TECHNOLOGY

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Undesired contaminations with microorganisms or mycotoxins in high extraction flours or whole grain products are increasingly reported. It is known that these contaminants are mainly concentrated in the outer bran layers of the grain kernel. Within this study it was investigated whether the total contaminations in the end product can be reduced by a selective mechanical removal of outer bran layers (peeling) of naturally contaminated grains prior further processing. Peeling studies were conducted with naturally contaminated wheat (\textit{Triticum aestivum L.}) using a standardized cleaning procedure, a Buhler Decontamination (DC)-Peeler (MHXM-W) or DC-Light-Peeler (MHXM-WL) and a standardized subsequent milling process. The analyses of the final milling products (flour, fine and coarse bran) indicated a significant reduction of microorganisms (aerobal, enterobacteria, molds) as well as mycotoxins (DON) if a prior peeling of the wheat kernels (0.2 – 2 \% of total wheat) is conducted. Therefore, it is suggested to establish the peeling process, as already used today by some millers and grain processors, as a standard pretreatment procedure for whole grain processing for effective contamination control.
GUT FERMENTED PRODUCTS OF WHEAT ALEURONE WITH PROTECTIVE EFFECTS ON HUMAN INTESTINAL TRACT

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An innovative process has been developed with milling technology and electrostatic separation to isolate high purity wheat aleurone cells with different particle size cells from wheat bran varieties. The wheat aleurone cells with its valuable dietary fibre mainly the arabinoxylans from the aleurone cell wall with a much lower A/X ratio than bran and with a high content of antioxidants and other micronutrients shows within human cell studies protective effects on human intestinal health.

The aleurone cells have been applied in different studies addressing its bio-actives content, its post ingestion intestinal effects and metabolism as well as systemic effects. These studies have shown that isolated wheat aleurone is slowly but completely degraded during in vitro fermentation by the human microbiota, compared to bran of which a significant fraction remains unfermented, even after 24 hours. Due to its complete fermentation, wheat aleurone results in a high production of SCFA with a relatively high amount of butyric. Recent fermentation trials with human microbiota revealed that aleurone significantly elevated bifidobacteria. Gut fermentation products of wheat aleurone suppresses cell growth and survival of human adenocarcinoma cells.

In conclusion, the present results provide evidence on the biological effects of fermentation samples from different wheat sources, in particular aleurone. Gut flora-mediated fermentation of wheat aleurone results in reduced levels of tumour-promoting DCA but higher levels of potentially chemopreventive SCFA, especially butyrate.

The aleurone layer was identified as the most beneficial sub-fraction, since its fermentation metabolites were able to induce apoptosis and to block cell cycle – two essential markers of secondary chemoprevention.

Keywords: Aleurone fibre, arabinoxylans, antioxidant capacity, fermentation, colon cells
Wheat grain is a complex structure made of the germ and starchy endosperm surrounded by several peripheral tissues differing in their structure and chemical compositions. In traditional wheat milling processes, this part of the grain is discarded as the bran, mostly used in animal feed. Bran could be however used for food ingredient preparation if it is fractionated to remove unwanted parts and increase bioactive compounds accessibility. Wheat outer layers mechanical properties are key properties to explain differences observed for bran fractionation. Up to now, these properties are deduced by tensile tests of hand-isolated tissues after wheat humidification, a procedure that could induce artefacts. Pulsed laser ablation has demonstrated a potential technique to reveal wheat tissue properties [1]. Ablation rate was deduced from microscopic observations which are time consuming. Taking advantage of compositional heterogeneity within the peripheral tissues, laser-induced breakdown spectroscopy (LIBS) could be a powerful tool to follow wheat tissue ablation.

With this aim, native grains of a soft common wheat (Crousty) were gradually ablated with a pulsed excimer laser ArF (193 nm, 15 ns, 1 Hz, 2 J.cm-2) coupled to a miniature optical fibre spectrometer. Spectra were acquired from each pulse. Chemometrics were successfully applied to exploit the complex LIBS spectral data. The moving two-dimension (MW2D) correlation was adapted to LIBS observations as the purpose of identifying specific transitions regions of spectra during ablation. Univariate analysis and microscopic observations validated these information indicating that spectra changed between the transition of one tissue to another. Specific identification of each tissue was further carried out by Partial Least Square – Discriminant Analysis (PLS-DA) model on all spectral data in order to identify the number of pulses required to ablate each tissue and then the ablation rate. The pericarp, the seed coat, the aleurone layer and the endosperm were successfully predicted by the PLS-DA model. Therefore, the LIBS simplicity and easiness could introduce laser ablation as a technique to investigate physico-chemical bases of wheat tissues fractionation.

**Keywords:** wheat grain, PLS-DA, moving 2D

**References:**


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DISCRIMINANT ANALYSIS APPLIED TO FTIR SPECTRA AS A TOOL TO MONITOR FRACTIONATION OF WHEAT GRAIN TISSUES

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Traditionally wheat grain fractionation is carried out through milling technology and lead to the separation of flour and semolina from germ and bran. However valuable constituents such as micronutrients or fibers are known to be particularly concentrated in these fractions from outer parts of the grain. Moreover, these technological fractions are not homogeneous in term of tissue and then biochemical composition. Monitoring fractionation process to recover all the potential nutritional benefit implied to be able to track the tissue separation along processing. Use of biochemical markers was successful in durum wheat milling technology or soft wheat bran fractionation to analyse the aleurone and pericarp content (Antoine et al., 2004; Peyron et al., 2002). Biochemical heterogeneity already observed within the grain could be also pointed out by FTIR spectroscopy. Indeed this rapid and non destructive method can detect a range of functional groups and then were sensitive to molecular composition.

In order to acquire specific signatures of tissues as thin as 8 µm and then not achievable with spatial resolution of classic IR microspectroscopy, tissues from two common wheat cultivars (Caphorn, Crousty) were hand dissected. FTIR-ATR spectra were recorded on starchy endosperm, embryonic axis, scutellum, aleurone layer, hyaline layer, testa, inner pericarp and outer pericarp. Peripheral tissues from another common wheat variety (Recital) were dissected, as well as from one durum wheat variety (Ardente) in order to analyse the effect of pigmentation of testa layer on FTIR spectra.

Taking advantage of the low penetration of FTIR-ATR method, all the cuticular layers within the peripheral layers were clearly pointed out. The analysis of testa spectra from red vs white wheat allowed to detect FTIR signature linked to the presence of pigment.

Cultivar variability was assessed by statistical analysis (PCA). Regardless of the variety, peripheral tissues of the mature grain (pericarp, testa, hyaline and aleurone layer) were discriminate thanks to their FTIR signature combined to discriminant analysis. Based on spectra obtained for Caphorn and introducing the testa variability (white/red), LDA allowed to attribute all the spectra of Crousty, Recital and Ardente from aleurone, testa and pericarp were correctly attributed. No distinction between spectral signature of inner and outer pericarp was confirmed. However only 53% of the hyaline spectra of Ardent cv were correctly classed. Spectral range used avoid any signal due to cuticle presence and is mainly based on polysaccharide FTIR signature.

The stability of the discrimination must be assessed on ground tissues in order to be further addressed to quantify the histological composition of technological fractions.

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IMPACT OF WHEAT BRAN DRY FRACTIONATION ON THE IN VITRO BIOACCESSIBILITY OF PHENOLIC ACIDS AND THE ANTIOXIDANT POTENTIAL OF BRAN-RICH BREADS

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Wheat bran is known to contain an important proportion of the wheat grain’s micronutrients and phytochemicals, that can greatly contribute to increase the nutritional quality of human foods if included in flours or used as food ingredients. However, in western countries, most of wheat-based foods are produced from refined endosperm from which the outer layers are excluded. In the present study, new dry-fractionation processes were tested in order to improve the nutritional potential of bran. Ultrafine grinding was used to drastically decrease the bran particles size to facilitate the separation of bran tissues and increase the breakage of aleurone cell walls to make the aleurone compounds more bioaccessible, and electrostatic separation was used to obtain fractions with different composition (rich in intracellular material or rich in cell walls). The different fractions obtained by these processes were used to produce bran-rich breads. The aim of this work was to study the effects of bran particles size, grinding process, and electrostatic separation on the nutritional quality of breads (bioaccessibility of phenolic acids and antioxidant capacity of absorbed compounds). Dry fractionation processes allowed to produce bran fractions with different particles size and different compositions. In vitro digestions of breads made from these fractions showed that the decrease of bran particles size results in a higher absorption of phenolic acids and a higher antioxidant capacity from the bioaccessible fraction. The breads made from bran fractions produced by electrostatic separation exhibited the highest bioaccessibility and antioxidant capacity. It was found that only the free & conjugated forms of ferulic acid from breads were bioaccessible, and that the bioaccessibility of sinapic acid was higher than that of FA, resulting in comparable contributions to antioxidant capacity. To conclude, it seems possible to increase the nutritional potential of bran by using dry-fractionation processes.
POTENTIAL OF WHEAT BRAN DRY FRACTIONATION FOR THE PRODUCTION OF FOOD INGREDIENTS

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The current wheat milling process aims at recovering white flour (starchy endosperm) and discarding bran and germ. Wheat bran is thus an under-valued by-product used for animal feeding, even if due to its high nutritional potential, it could be processed into food ingredients to increase the nutritional quality of human foods. Dry fractionation processes can be developed in order to make better use of all the different parts of wheat grain, and aim at recovering separately the different structures of the bran, to produce fractions rich in the different bran tissues, like pericarp-rich (rich in fibers) or aleurone-rich fractions (rich in vitamins, minerals, antioxidants). This poster describes the different steps of wheat bran fractionation, from the characterization of the starting material's properties to the nutritional and techno-functional evaluation of the different bran fractions obtained. The potential of two innovative fractionation processes was studied: ultra-fine grinding (including cryogenic grinding) and electrostatic separation of bran particles.

This integrated approach of wheat bran fractionation has shown that wheat bran fractions have a good potential as food ingredients, and that ultrafine grinding & electrostatic separation allow the production of bran fractions displaying higher nutritional potentials than the initial bran. The study of the properties of bran tissues & bran particles at small scale has been of great interest for the development of processes at pilot scale. More work is still needed to produce purer fractions, and understand their influence on breads properties.
SUPERCritical CO2 Lipids Extraction From Wheat Bran & Aleurone, And Nutritional Potential of the Extracted Oils: Influence of Particles Size & Solvent

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Wheat bran is currently an undervalued by-product. It contains 20-30% of wheat grain lipids, most of these lipids being located in the aleurone layer (that represents ≈45% of bran). Bran lipids are responsible for the formation of clogs and particles agglomerates during processing (grinding, sieving). It could therefore be interesting to extract them, to make bran processing easier, and use separately the extracted oils. While rice bran oil and wheat germ oil have been broadly studied and are used in food, cosmetic, and pharmaceutical industries, wheat bran oil is less studied and less used, even if it has been proved to exhibit colon tumor inhibitor properties (Reddy et al., 2000; Sang et al., 2006). Various solvents can be used to extract lipids from cereals bran. Supercritical CO2 extraction is an eco-friendly process that allows to recover samples and extracts devoid of residual solvent.

Objectives of this work: i) to evaluate the nutritional quality of oils extracted from standard wheat bran and from an aleurone-rich fraction, and ii) to study the influence of the type of extraction (supercritical CO2 with or without a co-solvent to modify its polarity) and the influence of bran particle size (intact or finely ground) on the lipid extraction yields and the oils composition.

This study has confirmed that wheat bran oil & wheat aleurone oil have interesting nutritional potentials. Ultrafine bran grinding and using supercritical CO2 extraction might be a good way to extract bran lipids, as it allows to recover 82% of total lipids. However, this extraction process could be optimized to extract more tocols and sterols, in order to recover both fully defatted bran, and lipidic extracts displaying high nutritional values.
INFLUENCE OF TEMPERATURE AND MOISTURE CONTENT ON THE MECHANICAL PROPERTIES AND GRINDING BEHAVIOUR OF WHEAT BRAN

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Wheat bran is known to be rich in nutritionally interesting compounds, most of the micronutrients being located in the aleurone cells where their availability is limited by complex cell wall fibres. Dry fractionation processes, by drastically decreasing the bran particles size by means of ultra-fine grinding, may facilitate cell walls breakage, tissues dissociation, and may allow to make the cell contents more accessible. By changing the properties of the material (its moisture content or the grinding temperature), its dissociation could be eased. As the mechanical properties of the bran are supposed to govern most of its behaviour during milling and grinding, to study the mechanical properties is a way to understand the basis of the fractionation ability of wheat bran. It also gives the possibility to act on these properties to improve bran fractionation. The aim of this work was first to study the mechanical properties of wheat bran under various conditions, in order to search the conditions where the material is the most fragile, and then to perform grinding of bran at small scale, at different temperatures, to determine the processing conditions that enable the best fractionation. Tension tests showed that mechanical properties of wheat bran can be modified and controlled by changing the ambient temperature and the bran moisture content. At very low temperature, the material becomes brittle and breaks more easily, and this is confirmed by the small scale grinding results, that showed that fine particles are obtained faster by cryogenic grinding than by grinding at ambient temperature. To go further, it may be interesting to study the joint effects of low temperature and moisture content on bran behaviour, to determine the influence of each constitutive bran tissue on the overall bran mechanical properties under various conditions, and to study the relation between tissues composition and tissues behaviour at low temperatures or high moisture content. Finally, grinding should be developed at pilot scale, to use these results to develop new fractions.
ANTIOXIDANT CAPACITY OF WHEAT BRAN AS A FUNCTION OF ITS STRUCTURATION STATE.

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Wheat bran is known to contain numerous micronutrients and phytochemicals, some of them having marked antioxidant capacity (Vit E, tocotrienols, phenolic acids, lignans, flavonoids, selenium, manganese and phytic acid). Ferulic acid (FA), the most abundant phenolic acid in wheat bran, is often presented as the major contributor to the antioxidant capacity of wheat grain fractions (Mateo Ansen et al., 2008). This compound is mainly located in the wall of the bran tissues, esterified to arabinose components of arabinoxylans, whereas others active compounds are mostly detected in the aleurone cell content. The objective of this work is to study the variation of antioxidant capacity of bran in relation with its structuration state. The bran was mechanically ground to reduce its particule size in order to increase the accessibility of radicals to ferulic acid with or without releasing the aleurone cell components. Bran was milled by ball milling under normal and cryogenic conditions and centrifugal milling with 0.250 and 0.125 mm of screen. The direct antioxidant capacity of samples was determined based in the capture of the ABTS radical, without prior extraction, with a method adapted from Serpen et al (2008). The water released phytic acid was followed as a biochemical marker of the aleurone cell opening (Antoine et al., 2004). Ferulic acid (total, free, conjugated) content was determined by HPLC. The structuration state of the bran was also checked by microscopic studies (SEM). The antioxidant capacity of the bran will be related to its particles size distribution (independently to the grinder used) and/or to the opening of cell wall structure, notably aleurone cells.

Key words: wheat bran, antioxidant capacity, milling and particle size distribution.

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THUMB FLEXIBILITY OF GLYCOSIDE HYDROLASE FAMILY 11 XYLANASES

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Endo-\(\beta\)-1,4-D-xylanases (xylanases), are glycoside hydrolases (GH) that catalyze the degradation of arabinoxylan, a major cell wall non-starch polysaccharide of cereals. GH family 11 xylanases are single-domain proteins with a \(\beta\)-jelly roll structure that is described as a partially closed right hand. The highly conserved thumb-like loop is an intriguing and characteristic structural element of these enzymes, of which the true dynamic nature and function in catalysis is still unknown. Crystallographic analysis of the structure of a \textit{Bacillus subtilis} xylanase A mutant, found as a dimer in an asymmetric unit, revealed that the thumb region can adopt an extended conformation. In contrast to the closed thumb conformation of GH family 11 xylanases and the previously observed small conformational changes upon substrate binding, a relocation of the tip of the thumb of more than 15 \(\text{Å}\) was observed. Site-directed mutagenesis of five thumb residues, including putative hinge point residues, and enzyme kinetics assays showed that Arg112, Asn114 and Thr126 play a role in the open-close thumb movement. Replacement of Arg112 by glycine or proline caused a strong decrease of turnover numbers and elevated Michaelis constants on xylan. Mutant N114P hindered thumb movement, provoking a fourfold decrease of turnover numbers and a sharp rise in Michaelis constants, while the proline mutant of Thr126 displayed an increase in specific activity. Thus, engineering of the thumb structure influences the binding of the substrate as well as the release of product from the active site. The thumb region and its dynamics appear to be of vital importance for the specific catalytic action of GH family 11 xylanases.
POTENTIAL OF EXTREMOPHILIC Xylanases FOR IN SITU PRODUCTION OF PREBIOTIC ARABINOXYLAN-OLIGOSACCHARIDES

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Arabinoxylan-oligosaccharides (AXOS), low molecular mass hydrolysis products of arabinoxylan (AX), increasingly stand in the spotlight as possible prebiotics¹,². In view of their possible beneficial health effects, the aim of this study was to investigate the potential of extremophilic xylanases to convert the AX population in wheat flour as completely as possible to AXOS [with average degree of polymerization (avDP) preferably between 5 and 30] in situ during bread making, without compromising dough and final bread quality.

Our results clearly indicate that with the hyperthermophilic rXTMB in situ enrichment of bread in AXOS is possible (1.5 g AXOS/100g dm, avDP=15), without compromising dough and bread quality. This implies that, taking the average bread consumption in Europe into account, the majority of the recommended AXOS daily intake, necessary to observe the desired physiological effects in humans¹, is provided by such bread. Further increase of the AXOS dose in situ can be achieved by enrichment of breads with AX rich fractions or bran.

References:


**IN VITRO FERMENTABILITY OF ARABINOXYLAN-OLIGOSACCHARIDES PRODUCED IN WHEAT BRAN IN A DRY BALL MILLING PROCESS**

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Wheat bran-derived arabinoxylan-oligosaccharides (AXOS) are considered as potential prebiotics¹. Production of AXOS from wheat bran is generally performed through incubation with xylanases, although the process is faced with limitations. While the lowly substituted AX in the aleurone layer are largely degradable, the highly substituted pericarp AX are not degraded at all, resulting in low AXOS yields and AXOS preparations with low arabinose to xylose (A/X) ratios.

In analogy to previous work², we investigated the potential of ball milling for production of AXOS in wheat bran and the in vitro fermentability of the produced AXOS, with the aim to contribute to efficient utilisation of the cereal bran and to produce a wider range of AXOS structures.

AXOS can be produced in situ in wheat bran in a single-stage dry milling process. The process produces AXOS with a higher A/X ratio compared to enzymically produced wheat bran-derived AXOS, which offers perspectives for production of a wide range of AXOS structures. AXOS produced from wheat bran through ball-milling are partly fermentable, and fermentation results in significantly increased levels of unbranched SCFA. Ball-milling may thus contribute to the production of physiologically active components from wheat bran, and, in this way, to the upgrading of cereal bran, in particular the low-value pericarp layer.

**References:**


AMYLOSE-LIPID COMPLEXES AS ADDITIVES IN STARCH BASED FOOD SYSTEMS

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While amylose-lipid complexes have been studied profoundly, little information is available about the possible functionality of such complexes when used as additive in starch based systems. We here studied the impact of both monodisperse short-chain semi-enzymically synthesized and more polydisperse longer-chain solution-grown complexes on starch gels and breadmaking. Semienzymically synthesized type I complexes induced severe viscosity changes when added to starch in a Rapid Visco Analyzer heating, constant temperature and cooling cycle. During heating of starch suspensions, these complexes (partly) dissociate (in line with their differential scanning calorimetry properties) thereby liberating both lipids as well as short amylose chains. The latter subsequently contribute to network formation during cooling of the gel by participating in double helix formation with long amylose chains leached from the starch granules, resulting in a viscosity increase. We next used in vitro methods for the determination of resistant starch levels and hydrolysis indices which were both based on chewing of the starch containing material. The gels containing amylose-lipid complexes had higher resistant starch levels and lower in vitro degradabilities than the controls. When the complexes were added in breadmaking, they decreased bread volume and changed its in vitro digestibilities. Resistant starch content increased especially for semi-crystalline type II amylose-lipid complexes. Amylose-lipid complexes can hence be used as a tool for the controlled release of lipids and short amylose chains, on the one hand, and, on the other, as an ingredient reducing starch in vitro degradability by increasing resistant starch contents.
FERMENTED WHEAT BRAN AS A FUNCTIONAL INGREDIENT IN WHEAT BAKING

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Cereal brans are important ingredients providing dietary fibre and phytochemicals, and wheat bran is one of the most common raw materials for increasing the level of insoluble dietary fibre in baking. Use of bran in high amount for nutritional upgrading of wheat bread is, however, a technological challenge due to inferior baking quality of wheat bread containing high amount of bran. One of emerging technologies to improve technological functionality of wheat bran is fermentation of bran with yeast and lactic acid bacteria prior using it in wheat baking (Salmenkallio et al. 2001). The aim of the current study was to develop fermentation of wheat bran further by establishing a link between the status of arabinoxylan fraction and endogeneous xylanases of wheat bran in response to the technological behaviour of bran in baking. We studied the influence of type fermentation type (yeast or spontaneous), fermentation temperature and type of wheat bran (from native or peeled kernels) on the microbial community, levels of bioactivity (folates and free phenolic acids as examples) and state of arabinoxylans as well as activity of endogenous xylanases in the bran ferments. Furthermore, technological potential of these bran ferments were established by introducing them at the 20% substitution level to the wheat baking.

Yeast-started fermentation of bran from peeled kernels was found to be the most efficient tool to increase the level of folates (+40%), free phenolic acids (5-fold) and the amount of soluble arabinoxylan (+40%), of wheat bran. In addition, peeled bran contained ten-fold lower activity of endogenous xylanases in comparison to native bran and fermentation of bran further diminished xylanase activity. Higher endogenous xylanase activity of native bran resulted in smaller molecular weight of WEAX in the wheat bread supplemented with this bran in comparison to the bread supplemented with bran from peeled kernels and with low endogenous activity. Chemical changes obtained in the fermented bran from peeled kernels resulted in improved bread volume (+10-15%) and crumb softness of wheat bread (25-35 % softer) supplemented with the bran. However, the type of wheat bran as well as fermentation temperature was shown to be determinant factors for improved bioactive potential and technological quality of fermented bran. Furthermore, this study showed that peeling prior to bran separation clearly reduced the microbial load in wheat bran, which was also reflected in the microbial community during yeast fermentation. This study established the potential of yeast fermentation to enhance the bioactivity and technological potential of wheat bran prepared from peeled kernels. Solubilisation of AX during 20 hours fermentation and diminished final endogenous xylanase activity were proposed as a main cause for improved technological functionality of fermented bran.

Key words: bran, fermentation, baking

References:
CONTROLLED DEPOLYMERIZATION OF OAT BETA-GLUCAN FOR BEVERAGE APPLICATIONS

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Beta-glucan of oats is mostly located in aleuronic or sub-aleuronic layers. The concentration of beta-glucan in oat bran can be enriched by separating the cell walls from endosperm using efficient milling and air classification technology. This type of enrichment process is suitable for both high-fat and defatted oat material. However, lipid removal prior to milling significantly enhances the separation process (Kaukovirta-Norja et al. 2008). For example, by using super critical CO$_2$ for lipid removal the maximal obtained beta-glucan concentration has been 34 % (of dry weight) compared to ca. 20 % with high-fat oat material.

Beta-glucan incorporation into beverage applications is challenging due to high viscosity and structural instability. By applying methods that reduce molecular weight of beta-glucan, the suitability of beta-glucan in beverages can be enhanced. For example, enzymatic hydrolysis, mechanical shear stress and acid catalyzed hydrolysis are suitable methods for the depolymerisation of beta-glucan molecule.

We have developed a novel technology for controlled depolymerisation of oat beta-glucan (Kaukovirta-Norja et al. 2009). Technology is based on acid catalyzed hydrolysis during extrusion process. This provides beta-glucan with narrow molecular weight distribution, and totally inactivates the endogenous enzymatic and microbial activities present in oat raw material. By extruding beta-glucan enriched oat bran in presence of phosphoric acid, beta-glucan molecules with average molecular weights (M$_w$) of 20 000–100 000 g/mol were obtained. The M$_w$ of beta-glucan can be tailored by adjusting the temperature of the extrusion chamber. The small molecules obtained facilitate the incorporation of around 10 g of beta-glucan in a 500 g serving. In this kinds of beverages beta-glucan is stable over a wide range of pH values and temperatures.

Compared with enzymatic hydrolysis the acid catalyzed hydrolysis requires a shorter reaction time, and enables more effective control over beta-glucan molecular weight. However, both enzymatic and acid catalysed depolymerisations enable effective incorporation of beta-glucan into beverages. In addition, enzymatic treatment is environmentally more friendly, as side-streams related to neutralization of acid hydrolysed material are avoided.

Keywords: Oats, beta-glucan, enzymatic and acid catalysted hydrolysation

References:

USE OF XYLANASES AND OXIDATIVE ENZYMES TO IMPROVE GLUTEN NETWORK PROPERTIES IN WHOLE GRAIN WHEAT BREAD

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For superior palatability of whole meal wheat bread, the challenge is to conquer deficient gluten network formation which is due to the presence of the outer layers of the grain. In particular, insoluble arabinoxylans of wheat are known to influence negatively the gluten properties. Enzymes offer a tool to modify the sensory properties of bread. Enzymatic hydrolysis of arabinoxylan or crosslinking of gluten proteins or arabinoxylan change the gluten properties and thus also the texture of bread.

In this work, xylanases and the crosslinking enzymes tyrosinase and laccase were examined with an attempt to improve the gluten network properties of whole meal wheat bread. Dough rheology, bread specific volume, crumb softness and the state of arabinoxylan and proteins of the breads treated with the enzymes were analyzed. In addition, digestibility of the breads was studied using a method combining chewing in vivo and treatment with pepsin in vitro.

The xylanases and also the oxidative enzymes, laccase and tyrosinase, improved the instrumental texture of whole meal wheat bread. The highest increase in bread volume was gained with the combined treatment of laccase and xylanase. During storage, softness of bread was also maintained best in the breads treated with xylanase in combination with laccase. There were not significant differences in the amount of large bread particles after in vitro gastrointestinal digestion. However, the micrographs of the large particles showed enzyme dependent differences in swelling of starch granules, aggregation of starch and formation and rigidity of protein network. This result might suggest different digestibility of the breads also in vivo.

Keywords: wholemeal, wheat, bread, texture, enzymes, xylanase, crosslinking
Arabinoxylan (AX) has a major impact on the functional properties of wheat bran, and it has been shown that technological properties of bran can be improved by using endoxylanases, which depolymerise and solubilise AX. Water content is an important parameter in enzymatic modifications, influencing enzyme activities, diffusion of components and rheological properties of the material. Enzymatic treatments are typically conducted at high water content. However, in industrial applications, low water content may be advantageous, especially when targeting dry end products.

The aim of the study was to examine the impact of water content, ranging from 20 to 90%, on the efficiency of endoxylanase treatment of wheat bran. The treatments at ≤70% water content were performed in a farinograph mixing bowl, and the treatments at ≥80% were performed in a steel container with double-blade mixer. AX solubilisation, textural properties of the material, molecular weight distribution of water extractable AX (WEAX) and the level of remaining endoxylanase activity were analysed.

Interestingly, AX solubilisation was highest at the water contents of 40 and 90%. At water contents between 50 and 80%, AX solubilisation was lower than at 40 and 90%. The water content of the enzyme treatment affected also the molecular weight distribution of WEAX. At low water content, WEAX was less depolymerised than at high water content. At the water content of 40%, the bran-water mixture was transformed from powder-like material into very compact, plastic-like mass. It is possible that the compact structure of the material at 40% water content might have enhanced AX solubilisation via enhanced enzyme binding to the substrate or due to enhanced diffusion, or even by physical breakdown of the cell wall structures of bran due to shear forces. The results show that enzymatic solubilisation of bran AX can also be efficiently performed at low water content.

**Keywords:** wheat bran, arabinoxylan, xylanase, water content
FLOUR BLEND FROM NON-TRADITIONAL CEREALS IN LATVIA

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The type of cereal mainly used in food depends on specificity of the region, for example in the Far East it will be rice, in America – maize, in Central Asia, North America and Northern and Eastern Europe – rye and wheat (Tohver et al., 2005, Kunkulberga, 2010). In production of bread and pastry various grinds of wheat and rye flour traditionally are used, though new possibilities for expanding of the assortment are sought. Researchers worldwide have been studying use of triticale, hull-less barley, maize and rice in bread and pastry production (Tseng, 1974, Peña, et al., 1998, Taketa et al., 2004, Rakcejeva, 2009).

The aim of the research was development of flour blend for pastry and bread production from cereals which are not traditionally used in Latvia.

Triticale, rye and hull-less barley crop of 2009 cultivated in Priekuli Plant Breeding Institute, Priekuli was used in the current study. Rice and maize was purchased from a local retail store. Cereals used for study was ground in laboratory mill „Hawos“ (type of grind – 1). Raw materials and prepared flour blends were analysed for moisture (determined by „XM 120 Precisa”), content of total dietary fibre (AOAC 985.29 Total Dietary Fibre in Foods Enzymatic-Gravimetric Method) and content of protein (AOAC, “Official methods of analysis,” Method 945.18-B).

Wholegrain flour blend was developed for use in pastry and bread making, which contains 60% triticale, 15%– hull-less barley, 15% – rye, 5% – rice and 5% – maize. The study demonstrated that the highest content of fibre was found in hull-less barley sample (17.7 g 100 g-1), while the least content – in rice (5.97 g 100 g-1), but in the flour blend it reached 13.68 g 100 g-1. Whereas the highest content of protein was determined in hull-less barley flour sample – 11.79 g 100 g-1, the lowest content – in rye flour 6.46 g 100 g-1, but in the flour blend it was 8.75 g 100 g-1.

Results show that it is possible to obtain product more rich in fibre, comparing to breads and pastry made from fine wheat flour, if triticale, hull-less barley, rye, rice and maize flour is used and satisfy consumer demands.

Key words: triticale, hull-less barley, whole grain flour, flour blend

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(2) D. Kunkulberga, V. Seglins (2010) Bread making technology, Publishers of Riga Technical University, Riga, 292 pp. (in Latvian)

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PASTA AND EXTRUDED CEREALS AS VEHICLE FOR TRADITIONAL AND INNOVATIVE DIETARY FIBRE

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Daily fibre intake of 30g/person is recommended of the German Society of Nutrition. In all the industrialized countries including Germany is these not met. Most people understand the importance of dietary fibre in their diet. Much has been said about its importance in heart health, diabetes, cancer prevention and even weight control. But not all fibre will help you achieve your goals in these areas. Dietary fibre is broadly classified into soluble and insoluble fibre; both types of fibre are important for nutrition and have different effects on the human metabolism.

In food stuffs like pasta and extruded cereals the implementation of higher levels of traditionally and innovative is possible. The German per capita consumption of pasta is 7 kg/a and of breakfast cereals 3 kg/a and is growing. The trend of consumption in the other European countries is similar or at higher level. In our evaluation trials we implemented insoluble fibres from wheat and oat bran and soluble fibres such as oligofructans of different chain length, resistant maltodextrin and polydextrose. The process ability was tested in pasta, direct expanded cereals and flakes. The maximum of technological acceptable amount of fibres was evaluated. Criteria for quality determination:

in pasta: sensory, bite strength, cooking loss,
in cereals: sensory, expansion index, bulk density, abrasion, resistance in milk.
The acceptable amount of useable fibre depends on process and product.

For direct expanded cereals up to 15% of insoluble fibres are process able, the limiting amounts at pasta and flakes are 8 %.

It is possible to steer the sensory properties of extruded cereals either to more crispiness or more tenderness. Resistant maltodextrin bring more tenderness whereas short chain FOS and polydextrose lead to crunchiness. The resistance in milk increases by increasing content of soluble fibres and the cereals will stay crispy longer.

In case of pasta especially the long chain inulin cause qualitative improvement (transparency) bite strength. Sugar type short chain fibres cause raw surfaces and lower cooking stability.

The fortification of pasta and extruded cereals by innovative dietary fibre is possible without technological problems and helps to generate products with better quality than reference. The know-how of IGV on selection and combination of fibres by different formulations and technological processes is usable to create products by innovative and attractive properties.

Keywords: pasta, breakfast cereals, extrusion, bran, soluble dietary fibre

References:


FORTIFICATION OF EXTRUDATES BY BRAN VS. GENERATION OF ACRYLAMIDE

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Fortification of breakfast cereals by grain based dietary fibre - such as bran - meets the recommendations of nutritionists, the wishes of producers and consumers to the same degree. The technological realisation of the fortification is possible by the extrusion process. The components of the formulation are easy to combine, stable against demixing and can be adjusted perfect to the required fibre level.

The selection of fibre depends on availability, the needs of formulation and the required effects and properties of the final products. Because of positive nutritional effects, low price, unlimited availability and high consumer acceptance in many cases the bran of wheat or rye are used.

In addition to these positive effects of the bran, the possible generation of acrylamide (AA) is observed and must be minimized by appropriate measures. The generation of AA is influenced by the processing parameters, the content of reactive sugars and the content of asparagine. The asparagine content is low in rice (60 mg/kg), moderate in wholemeal flour (480-510 mg/kg) and very high in rye bran (2610 -3180 mg/kg). In combination with free sugars unacceptable amounts of acrylamide will be generated (600 µg/kg and more) especially at low moisture levels during the thermal stress.

If the bran components are fine grinded to increase the technological process ability and to increase the sensory properties (mouth feeling), the generation of AA is increased (2-3 times more) additionally. By the use of asparaginase enzyme (300 ppm) a significant reduction of the generated AA level is possible. This effect is very effective in case of higher moisture levels and extended reaction times (50 min) for the enzyme. Such conditions are possible for bran fortified toasted flakes (AA content 45 µg/kg).

In the case of direct expanded cereals these conditions can only be achieved by a pre-treatment of the high asparagine components (bran) with the complete processing water and the asparaginase enzyme. By a new strategy to support the enzyme activity and to block the generation of AA the additional application of citrates is used. The processing parameters have been optimized. The sensory quality of the extrudates was excellent and the AA content lower than 80 µg/kg and meet the quality requirements for Germany.

The EU commission is discussing signal values for different products in 2010. For breakfast cereals an AA limit of 300 µg/kg is calculated in the draft. Since 2008 the AA signal value for breakfast cereals in Germany is at the low level of 80 µg/kg. By the methods developed at IGV this signal value can be realised for extrudates fortified by fine grinded bran with excellent sensory properties.

Keywords: cereals, fortification, bran, extrusion, acrylamide

References:
DRINK POWDERS FOR MILK SHAKES WITH DEFINITE NUTRIENT PROFILES FOR CLINICAL INTERVENTION STUDIES AND CONSUMER ACCEPTANCE TESTS
OFFER OF IGV GERMANY

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Within the German research project PROFIMET “Effect of proteins and dietary fibre on parameters of the metabolic syndrome” in co-operation with German Institute of Nutrition (DIfE) the IGV GmbH was responsible for design, optimisation, characterisation and finally the organisation of pilot scale production of drink powders with well defined composition and amount.

The intervention study was realised with randomised controlled and blind two phase test during six and twelve weeks at 80 overweighed or adipose persons. The aim of the project was to study the influence of a high protein and/or a high dietary fibre diet on insulin sensitivity, metabolism of blood glucose and fatty degeneration of liver.

For the evaluation of the effects IGV had to design drink powders for milk shakes with four different nutrition profiles for the intervention study:

- Basic neutral with high content of cereal based carbohydrates
- High fibre (HF) high fibre components with 15 g dietary fibre per serving
- High protein (HP) high protein components with 25 g protein per serving
- Medium HF/HP containing 7,5 g dietary fibre and 12,5 g protein per serving.

Main topic of the product design: the manifold flavorings and the very good sensory properties because every proband had to consume during a period of 18 weeks in total 252 servings!

To achieve these requirements for the drink powders have been:

- Useful and similar consistency of all four powder types
- Attractive harmonised taste
- Possibility for choice between different flavours
- Good storability of the powders (six month for the duration of the study)
- Single packing per serving with exact labelling of type, taste, code on each portion bag
- Simple preparation by shaking the powder from the bag with 1,5% fat milk
- Exact formulation of composition and weight in each portion bag

Statistical methods (ranking test, just-about-right-test, penalty analysis) have been used for optimising the formulation in consistency and taste.

Types of the flavour composition: banana, vanilla, chocolate, milk coffee and caramel

In addition to the drink powders four different formulations (basic, HF, HP HF/HP) have been made for pan cakes. So the probands could switch between drinks with different flavours and pan cakes for the daily intake of the samples.

The pilot scale production has been realised at certificated SMEs in a volume of 55.000 bags of drink powder and 20.000 bags for pan cakes.

Results of the project will be published 2010 by German Institute of Human Nutrition

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IDENTIFICATION OF LACTIC ACID BACTERIA ISOLATED FROM OAT SOURDOUGHS AND INVESTIGATION OF THEIR POTENTIAL FOR THE IMPROVEMENT OF OAT BREAD QUALITY

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The use of sourdough in wheat and rye breads has been extensively studied, however little is known about its potential effect when baking oat bread. Consequently, the impact of sourdough on oat bread quality was investigated.

Two different sourdoughs were prepared from wholegrain oat flour (dough yield 200) without addition of starter cultures and continuously propagated at 28 (SD 28) or 37°C (SD 37) until the composition of the lactic acid bacteria remained stable. The dominant lactic acid bacteria were identified by sequence analysis of the 16S rDNA isolated from pure cultures. The isolated lactic acid bacteria were further used as starter cultures for the production of oat sourdough. SD 28* was prepared with addition of a starter culture containing each LAB isolated from oat SD 28 and SD 37* was inoculated with the strains isolated from SD 37. In addition, rheological properties as well as changes in the protein profile of SD 28* and SD 37* were investigated. The oat sourdoughs were further utilized for the production of oat sourdough bread.

Identification of the dominant lactic acid bacteria revealed differences in the microbiota of SD 28 and SD 37. Depending on the fermentation temperature, different lactic acid bacteria species became dominant. \textit{Leuconostoc argentimum}, \textit{Pediococcus pentosaceus} and \textit{Weissella cibaria} were the dominant LAB species isolated from SD 28 (28°C). In contrast, \textit{Lactobacillus coryniformis} became dominant in SD 37 (37°C). Rheological analysis of oat sourdoughs produced with the isolated strains as starter cultures revealed a softening of the sourdoughs as indicated by the decreased G* compared to non-acidified and chemically acidified controls which could not be attributed to proteolytic activity. Incorporation of oat sourdough into an oat bread recipe resulted in significantly increased loaf specific volume as well as improved texture, independent of addition level or sourdough type. Overall, the results of this study show that sourdoughs containing lactic acid bacteria isolated from oats have the potential to enhance oat bread quality.

\textbf{Keywords:} lactic acid bacteria, sourdough, oat, bread, rheology

\textbf{References:}

Three commercial wholegrain oat flours from Finland (WOF), Ireland (WOI) and Sweden (WOS) were evaluated for their bread making ability with the objective of finding predictive relationships between flour physicochemical properties and bread quality. Bread recipe and baking procedure were established in preliminary trials to obtain the most appropriate conditions for bread making. Small amplitude oscillatory shear measurements within the linear visco-elastic region were used to study the rheological properties of the oat batters. The flours were characterised by measuring moisture, ash, protein, starch, amylose, fat, dietary fibre and β-glucan content as well as starch damage and water hydration capacity. Rapid Visco Analyser (RVA) analysis was applied to determine the pasting properties of the flours and capillary gel electrophoresis was used to investigate the protein profile of the commercial oat flours. Overall, significant differences were found in the bread making properties of the wholegrain oat flours. Good bread quality was obtained when using WOS and WOI flour since breads showed high specific loaf volume and slice height as well as low density and hardness. Low quality breads were obtained when WOF flour was used. In addition, positive effects on oat bread quality were observed for low batter viscosity and high deformability, as obtained for WOS and WOI. Based on the physicochemical analysis of the flours, water hydration capacity was found to be the main reason for increased elasticity of WOF batters. Small flour particle size, damaged starch granules and high protein content were identified as the key factors causing increased water hydration capacity. These findings suggest that wholegrain flours with coarse particle size, limited starch damage and low protein content result in superior oat bread quality.

Keywords: oat bread, gluten-free, rheology, water hydration capacity

References:

Oat (Avena sativa) have received increased interest for human nutrition, as a consequence of their dietary benefits, their low allergenicity and their suitability for most celiac patients. Consequently, the development of high quality oat bread could enhance oat consumption, satisfy the consumer demand for novel and healthy foods and increase the range of products suitable for people suffering from celiac disease. However, to date, oat varieties have not been developed specifically for the production of bread. Moreover, a principal understanding of oat properties is necessary in order to achieve the desired bread quality.

Hence, six different spring oat varieties (Typhon, Ivory, Buggy, Nord 08/311, Energie, Zorro) were selected for examination. After milling, the flours were characterised by measuring moisture, ash, protein, starch, amylose, fat, dietary fibre and β-glucan content. Starch damage and water hydration capacity as well as enzymatic activities were also established and the flour pasting properties were investigated using a Rapid Visco Analyser. Capillary gel electrophoresis was applied for measuring the protein profiles of the different oat varieties. In order to determine the bread making potential of the varieties a simple wheat-free recipe was developed. The rheological properties of the oat batters were studied by applying small amplitude oscillatory shear measurements within the linear visco-elastic region and the breads were analysed using standard bread analysis methods.

In general, the most significant differences in the bread characteristics were found in the crumb structure. The varieties Buggy, Energie and Zorro resulted in good bread quality with an even gas cell distribution, characterized by a high number of relatively small pores. In contrast, Typhon, Ivory and Nord 08/311 had a large hole in the centre of the crumb and accordingly poor quality. Breads differed little in specific loaf volume, bake loss and density. Rheological analysis revealed positive effects of low batter resistance to deformation on oat bread quality. Based on the physicochemical characterisation, protein and fat content were identified as key factors responsible for differences observed in bread quality, provided that starch damage and water hydration capacity are low. Additionally, high setback and final viscosity, as determined by Rapid Visco Analyzer (RVA) analysis, positively affected oat bread quality. High α-amylase activity was found to negatively influence the bread making performance of oats. Overall, protein and fat content, starch pasting properties as well as α-amylase activity were responsible for the bread making properties of oat varieties.

**Keywords:** oats, oat varieties, bread quality, rheology, protein

**References:**

COMPETITIVENESS OF COMMERCIAL STARTERS IN BUCKWHEAT AND TEFF SOURDOUGHS

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Recently, the application of sourdough (SD) technology in gluten free (GF) baking has been proven as a potential tool to improve the quality of GF bread. In industrial SD processes, the application of selected and competitive starter cultures is considered the pre-requisite in order to ensure constant quality of the final product. However, to date no information on the applicability of commercially available starters in GF sourdough fermentations is available. In this study we have investigated the competitiveness of two commercial starters, i.e. SA and SB, for the production of GF sourdoughs from the GF flours buckwheat or teff. The starter SA was used for type A sourdough, which was incubated at 25 °C with 10% (w/w) refreshment every 12 hrs; whereas starter SB was applied for type B fermentation, carried out at 35 °C with 10% (w/w) refreshment every 24 hrs. Sourdoughs were propagated till a stable biota was established. Lactic acid bacteria (LAB) and yeasts constituting the dominant microbial community were isolated and identified by sequencing of the 16S rDNA and 28S rDNA, respectively. In addition, the dynamics of the microbial community were followed by specific PCR-denaturing gradient gel electrophoresis. Analysis of the microbial community revealed that not all the starters strains were competitive in the sourdough fermentation of buckwheat and/or teff flours. Remarkably, none of the starters yeasts could survive the fermentation process. Autochthonous LAB and yeasts, e.g. Lactobacillus brevis and Weissella cibaria in buckwheat and Saccharomyces cerevisiae in teff, could associate and dominate with some of the starters strains. We also observed that under otherwise identical fermentation conditions, the fermentation substrate played a key role in determining the competitiveness of the starters strains. For example, among the species of LAB constituting SB, Lactobacillus plantarum group, Lactobacillus paralimentarius and Leuconostoc argentinum persisted only in buckwheat sourdough, whereas Lactobacillus pontis and Lactobacillus reuteri were dominant only in teff. Given that the persistence and dominance of the starters strains is a pre-requisite for the successful application of sourdough starters, we conclude that the commercial starters used in this study are not suitable for the fermentation of buckwheat and teff. Investigations on the spontaneous biota of GF flours will help developing novel starters which are adapted and competitive for the production of GF sourdough bread.
EFFECTS OF HIGH PRESSURE AND TEMPERATURE ON BUCKWHEAT STARCH CHARACTERISTICS

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Pressure-induced gelatinisation of buckwheat starch suspensions (25 % w/w) was studied and compared to heat-induced gelatinisation. Starch suspensions were treated at increased pressure (200 - 600 MPa) or temperature (60 – 95 °C) for 10 min. The degree of gelatinisation and the temperature- and pressure-ranges of gelatinisation were determined using differential scanning calorimetry, changes in birefringence and pasting behaviour. Furthermore, the structural changes during gelatinisation were investigated using microscopy. The pressure-induced as well as the temperature-induced gelatinisation curves were sigmoid-shaped. Gelatinisation occurred between 300 MPa and 500 MPa or between 60 °C and 70 °C. Scanning electron microscopy images showed retention of the granular structure after treatment with 600 MPa. However, when heated at temperatures above 65 °C, the formation of a “sponge-like” structure was observed. Better preservation of the granular structure for pressure-treatment compared to temperature treatment resulted in stronger gels for the former. Pre-treatment with pressure as well as temperature made the buckwheat starch granules more resistant to swelling and disintegration under the influence of additional heat.

Keywords: Buckwheat starch; High pressure; Gelatinisation; Microscopy; Rheology; DSC

References:
PROMOTING STRUCTURE FORMATION BY HIGH PRESSURE IN GLUTEN-FREE FLOURS

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In order to evaluate the potential of high pressure (HP) treatment to improve the functional properties of gluten-free flours, the effect of HP on the rheological properties of three gluten-free batters was investigated. Buckwheat, white rice and teff batters (40 %) were treated for 10 min at 200, 400 or 600 MPa. Changes in the microstructure of the batters after HP-treatment were observed using scanning electron microscopy. Pasting profiles revealed HP-induced starch gelatinisation. Furthermore, Lab-on-a-Chip capillary gel electrophoresis revealed protein polymerisation by thiol-/disulphide-interchange reactions in white rice and teff batters. For buckwheat proteins however, no such cross-linking mechanism was observed, which was explained by the absence of free sulphhydryl groups. An increase in viscoelastic properties at higher pressures was observed, and could be explained by the modifications occurring in starch and protein structure. Overall, this study has shown that HP-treatment has the potential to improve functional properties of gluten-free batters.

Keywords: Gluten-free; High pressure; Rheological properties; Lab-on-a-Chip; Gelatinisation; Disulphide bonds

References:
In this study, protein structural modifications induced by transglutaminase (TGase) treatment of brown rice (BR) flour were investigated. Size-exclusion HPLC (SE-HPLC) profiles of flour extracts under reducing conditions revealed the presence of macromolecular protein complexes as well as low molecular weight proteins. After TGase treatments (10 U/g of proteins) a general reduction in peak intensities indicated the polymerisation of BR proteins into larger, insoluble complexes. Protein fractionation was performed to better understand the activity and specificity of the enzyme. SE-HPLC of the protein fractions revealed glutelins polymerisation into high molecular weight structures after TGase treatment, while albumins and globulins were only slightly affected. Dynamic light scattering measurements showed that new supramolecular aggregates of glutelins co-existed with the macromolecular complexes already present in the untreated fraction. SE-HPLC and two dimensional gel electrophoresis revealed that the α and β glutelin subunits were primary substrates for the polymerisation reaction during TGase treatment. Front-face fluorescence approaches indicated that TGase treatment caused a decrease in protein surface hydrophobicity of BR flour, but not of the glutelin suspensions. It is concluded that TGase treatment of BR flour promotes the formation of highly polymerized glutelin structures in which albumins and globulins are entrapped.
QUALITY AND ANTIOXIDANT PROPERTY OF BREAD CONTAINING DIFFERENT AMOUNT OF BUCKWHEAT FLOUR

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Common buckwheat (Fagopyrum esculentum Moench) is recognized as an important functional food in some countries because of its potential antioxidant activity. The grains and other tissues contain numerous nutraceutical compound like a significant levels of rutin, catechins and other polyphenols. Moreover, buckwheat grains are a rich source of total dietary fibre and soluble dietary fibre that contains high amount of β-glucans. In developing functional bakery products (including bread), it is important to realize that achieving functional food quality does not simply involve delivering the active principle at the appropriate level for physiological effectiveness, but also supplying a product which meets the consumer’s requirements in terms of appearance, taste and texture. In this study buckwheat, due to its affirmative nutritional action, was incorporated in bread formulation. The aim was to examine the possibility of improving the quality of wheat flour based bread by using different amounts of whole buckwheat flour in order to obtain an antioxidant enriched bread with good physico-chemical and sensorial properties. Different quantities (0, 10, 20 and 30%) of buckwheat flour were added in bread formulation. Free phenols content (Folin-Ciocalteau assay), rutin content (by HPLC) radical scavenging activity (DPPH assay), insoluble and soluble fibre content (AOAC 991.43, 2001), colour measurement (Tristimulus Reflectance Colorimeter) were evaluated on bread crumb and crust. The alveoli area distribution (Image Analysis), loaf volume and sensory acceptability of the supplemented bread were also determined. From the colour analyses it is clear that the crumb stained toward a darker colours, tending to brown and assuming more vivid colour compared with the control bread. The progressive increase of buckwheat flour in formulation caused a loaf volume decrease and it was noticed that crumb alveoli quantity and its dimension were significantly influenced. Free phenols, rutin content and radical scavenging activity values were significantly (p < 0.05) higher in crust than in the crumb for all the samples. This finding could be only partially explained taking into consideration that other antioxidant compounds, which are formed preferably on the crust (e.g. Maillard reaction products) could react with the Folin-Ciocalteau assay. Moreover an increased release of these compounds is occurred from the matrix becoming more accessible in the extraction due to the higher temperature reached during baking in the crust rather than in the crumb. All the buckwheat bread samples showed higher rutin, free phenols and insoluble and soluble fibre content compared with the white bread. Concerning the free phenols the highest content was found in the sample with a 30% of buckwheat with a three fold and six fold increment for the crust and crumb respectively. Results of radical scavenging activity data are coherent with those obtained from the total phenols data. As expected, the radical scavenging activity increased with increasing percentage replacement of buckwheat flour. Therefore, results showed that the radical scavenging activity of the extracts is mainly due to phenols derived from the addition of buckwheat in the formulation. Indeed it was obtained a good correlation between the free phenols content and radical scavenging activity obtained data (p<0.001 R² =0.98). As expected total dietary fibre content (soluble + insoluble) was higher in buckwheat bread than in the white one. In particular the total fibre content was 5.1, 7.5 and 9.9 g per 100 g⁻¹ on dry basis for the bread with 10, 20 and 30% of buckwheat flour respectively. These amounts represent approximately 20, 30 and 40% of the recommended daily intakes by EFSA for Europeans (25 g). Moreover the obtained data showed that almost 75% of buckwheat total dietary fibre was the insoluble fibre which are in turn composed primarily of β-glucans an immunostimulating polysaccharide. Therefore, more insoluble β-glucan in buckwheat bread would be beneficial and provide consumer with the alleged immunostimulating effect.

References:

EFFECTS OF MILLET, AMARANTH, QUINOA, BUCKWHEAT AND MAIZE ON PHYSICAL PROPERTIES OF GLUTEN-FREE BREAD

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Celiac disease is a chronic intestinal disease caused by intolerance to gluten. Gluten is the main structure-forming protein in flour. Dough from gluten-free flours obviously differs from wheat flour dough with respect to consistency, cohesive and kneading properties (Miyazaki and Morita 2005, Renzetti et al. 2008) and gluten-free breads are very often of low quality, with poor crumb and crust characteristics as well as of poor mouth feel and low nutrient profile (Gallagher, Gormley et al. 2003).

The aim of the present study was to quantify the effect of non-wheat flours with nutritional value and technological advantages on the volume, structure, texture and colour of breads. Three Mixture experiments following a simplex-centroid design were carried out, where gluten-free wheat starch, water and minor components as albumin, fat, emulsifier, locust bean gum, salt and yeast were kept constant, whereas three flour components: millet, maize and either buckwheat, amaranth or quinoa were varied between 0 and 50% of the flour fraction. Baking tests with some replications have been carried out according to the ICC Standard method No. 131. Texture measurements of the bread were conducted with a texture analyser TA-XT2 (Stable Micro Systems, compression and relaxation test, 10mm deformation at 0.5mm/s). The structure of bread slices was analysed in terms of porosity with an image analysis system (Olympus).

The major findings were: Millet, amaranth and quinoa increased the volume and crumb firmness as well as the porosity. No or little effect has been observed by buckwheat and maize flour. Generally it can be concluded that especially the addition of millet, but also of amaranth and quinoa can improve the quality of gluten-free breads. Staling and sensory properties have not been investigated in this study and would need further research.

Key words: gluten-free bread, physical properties, millet, buckwheat, amaranth, quinoa, maize

References:


WHEAT CULTIVAR QUALITY FOR WHOLE MEAL BREAD

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Breeding and selection of wheat cultivars is focussed on agronomic properties, milling properties to obtain refined flour and production of white bread. As a consequence of the growing attention for wholegrain products, the question has come up whether this research approach is also representative for wholegrain products. The aim of this study is to understand if the wheat cultivar quality for bread making purposes is only dependent on the flour properties, or that also variation in the bran fraction affects the processing quality of wheat cultivars.

From the HEALTHGRAIN diversity screen 26 wheat cultivars grown and harvested in one year (2007) on one location (France) and without sprout damage have been selected. From each line white flour and whole meal was produced and their dough mixing properties (2g Mixograph) and bread making quality (10g micro bread making test) were determined.

The cultivars showed a large variation in bread making quality. The correlation between white bread volume and whole meal bread volume was unexpectedly high ($r^2 = 0.88$), demonstrating that wheat cultivar quality testing on white flour is representative for whole meal products as well. The results show that also whole meal bread quality is mainly depending on the quantity and quality of the protein of the endosperm. Indications were found that also fiber related parameters (in particular bound phenolic acids and type and quantity of arabinoxylans) influence the results. However, the effects of the protein variation governed all other effects in the dataset.

In a follow-up study, bran fractions of the different cultivars will be added to one standard base flour. In this way the effects of the varying properties and compositions of bran fractions of different wheat cultivars can be studied.
INCREASE THE HEALTHY COMPONENTS AND MAINTAIN BREAD QUALITY

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Wheat is a rich source of healthy components such as fibres, micronutrients and phytochemicals, which are concentrated in the outer parts of the grain. Most consumers prefer products of refined white flour to whole grain products, because they perceive the textural properties of whole grain products to be less attractive. Understanding the adverse effects of the outer grain fractions on bread quality may enable the development of products rich in healthy components that are also attractive to the consumer.

In this study the nature of the adverse effects of wheat bran fractions on bread quality was studied. Two fractions of the bran were used, representing different tissue layers and compositions. Ultra-fine grinding and electrostatic separation was applied to obtain bran fractions with different biochemical fibre composition and chemical fine structure.

All fractions were added to white flour. Water addition was adjusted to obtain dough with a constant consistency and compensate for possible differences in water absorption. Mixograph dough mixing, gluten aggregation tests and micro bread baking tests were performed.

Our results demonstrate that the adverse effects on bread quality are caused by negative effects of bran on gluten network formation. Bran components interact with the gluten network hindering the ability of the gluten to reaggregate. Two possible reactive fibre components were studied in detail: monomeric ferulic acid and phytate. The obtained insight in the mechanism in which bran fractions affect bread quality provide clear avenues to increase the amount of healthy components in bread whilst maintaining its product quality.
INTERACTIONS AMONG WHEAT PROTEINS, FIBRE POLYSACCHARIDES AND PHENOLIC ANTIOXIDANTS IN BREAD REVEALED BY FOURIER TRANSFORM INFRARED (FTIR) SPECTROSCOPY, RAMAN SPECTROSCOPY, SIZE-EXCLUSIVE HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (SE-HPLC) AND RHEOLOGY

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The positive roles of dietary fibres (DFs) and polyphenols (PPs) in health have triggered attempts to add these components into popular foods like bread. Flour that is used in bread baking comes mainly from wheat. We studied functional breads with enhanced DFs and PPs. Fruit fibre preparations including apple pectins with different methoxy contents and fruit phenolic antioxidants (i.e. kiwifruit, apple and blackcurrant extracts) were incorporated into a defined bread recipe. The resultant bread dough and finished bread were subjected to chemical and physical characterization. Inter-/intra-molecular bonding, secondary structure and conformation changes of dough were examined using FTIR (Digilab FTS-60 series spectrometer) (Wellner et al. 1996) and Raman spectroscopy (Reinshaw RM-2 Raman microscope) (Nonaka et al. 1993) based on the characteristic bands for dough components such as proteins and polysaccharides. Extractability, size distribution and ratios of specific protein fractions were determined using SE-HPLC (ZORBAX bio series GF-450 column) (Larroque et al. 1997; Maforimbo et al. 2006). Viscoelastic behaviour of dough during baking was analysed using a Physica MCR 301 rheometer. Total phenolic contents and antioxidant capacity of finished breads were evaluated by Folin-Ciocalteu assay and the Ferric reducing antioxidant power (FRAP) assay, after the extractions using an optimised Accelerated Solvent Extraction (ASE) method. Results showed that the extraction recovery was less (9.2-11.7%) for apple PP-bread compared to those of kiwifruit PP-bread (28.0-35.3%) and blackcurrant PP-bread (29.5-39.0%). FTIR and Raman studies suggested that addition of apple pectin and/or fruit PP extracts caused shifts in the wavenumber around regions of amide I & II bands, C = O and β-sheets, which are associated with the structures of proteins and polysaccharides. The SE-HPLC patterns of extractable gluten proteins were different, including disappearance of albumin and globulin peaks in all fruit PP-containing formulations, disappearance of gliadin peak in the kiwifruit PP-bread, and altered level of extracted glutenin (apple > blackcurrant > control > kiwifruit). The storage ($G'$) and loss modulus ($G''$) decreased over the frequency range of 1-100 s$^{-1}$ after the addition of fruit PPs and apple pectin indicate the association of molecular weight and structure of the polymer network with rheological behaviour and bread attributes. We conclude that interactions occurred among the added pectin, phenolics and components such as wheat proteins during dough development and bread baking, causing changes in physicochemical properties and appearance attributes, including height, colour and moisture content. The elevated total phenolic content and antioxidant capacity in the final product suggest that the addition of PPs to bread is a viable means to increase its nutritional status.

Key words: wheat protein, fibre, antioxidant, FTIR, Raman, SE-HPLC, rheology.

References:


The addition of several ingredients at low levels to wheat flour and dough named as “bread improvers” is commonly used in order to improve some aspects of dough behaviour and final bread quality. The formulation of bread improvers will be influenced by legislative control over the list of permitted ingredients that may be used in breadmaking. Almost any material added to a flour and water dough will have some improving effect. For example common salt (sodium chloride) provides a number of functions in baked products: it contributes to bread flavour; it lowers water activity of products and therefore extends product shelf-life; it inhibits yeast activity; it modifies dough rheology in breadmaking; it contributes to the formation of bread crust colour. On the other hand, some inorganic salts used as additives can influence the formation of undesirable compound acrylamide which arises mainly from amino acid asparagine during baking of bread and accumulates preferably in crust. The presented work is focused on the comparison of different inorganic salts commonly used as improvers on acrylamide content in bread and consequently on sensory properties of final bread products. There were examined sodium phosphate and sodium pyrophosphate in concentration of 2500 mg/kg of bread mix (according to the EU regulation); and ammonium chloride and calcium chloride in concentration of 3000 mg/kg of bread mix (under the UK recommendation on flour fortification). None of them was observed to impair the expected bread properties considerably; however, their impact on the acrylamide reduction was significant.

Key words: acrylamide, bread, inorganic salts, bread improvers

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FROM GRAIN TO FEED – FRACTIONATION OF PROTEIN RICH CROPS FOR THE USE IN EXTRUDED FISH FEED PELLETS

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The Danish project “Organic Aquaculture” the link between sustainable production and superior products” is examining the availability of relevant organically produced crops with a high protein content to be used as raw materials for fish feed. Fish meal is the main source of protein for fish feed. On a global scale the production of fish meal will not increase. There is a demand for developing sustainable protein sources as a substitution for fish meal. Protein from crops and legumes is an obvious solution; however, the crops and legumes need to be processed into fractions with higher protein content in order to compete with fish meal.

The process development was carried out at The Danish Technological Institute's pilot plant located in Sdr. Stenderup, Denmark, where equipment for grinding, protein fractionation and extruding is available in pilot scale and lab scale. Various grains very analysed for their protein concentration and amino acid composition to optimize the fish feed pellets, e.g. horsebean, lupin, peas and rapeseed. Among other grains horse beans where selected to be further processed and fractionated, due to their amino acid composition and protein content (22 % in wholegrain). A dehulling process was developed based on three process steps: hammer mill grinding, vibration sifting and zig zag air classifying. The hulls were 14 % of the total mass.

The protein content was concentrated from 29 % in the dehulled horsebean fraction to over 50 % total protein. The dehulled horsebeans were grinded in a hammer mill followed by a pin mill to obtain a very fine product with most particles below 250µm. The hammer mill used were a champion mill with a speed of 2950 rpm and the pin mill used was an Alpine 250 Z pin mill at 18.900 rpm.

The grinded product was air classified using a MP 400 Alpine Air Classifier at air settings of 10, 20, and 30. Air setting 10 provided the highest protein content followed by 20 and 30, which corresponds to higher protein content in the finest fraction.

The horse bean protein fraction was incorporated into a recipe for fish feed together with a rape seed- and a pea protein fraction to reduce the amount of fish meal used. The ingredients were extruded into pellets on a Werner Pfleider Continua 37 Twin Screwed Extruder.
**Poster Section 3**

**Nutrition and metabolism**

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CHALLENGING HOMEOSTASIS TO DETECT SUBTLE METABOLIC CHANGES WITH POTENTIAL LONG-TERM HEALTH BENEFITS

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The aim of healthy diets including wholegrain products and of functional ingredients is to keep us healthy for longer. Therefore, indicators are required that quantify the subtle but relevant effects of diets or ingredients on our health status that predict the capacity to deal with environmental and age-related stresses. One approach to ‘quantify health’ is to apply a homeostatic perturbation on processes that are relevant in maintaining health. Measuring classical and nutrigenomics markers after these ‘challenges’ provides information about the resilience of the individual against different types of stress and how this is affected by diet (1). In a series of human studies we have applied different challenge tests, with a focus on metabolic, inflammatory and oxidative processes. When focusing on glucose metabolism and development of diabetes an oral glucose tolerance test (OGTT) seems most adequate. In a first trial, an OGTT was administered to 19 healthy overweight men, to evaluate metabolic changes induced by a mild anti-inflammatory drug intervention (2). Metabolic changes were subtle and were only detected using metabolic profiling in combination with the OGTT. Intermediates of the glutathione synthesis pathway showed time-dependent suppressions in response to the challenge test, suggesting that inflammatory modulation may alter insulin signaling in overweight men.

When focusing on lipid metabolism and development of cardiovascular diseases an oral lipid tolerance test (OLTT) seems most appropriate. In a second study, an OLTT was given to 36 overweight men to quantify the effect of a 5-week intervention with an anti-inflammatory food mix in a double-blind placebo-controlled crossover design. The effect of the dietary intervention on the metabolism, oxidation and inflammation control could already be quantified in the fasting state (3), but was more significantly demonstrated by the effect of the oral lipid challenge.

An oxidative challenge can be applied by a physical exercise challenge. Such a test (i.e. cycling test) has been performed in 16 lean and 16 obese men, with markers of oxidation and transcriptomics and metabolomics markers as primary outcome and gut permeability as secondary outcome for the effect of a 4 week vegetable intervention. The results of this study will also be discussed.

Other types of challenges (LPS challenge, mental stress, bacterial infection) are being implemented in ongoing studies. The hypothesis that challenge tests will help define a “healthy” response and distinguish otherwise healthy subjects with an impaired response needs to be validated against accepted markers or endpoints. In nutrition research, applying challenge tests and measuring the integrative response is a new and promising strategy to quantify and understand maintenance of health.

Key words: biomarkers/challenge/health/homeostasis/systems biology

References:
THE USE OF A DYNAMIC IN VITRO DIGESTION SYSTEM (TIM) TO STUDY BENEFICIAL EFFECTS OF WHOLE GRAIN PRODUCTS


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Whole grain products – bioaccessibility of their beneficial compounds

It is commonly believed that whole grain products exert health promoting effects (1). These effects are not only limited to their prebiotic properties, but also to their content of antioxidants and minerals. However, the availability for absorption (= bioaccessibility) of these health promoting compounds depends on their association within the grain and food matrix and the presence of other (pro-/anti-) nutritive substances. There is a need for in vitro methods to investigate underlying mechanisms related to the bioaccessibility of health promoting (micro-) nutrients contained in these foods. In vitro methods offer the advantages of high reproducibility, accuracy, cost effectiveness and the absence of ethical constraints compared to in vivo studies. TNO- the Dutch Institute for applied scientific research- has developed such a model (TIM), which meets these requirements and simulates very closely the dynamic conditions of the digestive tract (2).

The mimicked conditions in this computer-controlled multi-compartmental model are based on in vivo data and include secretion of digestive enzymes at physiological activities, appropriate pH for the enzymes and relevant co-factors, physiological transit times for each step of digestion, and the dialysis of digestible products. The TIM system has been set up and validated for hydrophilic as well as for lipophilic (micro-) nutrients, such as minerals, vitamins and antioxidants.

Anti-oxidants in whole grain products in TIM studies.

The TIM system has been used to study the bioaccessibility of antioxidants, such as phenolic compounds. The most abundant phenolic compound in wheat grain is ferulic acid. Different in vitro and in vivo studies have been reviewed on the anti-inflammatory effects of ferulic acid. However, ferulic acid is mostly located in the bran of cereal grains, where it is linked to cell wall polysaccharides. This binding inhibits strongly the bioavailability of ferulic acid and so its bioactivity. Processing of the bran can increase the availability for intestinal absorption by modifying the polysaccharide matrix and consequently increasing the bioavailability and ultimately the bioactivity.

Experiments in the TIM-1 system indeed demonstrated that the bioaccessibility of ferulic acid in bread enriched with native bran was lower than 1-2% of the intake (3). Nevertheless, it showed an anti-oxidant effect in collected TIM-samples (4). Bread enriched with bio-processed bran (e.g. fermentation and/or enzyme treatment) showed a 5-fold increase in the bioaccessibility of ferulic acid (5). Also ultra-grinding of the bran resulted in an increase bioaccessibility of ferulic acid in the TIM-1 system, but to a lesser extend (6). The above findings in the TIM system in combination cell line studies were confirmed in a human volunteer study (7), demonstrating the high predictive quality of the TIM system for this type of research.

Bioaccessibility of minerals in whole grain products.

Whole-grain wheat contains considerable amounts of iron, magnesium and zinc, as well as lower levels of different trace elements, e.g. selenium and manganese. They are mainly found in the bran, highly concentrated in the aleurone layer of the wheat kernel. The essential question is about the bioavailability of the minerals and trace elements, because these minerals are strongly bound to phytate, which is also present at a high concentration in bran. The low bioavailability, however, can be overcome by processing such as pre-fermentation to activate microbial phytases that hydrolyze the phytate and improve the bioavailability of minerals.
Experiments in TIM have shown the efficiency of both the addition of exogenous phytases or pre-fermentation in enhancing the bioaccessibility of iron (1,9). In another study the gastric retention time and its effect on the bioaccessibility of minerals from grain products could be shown (10). The ranking in bioaccessibility of minerals was equal to what was found \textit{in vivo}.

In conclusion, the dynamic \textit{in vitro} system, TIM, shows a high predictive quality for the human situation and is an appropriate tool to study digestive processes and the bioaccessibility of grain products and related beneficial compounds.

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IMPROVED INSULIN ECONOMY IN PIGS FED WHOLE GRAIN CEREAL FRACTIONS IS ASSOCIATED WITH COLONIC PRODUCTION OF BUTYRATE

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Dietary starch degraded to glucose is the major contributor to energy absorbed from the gastro-intestinal tract during post-prandial periods. Intake of dietary fiber (DF) causes colonic fermentation and results in absorption of energy rich short chain fatty acids (mainly acetate, propionate and butyrate) from the large intestine. Thus, by substituting dietary starch with DF, the site of nutrient digestion is moved and more of the energy is absorbed as non-glycemic carbohydrates. Diets rich in DF may have a low glycaemic index (GI) and low-GI foods have been demonstrated to lower the postprandial glucose response even after consumption of a standardised second-meal (known as second-meal effect). When lunch is consumed, intestinal content from the previous meal (breakfast) is moved along to the large intestine, where it acts as substrate for bacterial fermentation. In the present study, pigs were fed three times daily with three diets (whole grain wheat, wheat aleurone and rye aleurone) similar in starch and DF contents. Pigs absorbed similar amounts of glucose, but had higher butyrate production and lower insulin secretion when fed the aleurone rich diets (as compared to wheat whole grain) and when fed lunch meal as compared to the breakfast meal. These results suggest that butyrate, besides being a fuel for enterocytes and possessing regulatory effects on cell turnover and inflammation, also seem to be important for satiety and for insulin economy and thereby important for regulation of glucose homeostasis.

Keywords: Diabetes; Glycemic Index; Obesity
A diet rich in whole grain cereals is suggested to protect against type 2 diabetes (1,2). However, little is known about the metabolic impact of different fractions of the grain or the underlying molecular mechanisms. The aim of this study was to investigate and compare the metabolic effects of diets supplemented with different fractions of the wheat grain in obese and glucose intolerant C57Bl/6J mice, a common model for human obesity and prediabetes (3). Mice were fed diets with 30 energy % derived from fat supplemented with seven different fractions from Tiger wheat: 1) whole grain wheat flour, 2) aleurone fraction, 3) intermediate (+) fraction, 4) pericarp fraction, 5) protein rich aleurone fraction, 6) germ fraction and 7) 76% white wheat flour, for 12 weeks. The group fed the whole grain wheat fraction had a significantly higher energy intake and gained significantly more weight during the study compared to the groups fed the intermediate and pericarp fraction. Also, the group fed the whole grain wheat had a significantly higher body fat content after the end of the study compared to the group fed the pericarp fraction. However, the diet supplemented with whole grain wheat resulted in higher plasma adiponectin levels compared to the diet with the pericarp fraction. There were no differences in plasma glucose, insulin, blood lipids, serum amyloid A or ghrelin between any of the seven groups at the end of the study. An oral glucose tolerance test performed after 10 weeks in all mice showed that the oral glucose tolerance was not differentially affected by the diets. Further, isolated adipocytes appeared equally sensitive to insulin irrespective of the diets. However, the diet with whole grain wheat seemed to result in a higher islet secretory capacity compared to a diet with only the pericarp fraction. A diet containing whole grain wheat has beneficial effects on plasma adiponectin levels and islet secretory capacity in the C57Bl/6J mouse despite resulting in a higher body weight and body fat content compared to a diet containing only the pericarp fraction.

Key words: Wheat, type 2 diabetes, obesity, C57BL/6J mouse

References:

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IMPACT OF \textit{Lactobacillus rhamnosus} FOR THE COLONIC FORMATION OF SHORT-CHAIN FATTY ACIDS IN RATS FED THREE DIFFERENT BARLEY FRACTIONS

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\textbf{Background}
Butyric acid and glutamine have been proposed to be important for colonic health. Pure barley $\beta$-glucans have been shown to give comparatively high amounts of butyric acid, and germinated barley foodstuff containing high amounts of $\beta$-glucans and glutamine, has been reported to reduce the inflammatory response in the colon of subjects with ulcerative colitis and also in rats with DSS-induced colitis.

\textbf{Aim}
To study the hindgut formation of carboxylic acids (CA), levels of short-chain fatty acids (SCFA) and amino acids in blood, and caecal composition of the bacterial flora in rats fed three different fractions of barley and whether the analytical parameters were changed when combined with a probiotic strain.

\textbf{Methods}
Whole grain barley (WGB), germinated barley (Malt) and a by-product of the brewing process (Brewer’s spent grain, BSG) high in dietary fibre and protein were fed to rats alone or in combination with \textit{Lactobacillus rhamnosus} 271. The amount of test material corresponded to an amount of 8\% dietary fibre in the diets and the experiment lasted for 12 days. On the final day portal blood, caecal tissue and hindgut material (caecum, proximal and distal colon) were collected. Also the content of proximal and distal colon was collected.

\textbf{Results}
The levels of butyric acid in caecum, distal colon and portal blood in rats fed Malt were higher than in the WGB and BSG groups. The plasma levels of glutamine were lower in the Malt group, and the caecal number of bifidobacteria was also lower. The caecal formation of CA increased when the probiotic strain \textit{L. rhamnosus} 271 was added to the barley fractions, though most effects were shown together with WGB. In blood, however, most pronounced effects were shown together with the malt.

\textbf{Conclusions}
Malt had the best potential to be a prebiotic substance of the three barley fractions tested, since it gave the highest levels of butyric acid.
EFFECTS OF PRE-BIOTIC EVENING TEST MEALS ON COLONIC FERMENTATION, GLUCOSE TOLERANCE, SATIETY, AND INFLAMMATORY MARKERS THE SUBSEQUENT MORNING

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Background: Low-GI foods [1, 2] and foods rich in whole-grain [3] are associated with reduced risk of type-2 diabetes and cardiovascular disease. The mechanisms and potential synergies in between these food concepts are not known.

Objective: To study the effect of barley-based bread evening meals, varying in GI and content of indigestible carbohydrates, on glucose tolerance and related parameters at a subsequent standardized breakfast.

Design: Seven test evening meals and a high-GI white wheat reference bread (WWB) were given as late evening meals to fifteen healthy subjects in a random order. Following morning, a standardized breakfast was provided, and blood sampled repeatedly during 3h for analysis of glucose, insulin, FFAs (fasting), triacylglycerides, glucagon, GIP, GLP-1, interleukin-6, interleukin-8, and adiponectin. Satiety was subjectively rated after breakfast, and gastric emptying rate were measured using paracetamol in plasma as marker. Breath hydrogen and SCFA were measured as an indicator of colonic fermentation at fasting and at 30 min.

Results: Low-GI Barley kernel based evening meals, as well as a high-GI WWB added with a mixture of barley fibre and resistant starch, improved glucose tolerance at the subsequent breakfast compared with WWB (P<0.05). At breakfast, the glucose response (IAUC 0-120 min) were inversely related to colonic fermentation as determined with H₂ breath tests (0–180 min, r=-0.23, P<0.01, butyrate 0 min; r = -0.23, P < 0.01, and acetate (mean) r=-0.20, P<0.05). In addition, the glucose response was negatively correlated with GLP-1 (AUC 0–120 min) (r= -0.26, P<0.05) and glucagon (AUC 0 – 120 min) (r = -0.18, P < 0.05), and positively correlated with fasting FFAs (r=0.37, P<0.001). IL-6 (0–180 min) was lower (P<0.01), and fasting adiponectin higher (P<0.05) at breakfast following a barley kernels based evening meal compared with WWB.

Conclusion: The results support the view that the pre-biotic content of the evening meal may induce benefits on glucose tolerance and related parameters at a subsequent breakfast through a mechanism involving colonic fermentation and generation of SCFA, where in particular butyric acid is implemented. The beneficial effect on glucose tolerance was seen also in a high-GI product with pre-biotic content similar to barley kernels. The results provide evidence for a link between gut microbial metabolism and key factors associated with insulin resistance, and the mechanism may be one explanation by which whole grain is protective against type 2 diabetes and cardiovascular disease.

Key words: glycaemic index, GI, whole grain, indigestible carbohydrates, second-meal effect, colonic fermentation, metabolic syndrome, glucose tolerance, insulin resistance

References:

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WHY ARE LOW GLYCAEMIC INDEX FOODS AND FOODS RICH IN WHOLE-GRAIN ASSOCIATED WITH REDUCED RISK OF TYPE-2 DIABETES AND CARDIOVASCULAR DISEASE?

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Foods with low glycaemic index (GI) and foods rich in whole-grain have shown beneficial effects in treatment and prevention of the metabolic syndrome, diabetes, and cardiovascular disease. Hyperglycaemia increases the inflammatory status. Also acute hyperglycaemia, as occur normally in the postprandial period, induce increased concentration of circulating cytokines (TNF-alpha, IL-6, IL-18) (Esposito, K., et al., 2002). Low-grade inflammation has been connected to adverse effects on insulin sensitivity, glucose- and lipid metabolism, and blood pressure (Heliövaara, M.K., et al., 2005). A whole grain diet has shown benefits similar to low-GI diets regarding prevention of type 2 diabetes and cardiovascular disease (McKeown, N.M., et al., 2002).

Whole-grain products are rich in indigestible carbohydrates (dietary fibre and resistant starch). Indigestible carbohydrates reach the colon and constitute substrates for fermentation by colonic bacteria, and it has been shown that indigestible carbobohydrates may improve glucose tolerance and increase satiety in a 10h perspective after the meal (Nilsson, A.C., et al., 2008). Colonic fermentation results in formation of microbial metabolites, particularly SCFA (short-chain fatty acids, mainly acetic-, propionic-, and butyric acids). Gut microbiota fermentation increase production of incretine- and satietogenic gut hormones (GLP-1, PYY), and for the first time, it was shown in our lab that ingestion of a whole grain meal (barley kernel based bread) increased the plasma concentrations of GLP-1 from the evening to the next morning. The increase in GLP-1 was seen concomitant with an increased colonic fermentation (determined as breath hydrogen excretion and increased production of SCFA (butyric acid in plasma)), and an increased glucose tolerance. It has been put forward that the enhanced production of gut peptides seen after intake of indigestible carbohydrates emanate from mechanism involving SCFA. Increased satiety is an important feature of a food product since it may prevent obesity, a major risk factor in metabolic diseases.

SCFA produced during colonic fermentation may enter the systemic circulation and beneficially influence glucose metabolism. In this context, in particular butyric acid, but also propionic acid, has been acknowledged. It is evident that both propionate and butyrate possess anti-inflammatory properties. Interestingly, we found decreased concentrations of plasma IL-6 and increased plasma concentrations of adiponec tin at breakfast following a barley kernel based evening meal. An increased inflammatory tonus is involved in the pathology of metabolic disorders and several neurodegenerative diseases. Increased inflammatory status results in a lower insulin sensitivity in the adipocytes, and hence, an increased concentrations of circulating FFA; resulting in a concomitant increased insulin resistance in muscle, liver, and pancreas. The consequences are a state of increased gluconeogenesis, increased triglyceride production, reduced insulin clearance, impaired glucose uptake in the muscle and lowering of insulin production in pancreas; resulting in hyperglycaemia, dyslipidaemia and hyperinsulinaemia. As we repeatedly have shown, both intake of low-GI foods and whole grain foods are connected with a decrease in the concentrations of plasma FFA. A hypothetic mechanism by which indigestible carbohydrates and gut microbiota may improve the systemic inflammatory status is by a lowering of the release of colonic bacteria endotoxines to the circulation. Endotoxins are known to trigger increase of metabolic disorders. Finally, whole grain foods are in addition to indigestible carbohydrates also rich in associated bioactive components such as choline, betaine, minerals, plant and sterols, vitamins, antioxidants and lignans, which may add to the beneficial effects.

Key words: Colonic fermentation, SCFA, whole grain, glycaemic index, inflammation, glucose tolerance
EFFECT OF THE GLYCAEMIC AND INSULINAEMIC INDICES OF WHEY AND CEREAL BREAKFAST MEALS ON GLUCOSE TOLERANCE AT A SUBSEQUENT LUNCH MEAL IN HEALTHY SUBJECTS

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Background: Results from meal experiments show that most low glycaemic index (GI) products improve not only acute glycaemia, but also the glucose tolerance at a following standardized meal served after 4-5 hours. One mechanism underlying this ‘second-meal’ improvement may be that a prolonged absorptive phase after a low-GI meal suppress release of free fatty acids (FFA) and thereby improve insulin sensitivity at a following meal (Wolever et al, 1995). For cereal products in general, a high glucose response will elicit a high insulin response. However, rye products have shown insulin saving properties and we usually observe low insulin levels after ingestion of rye, even if the glucose responses sometimes are high (Björck et al, 2007). On the other hand, products containing whey proteins (e.g. milk) elicit high postprandial insulin responses and low glucose levels.

Aim: To determine whether the rate of postprandial glucose delivery to the blood or the insulinaemic feature is the major determinant of glucose tolerance at a second meal in a 4h perspective.

Subjects and methods: 11 healthy, normal weight subjects (9M:2F), aged 20-25 y, were included in the study. The following test meals were served in randomized order as a breakfast after an overnight fast; white wheat bread (WWB) (high GI/high II), white pasta (low GI/low II), whole grain rye bread (high GI/low II) and WWB+whey (low GI/high II). Blood samples were collected at fasting and repeatedly during 4h after breakfast for analysis of glucose and insulin. At 4h after breakfast a standardised high-GI lunch meal was served consisting of meat balls and mashed potatoes. In addition to glucose and insulin, also free fatty acids were measured prior to the lunch and during the postprandial period (180 min).

Results: GI/II-data: WWB (100/100), white pasta (56/32), whole grain rye bread (81/56) and WWB+whey (53/140). No significant differences in GI between WWB and whole grain rye bread. Significant lower II’s after white pasta and whole grain rye bread compared with WWB. The II of WWB+whey was significantly higher than that of WWB. Results after the standardized lunch showed that only the white pasta meal was able to lower the glucose response significantly. However, there was a 32% lowering of post-lunch glycaemia also in case of the whole grain rye bread (not significant). The improved second meal glucose tolerance to white pasta can be explained by the slow release features of this product, as has been described previously (Granfeldt et al, 1991). No differences were found in insulin responses at lunch. A positive correlation was found between the FFA-levels 240 min post breakfast and the glucose AUC (0-120 min) obtained after the lunch meal.

Conclusions: As noted previously the whole grain rye bread displayed lower acute insulinaemic responses than expected from the glycaemia, suggesting that some component in rye improves insulin economy. Moreover, addition of whey protein to high GI white wheat bread significantly increased acute insulinaemia and lowered glycaemia, a phenomenon that can be exploited in the formulation of low GI cereal products. White pasta eaten as breakfast improved the glucose tolerance at a subsequent meal served 4h later. Hyperinsulinaemia induced by whey proteins, did not affect the second meal glucose tolerance, despite evoking low acute glycaemic response. The results suggest that the slow release features of cereal products/meals is important for benefits on second meal glucose tolerance in a 4h perspective, and not a low GI or II per se.

Keywords: glucose response, insulin sensitivity, wheat, rye, whey, pasta, second meal

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METABOLIC AND SATIATING PROPERTIES OF RYE AND WHEAT PRODUCTS

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Background and aim
Rye products have been shown to induce low insulin responses [1-3] and to facilitate glycaemic regulation [3]. Thus, rye products may protect against the metabolic syndrome and type 2 diabetes. The mechanism behind the well regulated blood glucose and the low insulin demand of rye products is not known, nor their potential effects on appetite regulation. In a previous Healthgrain study, there was an indication that rye kernels were more satiating than wheat kernels, not only at the acute meal situation, but also at a following, standardised meal. It is of interest to investigate appetite regulating properties of rye products further.

Study design
In the present study, both metabolic- and appetite regulating properties of rye and wheat products were investigated. The profile of the blood glucose curve was analysed using a recently introduced tool, the Glycaemic Profile (GP), taking into consideration both the duration of incremental glucose response as well as the peak value (min/mM) [3]. 10 healthy subjects were served endosperm- and whole grain rye breads, baked with and without lactic acid, boiled whole grain rye (RK) and wheat (WK) kernels and white wheat bread (WWB) as breakfasts in random order in a cross-over design. Plasma glucose, serum insulin, subjective satiety and breath hydrogen were measured in the postprandial phase. At 270 min after the breakfast, an ad libitum lunch buffet was served and the energy intake was recorded.

Results
The RK breakfast induced a lower voluntary energy intake (-16%) than WWB at lunch and also a significantly improved satiety in the early postprandial phase (0-45 min) compared to WWB. A low insulin response (II and insulin incremental peak) after breakfast was related to a lower voluntary energy intake at lunch. RK induced a significantly higher GP than wheat kernels and WWB, and indicated an improved glycaemic regulation. A high GP was related to a low insulin response (II and insulin incremental peak) and an improved late satiety (210 min). Thus, a high insulin response appears to cause a poorer glycaemic profile as well as an increased hunger and energy intake.

All rye products except endosperm rye bread with lactic acid induced higher breath H$_2$ than WWB (AUC 270-390 min). The breath H$_2$ (AUC 270-390 min) was positively correlated to the amount of dietary fiber in the breakfast and negatively correlated to the energy intake at. These results suggest that rye products are fermented in a greater extent than WWB and that a high fermentation is related to a lower energy intake.

Conclusion
The results indicate that rye products, especially in the form of whole kernel rye, show beneficial appetite regulation properties. Suggested mechanism involves low insulin response and fermentation of fibers and associated components. Poor blood glucose profiles, possibly caused by excessive insulin, appear to induce hunger.

References:
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(3) Rosén L et al. Endosperm and whole grain rye breads are characterized by low post-prandial insulin response and a beneficial blood glucose profile. Nutrition Journal 2009, 8:42.
EFFECTS OF HEALTHGRAIN DIET ON METABOLIC RISK FACTORS IN SUBJECTS AT RISK FOR TYPE 2 DIABETES


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Repeated consumption of meals with high glycemic response may lead to the development of insulin resistance and even increase the risk of type 2 diabetes (Ludwig 2002). The aim of this study was to determine the effects of a diet with multiple beneficial characteristics of whole grains (healthgrain diet) on glucose and insulin metabolism in subjects with the metabolic syndrome.

Eighty five subjects were recruited into a 12-week dietary intervention study. The inclusion criteria were age 40-65 y, BMI 26-39 kg/m², and at least three of the features of the metabolic syndrome (NCEP Adult Treatment Panel III, 2001). After a baseline period of two weeks, the subjects were randomized into a healthgrain and control group. In the healthgrain group, the subjects consumed cereal products with low postprandial glucose and insulin response. The products were breads filling up to 20-25 % of total energy intake (40 % share of endosperm rye bread, 10 % share of sourdough wholemeal wheat bread, and 50 % share of a selection of commercial rye breads). Wholemeal pasta was consumed twice a week, and the intake of oat biscuits was voluntary. In the control group, a selection of refined wheat breads and potatoes were consumed. Otherwise, the habitual diet and living habits were kept unchanged in both groups.

The subjects filled in a 4-d food record during the baseline period and three times over the intervention. Anthropometric measurements were performed, fasting blood samples taken, and blood pressure measured at the beginning and every four weeks over the intervention. A 2-hour oral glucose tolerance test (OGTT) and frequently sampled intravenous glucose tolerance test (FSIGT) were performed at weeks 0 and 12 to measure glucose and insulin metabolism.

Altogether 69 subjects finished the study: 34 subjects in the healthgrain group and 35 subjects in the control group. Dietary compliance during the intervention was good in both groups. The total consumption of test breads were 185 g/d and 194 g/d in the healthgrain and control groups, respectively. Hence, the intake of dietary fibre in the healthgrain group was higher (27 g/d) than in the control group (18 g/d) during the intervention. There was no difference in the intake of other nutrients between the groups.

There were no significant changes in anthropometric measurements, blood pressure, blood lipids, or fasting glucose and insulin concentrations over the study. In the beginning of the intervention, there was no difference in the OGTT between the groups. At the end of the intervention fasting glucose concentration was similar in both groups (6.1±0.5 and 6.2±0.5 mmol/l for the healthgrain and control group, respectively). However, there was a tendency towards improved glucose homeostasis during the OGTT in the healthgrain group (glucose concentration at 60 and 120 min 8.3±2.6 and 6.1±1.9 mmol/l, respectively) as compared with the control group (glucose concentration at 60 and 120 min 9.2±2.0 and 6.7±2.2 mmol/l, respectively), although this did not receive statistical significance (p=0.17 and p=0.31 at 60 and 120 min, respectively).

Key words: dietary intervention, metabolic syndrome, cereal products, oral glucose tolerance test

References:

SOURDOUGH FERMENTATION OF WHOLEMEAL WHEAT BREAD DECREASES GLYCEMIC RESPONSES IN SUBJECTS WITH IMPAIRED GLUCOSE METABOLISM

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Glycemic responses to most of the conventional breads are known to be high, including breads made of wholemeal flour (Foster-Powell et al. 2002). Processing is known to affect the responses (Hallfrisch et al. 2000). The aim of this study was to investigate postprandial responses of wholemeal wheat breads produced by using different baking technologies.

Eleven subjects with impaired glucose metabolism and at least two features of the metabolic syndrome were served test meals consisting of wheat breads made of 100% flour from peeled (3.5%) kernels. The breads were baked by straight dough or sourdough fermentation method, and with or without addition of xylanase during mixing of dough. White wheat bread was used as reference. Each test meal contained 50 g of available carbohydrate and they were served to subjects in random order one week between each occasion. The blood samples for measuring plasma glucose and serum insulin concentrations were drawn over four hours.

The wholemeal bread from peeled wheat produced using sourdough fermentation resulted in the lowest postprandial glucose and insulin responses (treatment x time; p<0.001 and p<0.05, respectively) among the four tested breads. Plasma glucose concentration was lower at time points 45, 60, 90 and 120 min (p<0.05) and higher at 240 min (p<0.01) as compared with the reference. Furthermore, serum insulin concentration was lower at the time point 90 min (p <0.05). The postprandial responses were not improved by addition of xylanase.

Sourdough fermentation resulted in a bread with the most favourable postprandial glucose and insulin responses among the three tested wholemeal wheat breads. The reduced postprandial responses achieved by sourdough fermentation may further improve the suitability of wholemeal wheat bread for persons with impaired glucose metabolism.

Key words: wholemeal wheat bread, sourdough fermentation, glycemic responses

References:

Evening meals rich in non-digestible carbohydrates (NDC) have been shown to lower postprandial glucose concentrations after ingestion of high glycemic index breakfasts. This is linked to colonic fermentation of NDC, but the underlying mechanism is not fully elucidated. We examined in which way glucose kinetics and related factors are changed after the breakfast due to colonic fermentation.

In a cross-over design 10 healthy male subjects ingested as an evening meal white bread (WB) or cooked barley kernels (BA). In the morning after intake of 50 g $^{13}$C-enriched glucose the dual isotope technique was applied to determine glucose kinetics. Plasma insulin, interleukin 6 (IL 6), tumor necrosis factor-α (TNF-α), short-chain fatty acid concentrations and hydrogen in breath were measured.

The glucose response after the glucose drink was 29 % lower after the BA evening meal. The insulin response was the same, whereas tissue glucose uptake was 30 % higher after the BA evening meal, indicating increased insulin sensitivity. The 4-h mean postprandial IL 6 and TNF-α concentrations after the glucose drink were higher after the WB evening meal. Butyrate concentrations as well as hydrogen in breath were higher in the morning after the BA evening meal. In healthy subjects factors related to colonic fermentation of NDC increase peripheral insulin sensitivity and moderate glucose-associated inflammation.
RESISTANT STARCH FORMATION IN PUMPERNICHEL BREAD FROM HIGH-AMYLOSE WHEAT AND ITS EFFECT ON GLUCOSE AND INSULIN RESPONSES IN HEALTHY SUBJECTS

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Background: There is an established correlation between high postprandial glucose levels and increased risk of cardiovascular disease (CVD). Increased consumption of slowly digested carbohydrates and enzyme-resistant starch (RS) can improve metabolic control, and reduce risk of e.g. CVD, obesity and diabetes. The suggested mechanisms for these health benefits are a lower postprandial glucose and insulin responses as well as increased fermentative activity in the colon. The colonic fermentation leads to production of short chain fatty acids, which are known to have several beneficial effects in the body. Previous studies on barley, corn and rice indicate that products based on high-amylose genotypes reduce the postprandial glycaemic response and increase levels of RS. Baking at low temperatures and presence of lactic acid appear to favour RS formation. Long-time/low-temperature baking such as for pumpernickel bread with added lactic acid is therefore thought to be suitable for optimization of starch digestibility and RS content in bread.

Aims:
• To compare the amount of RS formed in bread baked on high-amylose wheat (HAW, 38 % amylose), compared to bread baked on commercial whole grain wheat. The influence of adding lactic acid was investigated in bread baked on high-amylose wheat.
• To investigate the postprandial glucose and insulin responses in healthy subjects to pumpernickel bread based on the HAW genotype, with and without addition of lactic acid.

Method: Four different bread products were prepared, three long-time baked (20 h, 120°C) pumpernickel breads and one conventionally baked reference bread from white wheat (REF). Two of the long-time baked breads were based on high-amylose whole grain wheat, one of them containing lactic acid (HAW-la) and the other not (HAW). The third long time baked bread was based on commercial whole grain wheat (WGW). The amount of total, available and resistant starch was determined in vitro. Portions of 50 g available starch (calculated as total starch minus RS) from each of the bread products were randomly served to 14 subjects (7 men/7 women) after a nightlong fast. Postprandial glucose and insulin responses were measured during 3 hours after ingestion by capillary blood testing. Potential differences in glucose and insulin responses were analysed and compared for the four different bread types.

Results: The data analysis is on-going and results and conclusions will be presented on the poster at the HealthGrain conference in Lund.

Key words: Resistant starch, amylose/amylopectin ratio, glycaemic response, insulinaemic response

References:

EFFECTS OF THE REGULAR CONSUMPTION OF WHOLEMEAL WHEAT FOODS ON CARDIOVASCULAR RISK FACTORS IN HEALTHY PEOPLE

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Background: The intake of wholemeal foods is consistently associated with reduced risk of type 2 diabetes and cardiovascular diseases in epidemiological studies, although the mechanisms of this association are unclear.

Aim: To compare in healthy subjects the metabolic effects of a diet rich in wholemeal wheat foods vs. a diet containing the same products in refined form.

Methods: Fifteen healthy individuals (12M/3F), mean age 54.5±7.6 yrs, BMI 27.4±3.0 kg/m² (M±SD), participated in a randomised sequential crossover study. After a two-week run-in period, the participants were randomly assigned to two isoeenergetic diets with similar macronutrient composition, one rich in wholemeal wheat foods and the other with the same foods but in refined form (cereal fibre 23.1 vs. 9.8 g/day). After the treatment periods (each lasting three weeks) plasma glucose and lipid metabolism, antioxidant activity, acetic acid, magnesium, adipokins, incretins and hs-c-reactive protein (hs-CRP) were measured at fasting and during 4 hours following a standard test meal (kcal 1103, protein 12%, CHO 53%, fat 35%) containing wholemeal or refined wheat foods, respectively.

Results: Of the fasting and postprandial plasma parameters only plasma glucose was significantly affected by the treatment (slightly lower at 240 minutes after the refined wheat food meal as compared to the wholemeal wheat food meal). On the other hand, both total (-4.3%; p<0.03) and LDL (-4.9%; p<0.04) cholesterol levels were lower after the wholemeal diet than after the refined wheat diet at fasting.

Conclusions: Consumption of wholemeal wheat foods for 3 weeks reduces significantly fasting plasma cholesterol as well as LDL cholesterol levels in healthy individuals without major effects on glucose and insulin metabolism, antioxidant status and sub-clinical inflammation markers.

Key words: wholemeal cereals, glucose metabolism, insulin metabolism, lipid metabolism, cereal fibre

References:

EFFECTS OF WHOLE GRAIN INTAKE ON INSULIN, GLUCOSE AND LIPID METABOLISM IN SUBJECTS WITH METABOLIC SYNDROME (MetS) LIVING IN NAPLES (preliminary results).

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Background: The benefit of whole grain intake in the prevention of type 2 diabetes seems to depend on the improved insulin sensitivity; however whether this effect is independent of the action of whole grain on body weight is not clear.

Aim: To evaluate the effects of a 3-month dietary intervention using whole grain products on insulin, glucose and lipid metabolism in subjects with MetS living in Naples, Italy.

Subjects and Methods: Sixty-one subjects of both genders, age 40-65 years, with MetS (ATPIII-NCEP criteria) participated in the study. After a 4-week run-in, participants were randomly assigned, according to a parallel design, to either an Experimental diet based on whole grain products and low glycemic index (GI) or a Control diet based on refined cereal products and high GI (each treatment lasting 3 months). The two isoenergetic diets had similar nutrient composition but the Experimental diet was richer in cereal fibre (32 vs 13g/day), had a lower GI (42 vs 75) and glycemic load (GL) (117 vs 210). An intravenous glucose tolerance test (FSIVGTT) and a standard test meal were carried out, on separate days, at the beginning and at the end of the dietary period, to measure the effects of the intervention on glucose and insulin metabolism, plasma lipids and markers of inflammation. The standard test meal consumed at the beginning of each intervention was the same for all participants and based on refined wheat foods whereas at the end of the intervention it was composed of refined wheat foods with high GI or whole wheat products with a low GI, according to the dietary treatment.

Results: Seven participants dropped-out (2 in the Experimental and 5 in the Control diet group), whereas 28 subjects in the Experimental diet group and 26 in the Control diet group completed the intervention. The Experimental and Control group was not different at run-in for body weight (85±19 and 88±17 kg), BMI (31.9±6 and 31.6±5 kg/m²), waist circumference (107±15 and 106±12 cm), fasting plasma levels of glucose (104±11 e 105±10 mg/dl), cholesterol (201±46 e 198±35 mg/dl), HDL-chol (43±13 e 38±7 mg/dl), triglyceride (148±141 e 147±61 mg/dl) and C-Reactive Protein (CRP) (3.4±2.9 e 2.4±1.5 mg/l). Compared to run-in, these parameters did not change significantly after 3 months of diet in the two groups. At run-in, the Experimental and Control diet groups were not different for insulin sensitivity index (IS) (2.5±1.9 and 3.6±2.4) (data available on only 18 and 14 subjects, respectively), Glucose Effectiveness (GE) (0.02±0.005 and 0.02±0.01) and first phase insulin secretion (IAUC 1044±768 and 590±305 µU/ml*19 min), and Diffusion Index (115±76 and 205±370). Compared to run-in, these parameters did not change significantly after 3 months of intervention in either group and between the two groups. Test meal results: Plasma triglyceride response was similar in the two groups at run-in, but in the Experimental diet group plasma triglyceride levels decreased after 3 months compared to the run-in period (p=0.03); therefore the change in triglyceride levels induced by the two treatments was statistically significant (p=0.017). No difference in GLP-1 and hs-CRP plasma response was observed at run-in and after 3 months of treatment in either group and between groups.
**Conclusions**: These preliminary results do not seem to indicate that the long term consumption of a diet based on whole grain products has a greater impact on insulin metabolism in subject with stable body weight; conversely, this type of diet improves significantly postprandial triglyceride metabolism with possible important implications for the overall cardiovascular risk factor profile.

**Key words**: whole grain cereal, insulin metabolism, lipid metabolism, metabolic syndrome.

**References**:


EFFECT OF A HYPO-CALORIC DIET RICH IN WHOLE GRAIN FOODS ON WEIGHT LOSS, BODY COMPOSITION AND CARDIOVASCULAR RISK IN POSTMENOPAUSAL WOMEN: A 12 WEEKS RANDOMISED CLINICAL TRIAL

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Background and objective: In observational studies, a high intake of whole grain foods is associated with a lower body mass index (1) and lower risk of developing cardiovascular disease (2). However, only few clinical trials have investigated if these associations are causal. We studied whether inclusion of wheat based whole grain foods in an individualised hypo-caloric diet enhances weight loss and improves cardiovascular risk factors.

Study design: In this open-labelled randomised trial, 79 overweight postmenopausal women with metabolic syndrome features were prescribed a hypo-caloric diet with a daily deficit of min. 1,250kJ/d. After a 2 weeks run-in period the subjects were randomly assigned to 12 weeks supplementation with refined wheat (RW) or wholemeal wheat (WW) products corresponding to 2000 kJ/d. Blood samples and anthropometric measures were assessed at 0, 6 and 12 weeks.

Results: After 12 weeks, body weight decreased significantly in the RW (-2.8±0.3kg) and WW (-3.6±0.5kg) groups (P<0.01), but did not differ between the groups (P=0.15). The decrease in body fat percentage assessed by DXA scanning was greater in the WW (-6.8%) compared to the RW group (-4.8%) (P=0.03). Both total- and LDL-cholesterol increased by ~5% in the RW group but remained unchanged in the WW group (P<0.05), insulin, glucose, and C-reactive protein levels did not change in either group.

Conclusions: Both hypo-caloric diets were effective in inducing weight loss, but the diet with whole grain foods was more effective in reducing body fat. The diet with no whole grains increased total and LDL-cholesterol, two important risk factors of cardiovascular disease. These results point toward a role for whole grain consumption in energy balance and prevention of cardiovascular risk.

Key words: whole grain, wholemeal wheat, obesity, cardiovascular risk

References:
WHOLEMEAL WHEAT BREAD AND PASTA - EFFECT ON POSTPRANDIAL GLYCEMIA, APPETITE, AND SUBSEQUENT AD LIBITUM ENERGY INTAKE IN YOUNG HEALTHY ADULTS

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Background: The role of wholegrain foods in health and disease has received much attention in recent years, and has been proposed to play a role in energy regulation through lowering of postprandial glycemia and appetite.

Objective: To study the effect of iso-carbohydrate and iso-caloric meals based on wholemeal wheat breads and pasta and their refined counterparts on postprandial glycemia, appetite and ad libitum energy intake.

Design: Ten women and six men (age: 24.2±3.6; BMI: 21.7±2.2 kg/m²) with normal fasting glucose completed this 4-way crossover meal study. The test meals provided 50g carbohydrates and 2MJ each and consisted of refined wheat bread (RWB), wholemeal wheat bread (WWB), refined wheat pasta (RWP) and wholemeal wheat pasta (WWP) served with cheese and water after an overnight fast. Subjective appetite sensation and glucose was assessed for 180 minutes after which an ad libitum lunch meal was served and energy intake registered.

Results: Glucose responses were similar for wholemeal and refined products, but pasta meals gave significantly lower glucose responses 30 to 90 minutes after the test meal. WWB significantly reduced appetite and specific desires to eat sweet, savory, salty and fat-rich foods compared to RWB, but no effect was seen of WWP. No differences in ad libitum energy intake at the subsequent lunch meal were observed.

Conclusion: The results show that WWB rich in insoluble fiber increased subjective satiety unrelated to the glycemic response and support a role in energy balance regulation for wholemeal products and propose dietary fiber content as responsible factor.

1. Conflict of interest:  
None disclosed/The authors declare no conflict of interest.

2. Funding:  
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A WHOLEGRAIN CEREAL-RICH DIET INCREASES PLASMA BETAIN, AND DECREASES TOTAL AND LDL-CHOLESTEROL COMPARED TO A REFINED GRAIN DIET


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Background: Epidemiological studies have repeatedly found that wholegrain cereal foods reduce the risk of several lifestyle related diseases, but mechanisms and consistent clinical outcomes are elusive.

Goal: To compare the effects of a wholegrain-rich diet to a matched refined grain diet on plasma and bowel health parameters.

Design: A crossover study, with a one week wholegrain free diet, followed by a two week controlled diet with either a wholegrain-rich or refined grain based diet (both diets the same except for the use of wholegrain or refined grain foods), followed by a two week wholegrain free diet. Subjects undertook a post-prandial challenge on day 8 of the controlled diet.

Subjects: 17 healthy subjects completed the study (11 female, 6 male)

Results: The wholegrain cereal rich diet decreased plasma total and LDL cholesterol (both P<0.05), but did not change plasma HDL, triglycerides, fasting glucose, or C-reactive protein. Plasma betaine was elevated after one week (P<0.01) and alkylresorcinol concentrations were elevated during the wholegrain diet period (P<0.0001), with no change to plasma homocysteine. No carry-over effects were observed in plasma after one week of a non-wholegrain diet. C. Leptum populations in faeces were increased after the wholegrain diet (P<0.05), along with slightly decreased faecal water pH (P<0.1) and increased stool frequency (P<0.0001) compared to the refined grain diet.

Conclusions: A short controlled intervention trial with a variety of processed wholegrain products was able to improve biomarkers of cardiovascular disease riskcompared to a refined grain diet. Changes in parameters related to faeces and increases plasma betaine and alkylresorcinols point to both fibre and phytochemical components of wholegrains being important in mediating any potential health effects.
UPTAKE OF METHYL DONORS (FOLATE, BETAINE AND CHOLINE) FROM WHEAT BRAN AND ALEURONE IN HUMANS

EM Keaveney

on behalf of the HEALTHGRAIN project team, University of Ulster, Coleraine

Epidemiological evidence indicates that a high intake of wholegrain wheat or wheat bran products is associated with a lower incidence of chronic diseases including heart disease and diabetes\(^1\). The mechanisms of action, however, remain unclear. Wheat bran fraction, and particularly the aleurone fraction, are sources of folate, choline and betaine, components which act as physiological methyl donors. Two postprandial studies were conducted to assess the uptake of these methyl donors from minimally processed wheat bran and wheat aleurone and from wheat aleurone incorporated into a bread product. Study 1 used minimally processed bran and aleurone fractions (boiled in water) and Study 2 used aleurone-enriched bread.

Both studies were conducted in healthy adults and followed the same randomised, within-subject crossover design, with one week washout between treatments. In Study 1, subjects (n=14; 27.8 years; BMI 22.7kg/m\(^2\)) consumed either 50g wheat bran, 50g wheat aleurone or a control product, balanced for macronutrients and fibre. To improve palatability, all products were boiled with water (10 min) before serving warm. In Study 2, subjects (n=13; 33.9 years; BMI 25.0kg/m\(^2\)) consumed either aleurone-enriched bread (containing 50g aleurone) or a balanced control bread. The breads were leavened with sodium bicarbonate and baked at 200°C for 25 min. On each study occasion, following an overnight fast, subjects provided baseline blood samples before consumption of the products. Further blood samples were taken at 0.5, 1, 2 and 3h. Plasma was analysed for folate (microbiological assay), choline and betaine (LC-MS/MS), and data were analysed by repeated measures ANOVA.

Highly significant increases in plasma betaine were observed in both studies (P<0.001). In Study 1, plasma betaine concentrations increased at 1h to 2-fold and 2.5-fold baseline after consumption of the bran and aleurone fractions, respectively. In Study 2, plasma betaine concentrations increased at 2h to 2.5-fold baseline after consumption of the aleurone-enriched bread. Neither study showed significant increases in plasma folate or choline.

Results suggest that minimally processed wheat bran and particularly wheat aleurone, have the potential to significantly increase postprandial plasma betaine. Also, both minimally processed aleurone, and aleurone-enriched bread appear to impact on plasma betaine to a similar extent. Betaine functions as a methyl donor and has been shown to lower elevated plasma homocysteine\(^2\), which is an independent risk factor for heart disease and stroke\(^3\). The results of these studies may provide a plausible mechanism for the observation that wholegrain wheat or wheat bran products reduce chronic disease risk.

Keywords: wheat bran; wheat aleurone; methyl donors; betaine; chronic disease

References:

This study is financially supported by the European Commission 6th Framework Programme project HEALTHGRAIN (FP6-514006).
EFFECTS OF COMMERCIAL PROCESSING OF BARLEY ON LEVELS OF PHENOLIC ACIDS AND ANTIOXIDANT ACTIVITY: ROLE OF DIETARY PHENOLIC ACIDS ON ACTIVATION AND INHIBITION OF NUCLEAR FACTOR KAPPA B

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Convincing evidence suggest that consumption of whole grains lowers risk of diseases such as cardiovascular disease, diabetes, obesity, hypertension and gastrointestinal cancers (Jones, 2007). In addition to dietary fibre, whole grains contain minerals and phytochemicals including phenolic acids. Phenolic compounds possess antioxidant properties that may help in protection against reactive oxygen species (ROS) involved in different diseases. Cereal grains contain both extractable (free) as well as covalently linked phenolics.

As with other cereal grains, barley requires one or more processing procedures in order to reduce or change the kernels into a usable, edible form. Several commercial processing and milling procedures are available. Barley may be milled by pearling, flaking, cutting, grinding, roller milling and further processed by air classifying, sieving, extrusion, and infrared heating. The transcription factor nuclear factor kappa B (NF-κB) play a critical role in stress-, immune- and inflammatory responses. Also, NF-κB is identified as a promising therapeutic target both in cancer and chronic inflammation. We used monocytes stably transfected with a NF-κB-luciferase reporter construct in testing cereal extracts for NF-κB modulators (Hole et al., 2009).

The objectives of the present study were to investigate the effect of three commercially used processes (namely pearling, infrared heating and flaking and extrusion) on levels of phenolic acids and antioxidant activity in barley. Furthermore, different phenolic acids were tested for their ability to induce basal NF-κB activity to produce preconditioning effect, or inhibit disease related NF-κB activity.

In barley most of the phenolic acids are found in the bound form, giving a ratio of bound to free phenolic acids of 60 – 650. Pearling reduced the concentration of free p-coumaric acid (pCA) with 45 % , caffeic acid (CA) with 31 % and ferulic acid (FA), sinapic acid (SA) with 20 % and 29 % soluble antioxidant activity (FRAP – S) was lost. Pearling can be used to concentrate free phenolic acids in pearling flour with 3.6 – 5.9 times and soluble antioxidant activity FRAP – S with 2.1 times. Pearling decreased the concentration of bound phenolic acids with 15 – 67 % and individual diferulic acid (DFA) with 15 - 23 %. Also bound antioxidant activity (FRAP – IS) was lost after pearling with 50 %. As for free phenolic acids pearling process can be used to concentrate bound phenolic acids in pearling flour with 1.2 - 5.8 times and FRAP-IS with 3.8 times. Infrared heating and flaking had a very small effect on free and bound phenolic acids and antioxidant activity. Extrusion increased the concentration of free phenolic acids with 1.3-2.7 times and bound phenolic acids with 1.2 – 1.5 times. Bound antioxidant activity FRAP-IS increased with 25 % but free antioxidant activity FRAP – S decreased with 30 %. P-CA, FA, SA and 8,5-DFA significantly increased the basal NF-κB activity. Low concentrations of 8,5-DFA (10 mg/l) gave the same increase in basal NF-κB activity as 25 and 70 mg/l for FA and p-CA, respectively. High concentrations of FA, p-CA (70 mg/l) and 8,5-DFA (10 mg/l) reduced the LPS-induced NF-κB activity.

Generally, 8,5-DFA, FA and p-CA had the largest effect on both basal and LPS-induced NF-κB activity.

Keywords: pearling, infrared heating, flaking, extrusion, total antioxidant activity, NF-κB activity.

References.

INTAKE OF FIBER FROM CEREALS PROTECTS AGAINST COLORECTAL CANCER IN THE HELGA COHORT

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Intake of dietary fiber has been hypothesized to reduce colorectal cancer (CRC) risk. Potential mechanisms include dilution of fecal carcinogens, reduction of bowel transit time, production of short chain fatty acids or binding of carcinogenic bile acids (1). While intervention studies using fiber supplements have largely failed to find an association, results from prospective, observational studies indicate a possible protective role for dietary fiber consumption in relation to CRC (2). The present study examined associations between intake of dietary fiber from various sources in the diet (cereals, fruits, and vegetables) and risk of colon and rectal cancer in a prospective cohort study.

Materials and methods

The HELGA cohort consists of the Diet, Cancer and Health cohort (Denmark), The Northern Sweden Health and Disease Study (Sweden) and the Norwegian Women and Cancer Study (Norway) - all three are part of the European Prospective Investigation into Nutrition and Cancer (EPIC). The current topic has been investigated previously in an EPIC study (3), but the present study project included more cancer cases from updated registries and had a specific Nordic focus. The cohort was followed for cancer incidence using information from cancer registries, patient registries and cause of death registries until ultimo 2006. Baseline intake of dietary fiber from various sources was estimated based on a validated food frequency questionnaire, and associations between exposures and cancer incidence rate ratios were based on Cox proportional hazards models. Models presented are multivariable, adjusted for common CRC risk factors.

Results

Data analysis is still ongoing, and the following results are preliminary.

In total 116,399 persons were included in the analyses, of which there were 739 CRC cases. Cases had a higher BMI, lower education, higher meat and alcohol intake, and more were smokers. We found that intake of dietary fiber overall and fiber from cereals, but not fiber from fruits or vegetables, was associated with lower risk of CRC. This association was also seen for colon cancer alone, where the strongest association was seen for proximal colon cancer. A lower colon cancer risk was seen for higher intake of total fiber (IRR per 5 g/d: 0.93, 95% CI: 0.87-0.99). Higher intake of cereal fiber per 2.5 g/d was associated with lower risk (IRR (95% CI) of CRC: 0.96 (0.92-0.99) and CC: (0.94 (0.89-0.98). No associations were seen for rectal cancer alone.

Key words: dietary fiber, colorectal cancer

References:

CEREAL FIBER INTAKE IN MEN AT THE RISK AGE OF PROSTATE CANCER

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Background: Prostate cancer (PC) is the second cancer as the cause of cancer-related death in men both in western countries and in Latvia. Epidemiological studies show that fiber and particularly cereal fiber rich diet decreases the risk of prostate cancer, but the findings are inconsistent.\textsuperscript{1,2}

Objective: To estimate the intake of total fiber and separately cereal fiber and to determine cereal fiber sources in men at the risk age of PC and without findings of PC.

Methods: Setting: Latvia, city Riga. Subjects: 83 men aged 45 till 79 (mean age 59.8 years), PSA (Prostate Specific Antigen) in serum 0.311 - 4 µg/L, DRI (digital rectal examination) – no data about PC, living at home, eating habitual food, no data about prostate cancer in family. Usual dietary fiber, other nutrients and total calorie intake was assessed using 147-item country-specific food frequency questionnaire (FFQ) design with emphasis on cereal consumption. Subjects were interviewed using picture folder for the assessment of portion size. Nutritional data were processed on the originally developed software, using data base of the German Nutrient Data Base (BLS) from Max Rubner-Institute (MRI). The BMI (body mass index) of men was determined.

Results: The mean data: BMI 29 kg/m\textsuperscript{2}, the total energy intake 3200 kcal, total dietary fiber intake 35.2 g/d (11g/1000kcal), insoluble fiber 22.6 g/d (7.1g/1000kcal), soluble fiber 12.6 g/d (3.9g/1000kcal). Cereal fiber intake was 24.9 g/d (7.8g/1000kcal), from rye bread 10.5 g/d (3.3g/1000kcal), insoluble fiber 5.1 g/d (1.6g/1000kcal), soluble fiber 4.7 g/d (1.5 g/1000kcal) from rye bread.

Conclusion: The main food source of dietary fibre was cereals (70.7\%), especially rye bread accounting 42.2\% of cereal fiber and 29.8\% of total fiber intake. The results show that rye bread is the most important source of dietary fibre for aged men in Latvia. More research is needed to understand better potential protective role in prostate cancer genesis.

Keywords: cereal fiber, total fiber, prostate cancer

References:
PREBIOTIC EFFECTS OF AXOS AND RS ON OVER-NIGHT GLUCOSE TOLERANCE

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Background: Previously it has been shown that low glycaemic index (GI) cereal products that are rich in whole grain beneficially affect glucose tolerance, satiety and inflammatory markers in a perspective from evening meal to breakfast (Nilsson et al 2008). Not only kernel based products were shown to beneficially influence overnight glucose tolerance, but also flour based bread with corresponding levels of indigestible carbohydrates. The effect was suggested to be related to colonic fermentation of dietary fiber (DF) and resistant starch (RS). Furthermore, dietary supplementation with RS has shown to improve insulin sensitivity in healthy subjects possible due to elevations in the systemic concentrations of both ghrelin and short chain fatty acids (SCFA) (Robertson et al 2005). Arabinoxylan-oligosaccharides (AXOS) are degradation products of arabinoxylans, formed amongst others during enzymatic treatment of wheat bran. In vitro work by Sanchez et al (2009), suggest that AXOS have prebiotic effects and increase formation of beneficial SCFA, such as butyric- and propionic acids. In addition, AXOS was shown to beneficially modulate levels of health-promoting bacteria.

Objective: To evaluate the impact of including AXOS (average degree of polymerization:5) from wheat, RS (High-Maize 260) or a combination of AXOS and RS in bread evening meals, on glucose tolerance and related metabolic markers at a subsequent standardized breakfast.

Design: Twenty normal weight and healthy volunteers (10M:10F) aged 23.0±1.6y participated in this randomized cross-over meal intervention. The test products served as evening meals were; 1) High-GI white wheat bread (WWB), 2) WWB baked with 11.7% dry matter of AXOS and 11.4% dm of RS, 3) WWB incl. 22.5% dm of AXOS, and 4) WWB incl. 21.9% dm of RS (2RS). At a subsequent standardized WWB breakfast, both fasted and postprandial blood samples were collected. In addition, subjective appetite ratings were performed and breath hydrogen excretion as a marker of colonic fermentation was measured.

Results: So far the results for blood glucose, breath hydrogen excretion have been evaluated. Although not statistically significant, there was a tendency that addition of AXOS to WWB could improve overnight glucose tolerance. This was accompanied by a highly significant increase in breath hydrogen excretion after both AXOS bread products compared to WWB. Surprisingly, the high RS-level in the 2RS-product did not increase breath hydrogen excretion in the morning. Results for insulin and free fatty acids as well as appetite ratings are expected to be ready to present at the Healthgrain conference in Lund Conclusions: The absence of increase in hydrogen excretion in the morning after a high evening dose of RS suggests that the fermentation occurs at an earlier or later time point. AXOS has an interesting prebiotic potential and should be further evaluated.

Conclusions: The absence of increase in hydrogen excretion in the morning after a high evening dose of RS suggests that the fermentation occurs at an earlier or later time point. AXOS has an interesting prebiotic potential and should be further evaluated.

Key words: AXOS, RS, glucose tolerance, colonic fermentation, insulin resistance

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BENEFITS OF CEREAL BRANS

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Bran is an integral part of the grain contributing from about 7% of the kernel in corn to nearly 33% of the kernel in oats. Bran forms the outer layer of the grain and protects the grain from insects, pests and adverse climatic conditions. Bran layers are a store house of nutrients, from fiber to phytochemicals. The type and amount of nutrients and the health benefits of bran vary with species as well as agronomic conditions. The health benefits of bran are linked to its composition of fiber and phytonutrients. Kahlon (1) has demonstrated that the in-vitro bile acid binding capacity of bran varies with type of grain, with wheat bran having the highest binding capacity. Several studies have shown that bran has beneficial effects on laxation, cholesterol lowering, weight management and blood glucose attenuation. The small chain and soluble polymers in bran fibers act as a prebiotic and are good substrates for intestinal microflora. Fortification of food products with cereal brans can affect sensory quality, but new processing technologies facilitate the addition of bran to more foods. A review of benefits of bran and its components will be presented.

References:
COMPARISON OF WHOLE GRAIN SUSTAGRAIN BARLEY, WHOLE GRAIN WHEAT, AND Refined Rice-based Breakfast and Snack Foods on Short-term Satiety and Energy Intake

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\(^1\) University of Minnesota, St. Paul, MN
\(^2\) ConAgra Foods, Omaha, NE

Sustagrain barley is a waxy, hulless type of barley that has higher total dietary fiber (30%), beta-glucan (12%) and reduced starch content (30%) compared to other cereal grains. Sustagrain barley can be used in formulating a variety of food products, including cereals, snacks, breads and side dishes. The purpose of this study was to compare the effect of consumption of whole grain Sustagrain barley, whole grain wheat and refined rice-based cereal and snack foods on satiety and energy intake at the lunch meal. Forty-seven healthy subjects consumed a hot cereal breakfast and mid-morning granola snack mix made of barley, wheat, or refined rice, followed by an ad libitum buffet lunch using a crossover design. Plate waste was used to measure energy intake at lunch. Hunger, fullness, desire to eat, amount of food consumed, and thirst were assessed using a modified Visual Analog Scale (VAS) before and after the breakfast, snack and lunch. Energy intake at lunch did not differ among products. There were no differences in the area under the time curve in modified VAS scores among products for any parameter. However, subjects reported significantly less hunger before lunch compared to their hunger before breakfast when consuming the barley, but no significant reduction in hunger before lunch after consumption of wheat or rice. The intake of a whole grain high-fiber barley, whole grain wheat, or refined rice breakfast and snack did not decrease energy intake at the lunch meal, but consumption of whole grain high-fiber barley foods significantly decreased hunger before lunch. Longer term studies are needed to assess the impact of whole grain foods on energy intake, satiety and weight management.

Key Words: Whole grain, satiety, Sustagrain barley, wheat, rice, energy intake
Poster Section 4
Consumer aspects

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INTAKE AND DETERMINANTS OF INTAKE OF WHOLE GRAINS IN NORWAY, SWEDEN AND DENMARK

C. Kyrø¹, G. Skeie² and A. Olsen¹

¹ Danish Cancer Society, Institute of Cancer Epidemiology, Copenhagen, Denmark
² Institute of Community Medicine, University of Tromsø, Norway

Background: Intake of whole grains (WG) has been associated with a lower risk of developing chronic diseases such as type 2 diabetes, cardio-vascular disease, obesity and some types of cancer¹. Furthermore, the intake of WG has been associated with lifestyle and socio-economic factors as well as a generally healthier lifestyle². Because of the numerous health benefits of WG, knowledge about the consumption and the determinants of intake is needed. Much of the research on the health effects of WG has been done in the USA. In the Scandinavian countries, however, the population consumes much more WG and therefore serves as a better basis for research on whole grain foods. The present study described the intake of WG in Norway, Sweden and Denmark. Furthermore the study revealed the socio-economic, lifestyle and dietary determinants of intake of WG with the purpose of identifying confounders of importance when studying health benefits of WG.

Methods: The established “HELGA cohort” (n=120,016), consisting of the following three prospective cohorts, was used in the present study: The Norwegian Women and Cancer Cohort, The Northern Sweden Health and Disease Cohort and the Danish Diet, Cancer and Health Cohort. Intake of WG and determinants of intake of WG was assessed by using data from a single 24-hour dietary recall (n=8702) of a randomly selected part of the HELGA cohort. Multiple linear regression analyses were used for the determinant analyses with the total intake of WG as the dependent variable.

Results: Among women, the median intake of WG products (grams of WG product/day) was highest in Norway (114 g/day), second highest in Denmark (108 g/day) and lowest in Sweden (64 g/day) (p<0.001). For men (no data available for Norwegian men), the intake was highest in Denmark (138 g/day) and lowest in Sweden (79 g/day) (p<0.001). The median intake of WG (grams of WG/day), which is estimated by using the WG content of each WG product, among women was highest in Norway (44 g/day), second highest in Sweden (35 g/day) and lowest in Denmark (31 g/day) (p<0.001). For men, the intake was highest in Sweden (49 g/day) and lowest in Denmark (41 g/day) (p<0.001). Fruits, vegetables, dairy products and tea were found to be positive dietary determinants, whereas red meat and white bread were found to be negative dietary determinants. Smoking and BMI were negative determinants, whereas length of education was found to be a positive determinant (for Norwegian women only).

Conclusions: The intake of WG was highest in Norway for women and lowest in Denmark and Sweden, depending on the assessment method used (WG products vs. WG). The intake of WG was found to be positively associated to “healthy” dietary, lifestyle and socio-economic factors and negatively associated to “unhealthy” factors, suggesting that these factors are important to consider as confounders when studying WG-disease associations.

Keywords: Whole grain, whole grain intake, confounders, determinants

References:
HEALTHGRAIN WHEAT BREADS EVALUATED IN SENSOBUS BY BELGIAN AND FINNISH CONSUMERS

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The consumer acceptance of different types of wholemeal wheat breads was evaluated, both without and with nutritional information. The sensory profiles of the breads were also determined. The study was conducted in Finland and Belgium using the Sensobus mobile sensory and consumer laboratory of Puratos. 328 persons (45% men) participated in the study in Finland, and 204 (40% men) in Belgium. Consumers tasted the breads and ranked them according to their preference. Different wheat flours developed in the HEALTHGRAIN project were used to produce the model breads. Four different wheat breads were prepared and tested: 1) bread made of wholegrain flour with flour improvers (gluten and emulsifier), 2) bread made of flour of peeled kernels as in 1), 3) bread made of “Healthflour” as in 1), and 4) bread made of flour of peeled kernels using xylanase but no flour improvers (“E-code free”). The breads were labeled as “100 % Whole Grain” (bread 1), “Contains 95 % of the Grain” (breads 2, 3 and 4), “High in Fibre” (all breads), or “No Additives” (bread 4). Breadmaking process and recipe (salt and margarine content) were slightly different in Finland and Belgium.

The test breads were different in their sensory profiles (texture and flavour) and consumer acceptance. Also the differences in the bread-making process and the salt and margarine content affected the sensory profile of the breads. In Finland, when no labeling information was given, the Finnish consumers preferred the bread made without additives (bread 4), which was the darkest in color, the hardest in texture and the most intense in flavour. The Belgian consumers did not have clear preferences among the breads, and also based on the sensory profile the differences between the breads evaluated in Belgium were very small. When nutritional information was presented, the preference result did not change in Finland, whereas in Belgium the bread labeled “Wholegrain, High in Fibre” (bread 1) was preferred and “Contains 95 % of the Grain, High in Fibre” (bread 2) was the least preferred. The results support the earlier results of HEALTHGRAIN Module 1 (Arvola et al., 2007, Saba et al., 2010) that consumers in different parts of Europe have different preferences on wholegrain wheat breads. Finnish consumers, maybe because they are so familiar with rye bread, liked the darkest bread the most. The wholegrain claim had positive impact on consumer preferences in Belgium whereas in Finland none of the claims was preferred over the others.

Keywords: Wholemeal, wheat, bread, consumer acceptance, claim, sensory

References:


HEALTH GRAIN PRODUCTS - CONSUMERS EXPECTATIONS, LATVIA

D. Kunkulberga\textsuperscript{1} and V. Seglins\textsuperscript{2}

\textsuperscript{1}Latvia University of Agriculture, Jelgava, Latvia
\textsuperscript{2}University of Latvia, Riga, Latvia

The HEALTHGRAIN is a FP6 supported Project and the aim is to improve the well-being, reduce the risk of metabolic syndrome related diseases in Europe, to produce health promoting and safe cereal foods and ingredients of high eating quality, that can be done by increasing the intake of protective compounds in whole grains or their fractions. The project First Module is focusing the attention on the consumer research and the expectations of a consumer. Latvia is not directly involved in the project activities and therefore these issues have been overviewed in the presented paper.

Latvia is a country with very long coarse bread baking traditions and especially rough rye bread baking traditions, that are still present. Currently there are around 60 enterprises in Latvia producing about 400 tons of baked bread products daily, but only eight enterprises capacity exceeds 10 tons per day. About a half of all the producers is backing some type of wholegrain products. These producers are located all over the country. However, the amount of produced goods is not notable and these products are not in the stable, dynamic or increasing segments in the market. The wholegrain products are still the typical niche products for the producers in Latvia.

The aim of the study was to query consumer expectations regarding wholegrain products and their particular groups. The study based on four separate polling realized from 2008. Each of these questionnaires includes interviewing more than 1000 respondents (0.1% households in the country). Inquiry include respondents in age of 18-65 over the country, but one polling concentrates at central part of Latvia, where more than 60% of all households lies. A supplementary inquiry performed in 2009. It is supported by direct interviews with bread producer enterprises.

The survey indicates that the choice of bread is very contrasting and most people are not eager to buy bread that contains high value grain or seeds. The research shows that women of all age groups, in urban areas as well in the countryside, more often choose wholegrain products. Unfortunately, it is acknowledged that consumers have very limited knowledge and willingness to know more about wholegrain products, including the qualities of healthy products. Indirectly this indicates that the society of Latvia needs more and various information, regarding the wholegrain products and their positive qualities. People should be informed of the impact on health promoting and safety.

However, there is a lack of adequate knowledge about the characteristics of the products and alteration in public opinion at the moment, to plan particular activities.

To reach these provisions there is a need for more extensive and priority studies of wholegrain bread products and potentials to diversify market products currently relatively uniform products. In our opinion, the most effective form of pointed out studies is cooperation between researchers from different countries and bread producers- both industrial scale and traditional bakeries.

Key words: wholegrain and seed bread, rye bread, consumers expectations, Latvia

References:

(1) Bread consumption changes in Latvia. SIA “Analītisko pētījumu un stratēģiju laboratorija”, 2008 (In Latvian).
HEALTHGRAIN in a Nutshell
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HEALTHGRAIN Consortium and Networks

HEALTHGRAIN Project Structure

The project was coordinated by Kaisa Poutanen, VTT with administrative support of Riitta Kervinen, VTT. The research was carried out in five research modules (Figure 1). Consumer research module, led by Richard Shepherd, University of Surrey, studied consumer expectations and perceptions for cereal-based products that have been modified to contain more health-promoting components. The plant breeding module, led by Peter Shewry, Rothamsted Research, aimed to facilitate the improvement of the health benefits of wheat and other cereal grains by identifying and inducing variation in content and composition of bioactive components and tools to facilitate their selection in breeding programs. In the technology and processing module, led by Jan Delcour, Katholieke Universiteit Leuven, new fractionation and bioprocessing methods were developed for nutritionally optimized cereal foods and new food ingredients from grains. The major objective of the nutrition module, led by Inger Björck, University of Lund, was to identify mechanisms underlying potential health benefits of grain based foods, especially considering the pathology of metabolic syndrome. The dissemination module, led by Jan-Willem van der Kamp, TNO, was focused on communication of results within and outside of the network, and on training and technology transfer activities. Roberto Ranieri, Barilla, was the chair of the industrial advisory group.

HEALTHGRAIN project also included a comprehensive implementation program to promote the interaction of various stakeholders, including an Industrial Platform, Nutrition Information Network and Consumer Communication Panel.

Figure 1 Structure of the HEALTHGRAIN project
Project partners

The HEALTHGRAIN consortium included 44 partners from 15 European countries (Table 1; red spots in Figure 2) including leading research institutes and universities, major grain processing industries and some small and medium size enterprises.

Table 1 HEALTHGRAIN project partners. *(The table continues on next page)*

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| 1  | VTT        | Technical Research Centre of Finland  
Prof. Kaisa Poutanen | Finland |
| 2  | ABI        | AgroBiolInstitute  
Dr. Ivelin Rizov | Bulgaria |
| 3  | Syral      | SYRAL Belgium  
Dr. Andreas Redl | Belgium |
| 4  | ANET       | ANET – New Media Solutions  
Mr. Robert Allerstorfer | Austria |
| 5  | BARILLA    | Barilla G. e R. Fratelli - Società per Azioni  
Dr. Roberto Ranieri | Italy |
| 6  | MRI        | Max Rubner-Institut  
Dr. Meinolf Lindhauer | Germany |
| 7  | BOKU-DFST  | University of Natural Resources and Applied Life Sciences  
Prof. Emmerich Berghofer | Austria |
| 8  | Branscan   | Branscan Limited  
Mr. Ayten Erdentug | United Kingdom |
| 9  | BUTE       | Budapest University of Technology and Economics  
Prof. András Salgó | Hungary |
| 10 | BÜHLER     | Bühler AG  
Mr. Walter von Reding | Switzerland |
| 11*| Cerchem    | Cereal Chemistry Equipment CVBA  
Ms. Hilde Keunen | Belgium |
| 12 | AU         | University of Aarhus  
Prof. Knud Erik Bach Knudsen | Denmark |
| 13 | DPRNUT     | DPRNutrition LTD  
Prof. David Richardson | United Kingdom |
| 14 | DTU        | The Technical University of Denmark  
Prof. Birte Svensson | Denmark |
| 15**|           |                                    |         |
| 16 | ICC        | International Association for Cereal Science and Technology  
Dr. Roland Poms | Austria |
| 17 | IFR        | Institute of Food Research  
Dr. Clare Mills | United Kingdom |
| 18 | IGV        | IGV Institut für Getreideverarbeitung GmbH  
Dr. Ralph Thomann | Germany |
| 19 | IHAR       | Institute of Plant Breeding and Acclimatization  
Dr. Danuta Boros | Poland |
| 20 | INRA       | Institut National de la Recherche Agronomique  
Dr. Xavier Rouau | France |
| 21 | INRAN      | Istituto Nazionale di Ricerca per Gli Alimenti e la Nutrizione  
Dr. Anna Saba | Italy |
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* Cerchem withdrew from the consortium 30 November 2008.
** There is no participant 15.
*** SD-TECH joined the consortium 1 April 2008.
Figure 2 The HEALTHGRAIN Consortium. Red spots: HEALTHGRAIN project partners; Green: countries with HEALTHGRAIN partners and members of IP, NIN and/or CCP; Orange: countries with members of IP, NIN, and/or CCP

Part of HEALTHGRAIN Consortium collected in a picture during the HEALTHGRAIN meeting in Cork, Ireland, January 2008
Industrial Platform members

An Industrial Platform was established as part of the project to ensure efficient communication between the HEALTHGRAIN consortium and actors in the cereal food chain. Altogether 54 companies joined the Industrial Platform (Table 2). In addition it includes seven industrial companies which are also project partners.

Table 2 Industrial Platform members including seven members which are also project partners (light green shaded) *(The table continues on next page)*

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<td>Agrasys S.L. Dr. Pilar Barceló</td>
<td>Spain</td>
</tr>
<tr>
<td>Arvalis–Institut du végétal Mr. Fabien Skiba</td>
<td>France</td>
</tr>
<tr>
<td>AVENLY Oy (Ltd) Prof. Hannu Salovaara</td>
<td>Finland</td>
</tr>
<tr>
<td>Barilla G. e R. Fratelli - Società per Azioni Dr. Roberto Ranieri</td>
<td>Italy</td>
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<tr>
<td>Bolletje B.V. Ing. Ben Uitdewilligen</td>
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<tr>
<td>Branscan Limited Mr. Aytun Erdentug</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Bremerhaven Institute for Food Technology and Bioprocessing TTZ-BILB-EiBT Ms. Marta Macias</td>
<td>Germany</td>
</tr>
<tr>
<td>Bühler AG Mr. Walter von Reding</td>
<td>Switzerland</td>
</tr>
<tr>
<td>Cargill R&amp;D Centre Europe Dr. Anne Franck</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Cereal Partners Worldwide, Nestle UK Dr. Wolfgang Bindzus</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>CreaNutrition AG Mr. Ruedi Duss</td>
<td>Switzerland</td>
</tr>
<tr>
<td>Crop Tailor AB Mr. Marcus Bräutigam</td>
<td>Sweden</td>
</tr>
<tr>
<td>CSM Bakery Supplies Europe Dr. Jan de Vries</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Danisco A/S Mr. Jens Frisbak Sörensen</td>
<td>Denmark</td>
</tr>
<tr>
<td>Danone Baby Nutrition Mrs Brigitte Borgmann</td>
<td>France</td>
</tr>
<tr>
<td>Kraft Biscuits Europe R&amp;D Dr. Aliette Verel</td>
<td>France</td>
</tr>
<tr>
<td>Doygun Mr. Selcuk Berksan</td>
<td>Turkey</td>
</tr>
<tr>
<td>DSM Food Specialties Mr. Frans Koster</td>
<td>The Netherlands</td>
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<tr>
<td>Ernst Böcker GmbH &amp; Co. KG Dr. Markus Brandt</td>
<td>Germany</td>
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<tr>
<td>Fazer Bakeries Ltd M.Sc. Risto Viskari / M.Sc. Sanna-Maria Hongisto</td>
<td>Finland</td>
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Table 2 Industrial Platform members including seven members which are also project partners (light green shaded shaded) *(The table continues on next page)*

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<tr>
<td>Green Technologies SARL</td>
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</tr>
<tr>
<td>Dr. Michel Dubois</td>
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</tr>
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</tr>
<tr>
<td>Mr. Miska Kuusela</td>
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</tr>
<tr>
<td>Holgran - A trading name of Premier Foods</td>
<td>United</td>
</tr>
<tr>
<td>Jo Butten</td>
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<tr>
<td>IsoLife bv</td>
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<tr>
<td>Mr. Thomas Roick</td>
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<tr>
<td>Kampffmeyer Mühlen GmbH</td>
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<td>Dr. Christoph Persin / Mr. Michael Gusko</td>
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<tr>
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<tr>
<td>Mr. Gerard Verkerke / Dr. Johan Plijter</td>
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<tr>
<td>Mr. Hirohito Yamakawa</td>
<td>Netherlands/</td>
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<td>Primulan Leipomot Oy</td>
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<td>Mrs Arja Martikainen</td>
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Table 2 Industrial Platform members including seven members which are also project partners (light green shaded)

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<tr>
<th>Company / Contact person</th>
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<td>Dr Vitale Cesa</td>
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<tr>
<td>Mr. Josef Schweiger</td>
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<td>Saaten-Union Resistenzenlabor GmbH</td>
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<tr>
<td>Dr. Jens Weyen</td>
<td>Germany</td>
</tr>
<tr>
<td>Sarl Gustalis (previously Bourgogne Terre de Culture (B.T.C.)</td>
<td>France</td>
</tr>
<tr>
<td>Mr. Jean-Philippe Fasquel</td>
<td></td>
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<td>Sejet Plantbreeding</td>
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<tr>
<td>Mr. Esko Pajunen</td>
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<td>Solides Divises Technologies</td>
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<td>Mr. Arnaud Dubat</td>
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<td>Vaasan &amp; Vaasan Oy</td>
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<td>Lic. Sc. Tarja Kujala</td>
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<td>Dr. Ir. H.W. van der Klooster</td>
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Nutrition Information Network and Consumer Communication Panel members

A group of food and health experts from all over Europe with links to the policy making process of recommendations for healthy eating were invited to join the Nutrition Information Network (NIN), Table 3.

Table 3 Nutrition Information Network members.

<table>
<thead>
<tr>
<th>Nutrition expert / Organisation</th>
<th>Country</th>
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</thead>
<tbody>
<tr>
<td>Dr. Prof. Nils-Georg Asp SNF Swedish Nutrition Foundation</td>
<td>Sweden</td>
</tr>
<tr>
<td>Prof. Furio Brighenti University of Parma, Department of Public Health</td>
<td>Italy</td>
</tr>
<tr>
<td>Prof. Dr. Rosaura Farré Rovira Centre d’Ensenyament Superior de Nutrició i Dietètica</td>
<td>Spain</td>
</tr>
<tr>
<td>Prof. Wenche Frølich Universitetet i Stavanger</td>
<td>Norway</td>
</tr>
<tr>
<td>Dr. Eva Gelencsér Central Food Research Institute</td>
<td>Hungary</td>
</tr>
<tr>
<td>Prof. Maria Hassapidou Alexander Technological Institution</td>
<td>Greece</td>
</tr>
<tr>
<td>Prof. Andre Huyghebaert University of Ghent</td>
<td>Belgium</td>
</tr>
<tr>
<td>Prof. Denis Lairon UMR 476-INSERM/1260-INRA</td>
<td>France</td>
</tr>
<tr>
<td>Dra. Ascensión Marcos Spanish Nutrition Society</td>
<td>Spain</td>
</tr>
<tr>
<td>Prof. Pedro Moreira Faculdade de Ciências da Nutrição e Alimentação da Universidade do Porto</td>
<td>Portugal</td>
</tr>
<tr>
<td>Prof. Marek Naruszewicz Medical University of Warsaw</td>
<td>Poland:</td>
</tr>
<tr>
<td>Dr. Gérard Pascal Institut National de la Recherche Agronomique</td>
<td>France</td>
</tr>
<tr>
<td>Prof. Pekka Puska / Prof. Pirjo Pietinen Terveyden ja hyvinvoinnin laitos, National Institute for Health and Welfare</td>
<td>Finland</td>
</tr>
<tr>
<td>Prof. Dr. Gerhard Rechkemmer Max Rubner-Institut, Bundesforschungsinstitut für Ernährung und Lebensmittel</td>
<td>Germany</td>
</tr>
<tr>
<td>Prof. David Richardson DPRNutrition Ltd</td>
<td>Great Britain</td>
</tr>
<tr>
<td>Prof. Ian Rowland University of Reading</td>
<td>Great Britain</td>
</tr>
<tr>
<td>Assoc. Prof., MV.D., Ph.D. Jiri Ruprich Centre for the Hygiene of Food Chains</td>
<td>Czech Republic</td>
</tr>
<tr>
<td>Dr. Alwine Kardinaal TNO Quality of Life</td>
<td>Netherlands</td>
</tr>
<tr>
<td>Prof. Wim H.M. Saris DSM Food Specialities</td>
<td>Netherlands</td>
</tr>
<tr>
<td>Prof. Chris Seal University of Newcastle upon Tyne</td>
<td>Great Britain</td>
</tr>
<tr>
<td>Prof. Alfonso Siani National Research Council - Institute of Food Sciences</td>
<td>Italy</td>
</tr>
<tr>
<td>Dr. Inge Tetens Technical University of Denmark - National Food Institute</td>
<td>Denmark</td>
</tr>
<tr>
<td>Univ.Prof. DI Dr. Wilhelm Windisch University of Natural Resources and Applied Life Sciences Vienna</td>
<td>Austria</td>
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</table>
Experts in communication to consumers were invited to Consumer Communication Panel (Table 4).

Table 4 Consumer Communication Panel members.

<table>
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<tr>
<th>Company / Contact person</th>
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<tr>
<td>Dr Joel Abecassis</td>
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<tr>
<td>Institut National de la Recherche Agronomique</td>
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<tr>
<td>Dr. Marina Carcea</td>
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<tr>
<td>Instituto Nazionale di Ricerca per gli Alimenti e la Nutrizione</td>
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<tr>
<td>Julien Couaillier</td>
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<tr>
<td>Passion Céréales</td>
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<tr>
<td>Hertha Deutsch</td>
<td>Austria</td>
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<tr>
<td>Association of European Coeliac Societies</td>
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<tr>
<td>Prof. Wenche Frolich</td>
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<tr>
<td>Universitetet i Stavanger</td>
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<tr>
<td>Ir. Hilde De Geeter</td>
<td>Belgium</td>
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<tr>
<td>Vlaams Centrum voor Agro- en Visserijmarketing</td>
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<tr>
<td>Prof. Pedro Moreira</td>
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<tr>
<td>Faculdade de Ciências da Nutrição e Alimentação da Universidade do Porto</td>
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<tr>
<td>Ir. ing. Erika Smale</td>
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<td>Productschap Akkerbouw</td>
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<tr>
<td>MSc Morten Strunge Meyer</td>
<td>Denmark</td>
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<tr>
<td>Association of European Cancer Leagues</td>
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<tr>
<td>David Sutherland</td>
<td>Spain</td>
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<tr>
<td>LYCOCARD - Caledonian Science Press Ltd</td>
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<tr>
<td>Dr. Heiko Zentgraf</td>
<td>Germany</td>
</tr>
<tr>
<td>Vereinigung Getreide-, Markt- und Ernährungsforschung e.V.</td>
<td></td>
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</table>

International Scientific Advisory Group members

The International Scientific Advisory Group (ISAG) (Table 5) was established to assist the Board in self-evaluation of the project. Three internationally respected scientists in the field of Modules 2–4 were invited to the group.

Table 5 International Scientific Advisory Group members

<table>
<thead>
<tr>
<th>Expert / Company</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Béatrice J. Conde Petit</td>
<td>Switzerland</td>
</tr>
<tr>
<td>ETH-Zentrum Inst.f.Lebensmittel-u.Ernährungswissens (In 2008 left ETH and withdrew her membership in the ISAG).</td>
<td></td>
</tr>
<tr>
<td>Prof. Simin Liu</td>
<td>USA</td>
</tr>
<tr>
<td>University of California, UCLA School of Public Health Department of Epidemiology</td>
<td></td>
</tr>
<tr>
<td>Prof. Alan Schulman</td>
<td>Finland</td>
</tr>
<tr>
<td>MTT Agrifood Research Finland, Jokioinen &amp; Institute of Biotechnology, University of Helsinki</td>
<td></td>
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</table>
Snapshot of HEALTHGRAIN Results

Cereal foods are major dietary sources of energy, carbohydrate and fibre. A starting point for HEALTHGRAIN was that epidemiological studies increasingly have shown that intake of whole grain and cereal dietary fibre protects against the rapidly increasing chronic diseases related to a sedentary lifestyle, such as cardiovascular disease and type 2 diabetes. Dietary recommendations urge to eat more carbohydrates, dietary fibre and whole grain foods. Current cereal processing methods, however, are optimised to deliver products made of refined grain. The project was planned to provide the scientific basis for improvement of this situation (Poutanen et al 2008, 2010).

The HEALTHGRAIN Integrated Project aims to improve well-being of consumers and to reduce the risk of diseases related to metabolic syndrome in Europe by increasing the intake of protective compounds in grains. The aim is to develop health promoting and safe cereal foods and ingredients which are attractive to consumers.

The target health-protective bioactive compounds in grains included, in addition to dietary fibre components, lignans, phenolic acids, alkylresorcinols, phytosterols, folates, tocopherols and tocotrienols, other vitamins, trace elements and minerals. All of these compounds are concentrated in the outer layers of the grain, and are thus removed in production of white wheat flour. HEALTHGRAIN developed technologies to produce cereal foods containing more of these protective compounds. Food factors influencing postprandial glycemic and satiating properties were also studied in order to develop foods which contribute to metabolic health and weight management.

Figure 3 Health benefits of cereals must end up in processed foods.

The scientific and technological objectives set to HEALTHGRAIN were:
1. To study consumer expectations and attitudes to healthy cereal foods
2. To provide new sources of high quality raw material for use in plant breeding and tools to facilitate selection of improved cultivars
3. To develop technologies and processing methods for nutritionally optimised cereal foods and new food ingredients from whole grains
4. To identify mechanisms for health benefits of foods rich in whole grain cereals and cereal fractions, and to exploit these mechanism in the tailoring of new cereal products to combat risk factors for coronary heart disease, type II diabetes and obesity
5. To provide an interactive dissemination, training and technology transfer program

Below, some already published and reported results are briefly reviewed.
Module 1 Consumer Research

Two studies were conducted to learn about consumer expectations and perception of healthy cereal foods. The first aimed at understanding product related expectations that may influence the willingness to use wholegrain foods vs. refined grain products. Data were collected in Finland, Italy and the UK by 500 consumers per country (Dean et al., 2007; Arvola et al., 2007; Vassallo et al., 2009). On average, consumers were aware that wholegrain products are healthier than refined grain products. In Italy and the UK the respondents were less likely to differentiate between the healthiness of whole and refined grain products than the Finnish respondents. The study also showed that health benefits were better accepted for modifications of basic foods, such as bread and pasta, than for foods such as biscuits.

In the second study, involving 2395 respondents in Finland, Germany, Italy and the UK, the effect of health related statements on willingness to buy was compared for products with a strong claim (Contains cereal-based compounds which balance the blood glucose levels and therefore lower the risk of type-2 diabetes), a weak claim (Promotes regulation of blood sugar balance) and without a claim (Saba et al 2010). The questionnaire was designed to test relative importance of health claims and other information in influencing a rating such as healthiness or likelihood of buying. When product types, health claims, visual cues and presence of wholegrain were compared, product type had the largest effect on consumers’ perceptions of food products, so that for example although both bread and yoghurt with cereals we considered healthy, the willingness to buy was lower for the latter. Strength of health claim had a strong effect on perceptions of healthiness, but it had only a very small effect on likelihood of buying. There were also geographical differences in the perceptions; in particular the perception of healthiness was among the Italian consumers not impacted by health claims and presence of wholegrain.

A Health Belief Model was used to predict willingness to use the breads with different claims. The behavioural evaluation components of the model -perceived healthiness and pleasantness - and the health motivation component were good predictors of willingness to use the products. Threat perception components -perceived susceptibility and perceived anticipated severity of disease – on the contrary were poor predictors. New models would be needed 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.

Module 2 Plant breeding and grain quality

In the first part of the HEALTHGRAIN diversity screen 150 wheat lines, 10 rye lines and 40 other cereals were grown in 2004-5 on a single site in Hungary. The results on variation in grain phytochemicals, vitamins and fibre content in were published as a special section in the November 2008 issue of Journal of Agricultural and Food Chemistry. (Andersson et al 2008, Gebruers et al 2008, Lampi et al 2008, Li et al 2008, Nurmi et al 2008, Nyström et al 2008, Piironen et al 2008, Rakszegi et al 2008, Shewry et al 2008, Ward et al 2008). Substantial variation was observed in the bioactive components studied, ranging in wholemeal wheat from 1.4 fold for tocols to 3.6 fold for phenolic acids, and up to 4.7 fold for water-extractable arabinoxylan in white wheat flour.

The second part of the variety screen, comprising of 26 wheat and five rye lines, grown in Hungary in 2006 and 2007 and also in Poland, France and UK in 2007. In spite of the environmental variation, the results confirmed the varietal ranking of the lines in terms of composition. The same analyses were carried out on the material as in the previous screen, allowing the heritability of the different groups of
components to be calculated as ranging up to 70% of the total variance. The results are submitted as a series on papers in the beginning of 2010.

The analysis methods developed and applied in the above described work have been published by AACC International as the “HEALTHGRAIN Methods Book”, edited by Jane Ward and Peter Shewry. A rapid method for determining choline and betaine in aqueous extracts of flour, bran and wholemeal has been developed using $^1$H NMR spectroscopy. The values for betaine determined by this method have also been validated by comparison with analyses of the same series of samples using a classical HPLC-based approach.

In order to generate new variation in wheat, a high amylose (resistant starch) phenotype has been created by crossing a breeding line with mutant forms of granule-bound starch synthase genes with five modern wheat varieties. Mutations have also been identified in mutant population developed in wheat cv. Cadenza at three genes encoding starch branching enzyme, hopefully leading to new high amylose starch mutants. Transgenesis has been used to confirm the functions of genes thought to be involved in the biosynthesis of arabinoxylan and beta-glucan. Transgenic wheat lines have been developed to over-express and suppress beta-glucan synthase, putative xylan synthase and arabinosyl transferase genes, with the ultimate aim to modify structure and content of the major dietary fibre components of the grain, arabinoxylan and β-glucan.

The analysis results of the diversity screen have also been used in development of NIR calibrations to allow analysis of grain and flour samples in breeding and trade. In particular, NIR has been used to develop robust calibrations for arabinoxylans which may be exploited with manufacturers of NIR instrumentation. Another approach has been to develop biotechnical kits for determination of arabinoxylan content and properties, based on antibodies.

Module 3 Technology and processing

The development of new technologies in HEALTHGRAIN comprised 1) new grain dry fractionation, focusing on aleurone part of the grain, 2) wet processing methodologies as well as new enzymes and enzymatic and fermentation processes for production of bioactive compounds and fractions, 3) production of foods with high nutritional and sensory quality and specific physiological responses, 4) technologies for gluten-free foods suitable for celiac patients and 5) demonstration and evaluation of the technologies for industrial use.

Tools have been developed for the control of fractionation processes of grains, and to produce functionally and nutritionally improved flours and bran fractions (Hemery et al 2007, 2009, 2010). The outer layers of grains have been studied for their detailed chemical composition in order to know which parts should be included for retention of compounds (Barron et al 2007, 2008, Landberg et al 2008, Hemery et al 2009). Wheat and rye bran have been fractionated to yield well characterized fractions using in particular cryogenic and electrostatic technologies. An industrial feasibility study of ‘Healthflour’ production revealed that ‘Healthflour’ has less potential food safety issues than whole wheat flour. The production cost of ‘Healthflour’ is about 4% higher than the production cost of regular whole wheat flour.

An enzyme toolbox was created, comprising especially new xylanases (André-Leroux et al. 2007, Berrin et al 2007, Cervera Tison et al 2009, Juge 2008). Solubilization and partial hydrolysis of arabinoxylan was studied with the aim of producing prebiotic oligosaccharides (Swennen et al 2006), but also to improve the baking properties of bread. In situ enrichment of bread in arabinoxylan oligosaccharides was also
developed. As the level of arabinoxylan oligosaccharides that can theoretically be obtained in white wheat flour based bread is probably insufficient for physiological effects, enrichment of breads with arabinoxylan-rich fractions or bran was used for the production of bread rich in arabinoxyloligosaccharides. For a number of enzymes tested on different bran materials, the yield of extraction of potentially health promoting arabinoxylan oligosaccharides was negatively correlated with the arabinose to xylose ratio of the wheat bran arabinoxylan. Ball milling was an alternative way for production of wheat and rye bran derived arabinoxylan oligosaccharides (Van Craeyveld et al 2009).

Retarded starch digestibility was one of the aims, and amylase-lipid complexes were studied as one means producing starch with lowered enzymatic accessibility (Putseys et al 2009, 2010). Sourdough fermentation was show to retard glycemic responses of whole meal bread (Lappi et al 2010).

Bioprocesses selectively impacting the health profile of cereal constituents both in vitro and in situ were developed as were enzyme and fermentation assisted wet processing technologies for isolation of selected functional bioactive compounds. Enzymatic hydrolysis of dry milling fractions of wheat in combination with yeast fermentation liberated ferulic acid from the cell wall matrix (Katina et al 2007, Mateo Anson et al 2009). Naturally occurring levels of alkylresorcinols did not affect the leavening properties of wheat and rye bran breads. Alkylresorcinols were shown not to be degraded during the baking process.

Research into the improvement of gluten-free foods included use of cross-linking enzymes to improve the texture of buckwheat, oat and rice flours (Renzetti et al 2008-2010) to replace maize starch with more nutritious raw materials, and use of lactic-acid bacteria to improve the quality and shelf life of gluten-free bread (Moore et al 2007-2009).

Module 4 Nutrition and metabolism

The nutrition research, aiming at understanding the physiological processes modulated by differently produced grain foods, was performed 1) in in vitro models simulating events in the upper- and lower parts of the gastro-intestinal tract, 2) in animal experimental models, 3) in acute or semi-acute meal studies in healthy or at risk subject, and 4) long term dietary interventions in at risk and type 2 diabetic subjects.

In vitro models on intestinal bioavailability (TIM-1) and colonic fermentability and metabolism (TIM-2) concentrated in studies on the bioaccessibility, metabolism and bioactive potential of ferulic acid. Bioprocessing both increased butyric acid production from bran, and increased liberation and metabolism of phenolic acids (Mateo Anson et al. 2008-2010). Analysis and reporting of animal studies confirmed that butyrate formation is associated with arabinoxylan, and was higher in rye based diets than in whole grain wheat diets (Le Gall et al 2010). In pigs, rye diet caused higher ileal viscosity than wheat, and resulted in clearly lower starch digestibility in the small intestine, delivering starch for colonic fermentation. Experiments in a mouse model predisposed for the metabolic syndrome showed modest differences in metabolic impact of seven different wheat fractions studied.

Acute meal studies about the bioavailability of methyl donors and ferulic acid in healthy subjects, showed that ingestion of raw bran and aleurone meals induced significant increases in plasma betaine and ferulic acid after the test meal. Experiments with aleurone-rich bread rolls confirmed these results and demonstrated significant post-meal increases in plasma ferulic acid and betaine. Effects on plasma choline and folate, however, were small and non-significant. This was the first evidence that betaine
status is influenced by wheat aleurone, and that wheat products favourably impact plasma ferulic acid levels.

Human studies also have confirmed the difference between rye and wheat products: in acute meal studies, where rye products improved insulin economy as compared with corresponding wheat products. Rye breakfast meals, irrespectively of extraction rate of processing method, showed lower insulin index than white wheat bread. Wholegrain wheat bread was found more satiating than refined bread, with no changes, however, in subsequent ad libitum food intake (Kristensen et al 2010). Second meal studies have confirmed the involvement of colonic fermentation as a mediator of over-night metabolic benefits (Nilsson et al 2008, Östman et al 2007). The role of colonic fermentation in mediating health effects of high-fibre cereal foods is evident.

Only one of the four long-term studies has been completed and analysed. The aim was to determine whether inclusion of wheat based whole grain foods in a hypo-caloric diet enhances weight loss and improves CVD risk factors in 72 women. Body weight, waist circumference and percentage body fat decreased significantly in both groups over the study period with a significantly greater decrease in percentage body fat (-3%) in the whole grain group as compared to the refined grain group (-2.1%). Total and LDL cholesterol increased by 5% in the refined group but remained unchanged in the whole grain group. Insulin, glucose, and C-reactive protein levels did not change in either group.
Publications


Kristensen, M., Jensen, M.G., Riboldi, G., Petronio, M., Bügel, S., Toubro, S., Tetens, I., Astrup, A. Wholegrain vs. refined wheat bread and pasta - effect on postprandial glycemia, appetite, and subsequent ad libitum energy intake in young healthy adults. *Appetite, 2009.*


Östman, E., Björck, I. (2007) Role of food form on second meal glucose tolerance and satiety after whole

Piironen, V., Edelmann, M., Kariluoto, S., Bedo, Z. Folate in wheat genotypes in the HEALTHGRAIN

Poutanen, K. Cereal based foods to improve well-being and reduce risk of metabolic syndrome related
diseases, to be included in *Proceedings of the 31st European Brewery Convention Congress* 107: 962-


Poutanen, K., Shepherd, R., Shewry, P.R., Delcour, J.A., Björck, I.M., Kamp, J.-W. van der. Beyond
whole grain: the European HEALTHGRAIN project aims at healthier cereal foods. *Cereal Foods World,

Poutanen, K., Shepherd, R., Shewry, P.R., Delcour, J.A., Björck, I.M., Kamp, J.-W. van der, Ranieri, R.
More of the grain – Progress in the HEALTHGRAIN project for healthy cereal foods. *Cereal Foods World,


amylose-lipid complexes in starch-water systems and their impact on in vitro starch degradation. *Journal
of Agricultural and Food Chemistry*, 2010. DOI: 10.1021/jf903523h.

Putseys, J.A., Lamberts, L., Delcour, J.A. Amylose-lipid complexes: Formation, identity and physico-

Rakszegi, M., Boros, D., Kuti, C., Láng, L., Bedo, Z., Shewry, P.R. Composition and end-use quality of
150 wheat lines selected for the HEALTHGRAIN diversity screen. *Journal of Agricultural and Food

Renzetti, S., Arendt, E.K. Effect of oxidase and protease treatments on the breadmaking functionality of a

Renzetti, S., Arendt, E.K. Effect of protease treatment on the baking quality of brown rice bread: From
textural and rheological properties to biochemistry and microstructure. *Journal of Cereal Science* 50: 22-
28, 2009.

Renzetti, S., Behr, J., Vogel, R.F., Arendt, E.K. Transglutaminase polymerisation of buckwheat

Renzetti, S., Courtin, C.M., Delcour, J.A., Arendt, E.K. Fundamental studies on the improved bread
making performances of oat flour by oxidases and protease enzymatic treatment: rheological,


Shewry, P.R., Ward, J.L. (Eds.) HEALTHGRAIN Methods – Analysis of Bioactive components in Small Grain Cereals. AACC International. 2010


HEALTHGRAIN Dissemination Technology transfer and Training activities – overview (Module 5)

Paving the way for innovations in the cereal grain area.

Industrial Platform, Nutrition Information Network, Consumer Communication Panel

The aim of HEALTHGRAIN Module 5 activities can be formulated as *Paving the way for innovations in the cereal grain area*. As a first step in paving this way we established close links with stakeholders: industries, leading nutrition experts and organisations involved in communication to consumers.

The concept of the Industrial Platform (IP) - with paid membership and, in return, direct contacts with the project and first hand information, also via the (IP-NIN-CCP) login part of www.healthgrain.org - attracted already 29 member companies before the start of the project. In the following years another 32 companies joined. The funds provided by IP members enabled us to double our efforts in dissemination and training.

In the first project year 24 leading nutrition experts of 14 countries were invited and joined the Nutrition Information Network (NIN). Some of them and others joined the Consumer Communication Panel (CCP). In the Annual Project Meetings IP, NIN and CCP members attended the plenary sessions and contributed to specific meetings organised for these groups during these Meetings. Every autumn HEALTHGRAIN organised an Industrial Platform Workshop - with venues and dates linked with the Food Ingredient Europe meetings, or other major exhibitions. In addition to results of HEALTHGRAIN and related EU projects regulatory issues were discussed, focussing on EC Regulation 1924/2006 on Nutrition and Health Claims and on the definitions of dietary fibre and whole grain. On the latter topic Open Forum Discussions were organised.

Mutual contacts between IP members resulted in a range of joint activities. One joint activity - between an SME from Spain and a Major Scandinavian company is highlighted in the poster ‘Tridordeum – A Novel Cereal Species With Potential for Use in Functional Food Applications’ by P. Barceló. An overview of the IP, NIN and CCP related activities is shown in tables 6 and 7.

Conferences - involvement of HEALTHGRAIN

In addition to the hundreds of presentations given by HEALTHGRAIN participants in a wide range of national and international meetings, the project arranged enhanced presence in selected international conferences both by organising four HEALTHGRAIN symposia in larger meetings and by sponsoring 13 Conferences. An overview is given in Table 8.

Training activities - secondment of younger staff

In the first project year a system - supported with IP funding - was set up for facilitating exchange of students and junior staff between participants. The exchange should contribute both to the project and to the training and development of the seconded scientist/students.

Secondments proved to be highly useful for efficient generation of results, since the students applied for hosting institutes with advanced (analytical) equipment. And the students/ scientists reported that being and working in a different country and environment was very useful. The secondments are summarised in Table 9.
Training courses
An enquiry of training needs, made in 2006 among participants, in the Industrial Platform and in selected external groups, showed needs for training in analytical capabilities and in presentation skills. Therefore HEALTHGRAIN participants co-organised three *European Young Cereal Scientists and Technologists Workshops*, where every attendee presented his work, for an audience of both young colleagues and senior scientists. Three analytical courses were organised: two with the MoniQA Network of Excellence and one course, focussing on methods for analysing dietary fibres and other bio-active compounds. HEALTHGRAIN also organised and delivered the content of the HEALTHGRAIN Manual *Analysis of Bioactive Compounds in Small Grain Cereals*. An overview of training courses is given in Table 10.

### Table 6 HEALTHGRAIN ANNUAL MEETINGS - and involvement of Industrial Platform, Nutrition Information network and Consumer Communication Panel

<table>
<thead>
<tr>
<th>Meeting date</th>
<th>Meeting title</th>
<th>Activities for IP, NIN, CCP in this meeting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1-2/7/05 Vienna, Austria</td>
<td>HEALTHGRAIN Kick-off meeting</td>
<td>½ day 1st Industrial Platform meeting</td>
</tr>
<tr>
<td>2 14-16/6/06 Helsinki, Finland</td>
<td>1st Annual Meeting</td>
<td>½ day 1st Industrial Platform meeting 1½ day 1st Nutrition Info. Netw.(NIN) meeting</td>
</tr>
<tr>
<td>3 6-8/6/07 Budapest, Hungary</td>
<td>2nd Annual Meeting</td>
<td>½ Day 2nd NIN meeting. IP breeder members Visit to Martonvásár (breeding) + discussions. Industrial.Platform Workshop</td>
</tr>
<tr>
<td>4 11-13/6/08 Madrid, Spain</td>
<td>3rd Annual meeting</td>
<td>IP+NIN+CCP+Module 4 Workshop IP breeder members + Module 2 meeting</td>
</tr>
<tr>
<td>5 9-11/6/09 La Grande Motte, France</td>
<td>4th Annual Meeting</td>
<td>IP+NIN+CCP+HG Modules Workshop Visit to INRA (milling technology) IP members</td>
</tr>
<tr>
<td>6 4-5/5/10 Lund, Sweden</td>
<td>5th and final Annual Meeting</td>
<td>½ day IP+NIN+CCP Workshop</td>
</tr>
<tr>
<td>7 5-7/5/10 Lund, Sweden</td>
<td>Open HEALTHGRAIN Conference</td>
<td>Conference following the Workshop Reduced registration costs</td>
</tr>
</tbody>
</table>
### Table 7 Workshops for HEALTHGRAIN’s Industrial Platform and other stakeholders

<table>
<thead>
<tr>
<th>Meeting date</th>
<th>Meeting title</th>
<th>Attendance (number)</th>
<th>Remarks/ co-operation e.g. other 6th Framework EC projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 28-29/11/’05 Paris, France</td>
<td>Cereal products and ingredients with health benefits. Recent developments in technology and health claims</td>
<td>IP (45)</td>
<td>Decision to skip max. number of 45 for IP meetings</td>
</tr>
<tr>
<td>2 3-4/10/’06 Munich, Germany</td>
<td>Cereal Products and health – consumer perceptions and market opportunities”</td>
<td>IP + CCP,( 63)</td>
<td>Speaker of FP6 Helena (Nutrition - adolescence)</td>
</tr>
<tr>
<td>3 14/11/’06 Lleida, Spain</td>
<td>Variation in Composition of European grains and opportunities for health benefits</td>
<td>IP + Eucarpia meeting (47)</td>
<td>½ day Workshop preceding Eucarpia Cereal Section meeting</td>
</tr>
<tr>
<td>4 6/7/’07, Budapest, Hungary</td>
<td>Optimising Quality and Safety of Cereal Products, Workshop in HEALTHGRAIN Annual Meeting</td>
<td>IP (63)</td>
<td>Speaker of FP6 EUROPREVALL (food allergy)</td>
</tr>
<tr>
<td>5 29-30/10/’07 London, UK</td>
<td>Cereal grains - bioactivity and potential for personalised nutrition</td>
<td>IP (55)</td>
<td>Network of Excellence NuGO: 2 Speakers (Nutrigenomics)</td>
</tr>
<tr>
<td>6 12/6/’08 Madrid, Spain</td>
<td>Health benefits of whole grain components and products - new insights and support of claims”</td>
<td>IP+NIN+CCP+Module 4 (70)</td>
<td>1st meeting with all stakeholder groups in HG Annual Meeting: Successful!</td>
</tr>
<tr>
<td>7 3-4/11/08 Paris, France</td>
<td>Cereal Products and Health - Consumer perceptions and behaviour</td>
<td>IP+CCP (57)</td>
<td>Followed by ½ day Open Forum on definition of whole grain</td>
</tr>
<tr>
<td>8 9-11/6/’09, La Grande Motte, France</td>
<td>What could make cereal foods healthy Bioavailability and physiological impact of nutrients and non-nutrients?</td>
<td>IP+NIN+CCP+HG participants (112)</td>
<td>Major part in Annual Meeting; + discussion on whole grain definition</td>
</tr>
<tr>
<td>9 16-17/11/’09, Frankfurt, Germany</td>
<td>Cereal foods and weight management – new insights and tools for product development</td>
<td>IP (58)</td>
<td>External speakers: FP6 Diogenes (3) FP6 LYCOCARD (1). Followed by ½ day Open Forum whole grain definition</td>
</tr>
<tr>
<td>10 6/4/’10 Cambridge, UK</td>
<td>HEALTHGRAIN Dissemination workshop Wheat Improvement</td>
<td>Eucarpia attendants incl. IP members (70)</td>
<td>½ day Workshop with FP6 Bioexploit preceding Eucarpia cereals meeting.</td>
</tr>
<tr>
<td>11 5/5/2010 Lund, Sweden</td>
<td>Final ½ day Workshop - Preceding the Final Conference Feedback and new perspectives</td>
<td>IP+NIN+CCP</td>
<td></td>
</tr>
</tbody>
</table>
Table 8 Involvement of HEALTHGRAIN in International Conferences

<table>
<thead>
<tr>
<th>Meeting date</th>
<th>Conference Title</th>
<th>HEALTHGRAIN activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 11-14/3/'07, Berlin, Germany</td>
<td>International ICC Conference on Rye Sponsoring</td>
<td></td>
</tr>
<tr>
<td>2 31/3-2/4/'07, Norwich, UK</td>
<td>5th European Symposium Enzymes in Grain Processing Sponsoring</td>
<td></td>
</tr>
<tr>
<td>3 3-4/5/'07 Montpellier, France</td>
<td>Cereals &amp; Europe spring Meeting Sponsoring</td>
<td></td>
</tr>
<tr>
<td>4 10-13/7/'07, Paris, France</td>
<td>10th European Nutrition Conference (FENS) Satellite symposium</td>
<td></td>
</tr>
<tr>
<td>5 12-14/9/'07, Cork, Ireland</td>
<td>1st Intl' Symposium on Gluten free Cereal Products and Beverages Sponsoring</td>
<td></td>
</tr>
<tr>
<td>6 24-27/10/'07, Opatija, Croatia</td>
<td>4th International Congress &quot;Flour-Bread '07 Sponsoring</td>
<td></td>
</tr>
<tr>
<td>7 24-26/4/'08, Istanbul, Turkey</td>
<td>ICC International Conference Bosphorus 2008 Sponsoring</td>
<td></td>
</tr>
<tr>
<td>8 15-18/6/'08, Madrid, Spain</td>
<td>13th ICC International Cereal-Bread Congress, Sponsoring</td>
<td></td>
</tr>
<tr>
<td>9 Bologna, Italy, June 30 – July 3, 2008</td>
<td>International Symposium From Seed to Pasta – the Durum Wheat Chain Sponsoring</td>
<td></td>
</tr>
<tr>
<td>10 25-27/3/'09, Newcastle, UK</td>
<td>C&amp;E Spring meeting, Whole Grain Global Summit, Session on whole grain definition</td>
<td></td>
</tr>
<tr>
<td>11 1-3/7/09, Vienna, Austria</td>
<td>4th International Dietary Fibre Conference Sponsoring. Symposium Cereal grain fibre and health</td>
<td></td>
</tr>
<tr>
<td>12 7-9/9/09 Clermont-Ferrand, France</td>
<td>10th International Gluten Conference Sponsoring</td>
<td></td>
</tr>
<tr>
<td>13 13-16/9/09, Baltimore, MD, USA</td>
<td>2009 AACC International Annual Meeting HEALTHGRAIN Symposium</td>
<td></td>
</tr>
<tr>
<td>14 14-17/10/09, Freising, Germany</td>
<td>4th International Symposium on Sourdough Sponsoring</td>
<td></td>
</tr>
<tr>
<td>15 24-27/10/07, Opatija, Croatia</td>
<td>5th International Congress &quot;Flour-Bread '09 Sponsoring</td>
<td></td>
</tr>
<tr>
<td>16 8-11/6/10, Tampere, Finland</td>
<td>2nd Intl’ Symposium on Gluten free Cereal Products and Beverages Sponsoring</td>
<td></td>
</tr>
</tbody>
</table>

HEALTHGRAIN sponsorship included
- HEALTHGRAIN Board member as member of the Scientific Committee
- One or more presentations from the project
- HEALTHGRAIN posters
- HEALTHGRAIN Leaflets in the conference bag
- HEALTHGRAIN logo and website link on the conference’s website
### Table 9 Exchange of students and younger staff between participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Host organisation</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sabrina Laugesen</td>
<td>Technical University of Denmark</td>
<td>INRA, France</td>
<td>18-28 June 06</td>
</tr>
<tr>
<td>2 Marco Vassallo</td>
<td>INRAN, Rome, Italy</td>
<td>University of Surrey, UK</td>
<td>28 Oct. - 25 Nov. 2006</td>
</tr>
<tr>
<td>3 Eva Nagy-Scholz</td>
<td>Budapest University of Technology and Economics, Hungary</td>
<td>University of Helsinki, Finland</td>
<td>2-6 Oct. 2006</td>
</tr>
<tr>
<td>4 Ermelinda Botticella</td>
<td>University of Tuscia, Italy</td>
<td>Katholieke Universiteit Leuven, Belgium</td>
<td>January 2007</td>
</tr>
<tr>
<td>5 Edith Huettner</td>
<td>University College Cork, Ireland</td>
<td>VTT, Finland</td>
<td>1 week June 2007</td>
</tr>
<tr>
<td>6 Anne Nilsson</td>
<td>Lund University, Sweden</td>
<td>University of Aarhus, Denmark</td>
<td>September/October 2007, 4 weeks</td>
</tr>
<tr>
<td>7 Szilveszter Gergely</td>
<td>Budapest University of Technology and Economics, Hungary</td>
<td>BOKU University, Vienna, Austria</td>
<td>4 weeks October 2007</td>
</tr>
<tr>
<td>8 Joke Putseys</td>
<td>Katholieke Universiteit Leuven, Belgium</td>
<td>Lund University, Sweden</td>
<td>22.10.-16.11.2007</td>
</tr>
<tr>
<td>9 Csilla Nemeth</td>
<td>Rothamsted Research Limited, UK</td>
<td>INRA, France</td>
<td>4 weeks, 12 November–8 December 2007</td>
</tr>
<tr>
<td>10 Katrin Stengel</td>
<td>IGV, Germany</td>
<td>Barilla, Italy</td>
<td>7 weeks, 6.11.-21.12.2007</td>
</tr>
<tr>
<td>11 Youna Hemery</td>
<td>INRA, France</td>
<td>TNO, Netherlands</td>
<td>4 weeks, Feb 5 to March 4 2007, * extended by INRA till 27 April 2008</td>
</tr>
<tr>
<td>12 Markus Winkelmann</td>
<td>MRI, Germany</td>
<td>INRAN, Rome, Italy</td>
<td>28.7–1.8.2008</td>
</tr>
<tr>
<td>13 Ermelinda Botticella</td>
<td>University of Tuscia, Italy</td>
<td>Rothamsted Research Limited, UK</td>
<td>17.8.–17.9.2008</td>
</tr>
<tr>
<td>14 Csilla Nemeth</td>
<td>Rothamsted Research Limited, UK</td>
<td>INRA, France</td>
<td>1 October –1 November 2008</td>
</tr>
<tr>
<td>15 Edel Keaveney</td>
<td>University of Ulster, UK</td>
<td>Attending a course</td>
<td>8–15 September</td>
</tr>
<tr>
<td>16 Marianna Rakszegi</td>
<td>Agricultural Research Institute of the Hungarian academy of Sciences, Hungary</td>
<td>University of Tuscia, Italy</td>
<td>15 November –15 December 2008</td>
</tr>
<tr>
<td>17 Marianna Rakszegi</td>
<td>Agricultural Research Institute of the Hungarian Academy of Sciences, Hungary</td>
<td>University of Helsinki, Finland</td>
<td>2 –28 March 2009</td>
</tr>
<tr>
<td>18 Giuseppina Costabile</td>
<td>Federico II University of Naples, Italy</td>
<td>University of Kuopio, Finland</td>
<td>Four weeks in April 2009</td>
</tr>
<tr>
<td>19 Nuria Mateo Anson</td>
<td>TNO/ Maastricht University, Netherlands</td>
<td>VTT, Finland</td>
<td>5 - 21May 2009</td>
</tr>
<tr>
<td>20 Ermelinda Botticella</td>
<td>University of Tuscia, Italy</td>
<td>Rothamsted Research Limited, UK</td>
<td>4-31 Oct 2009</td>
</tr>
</tbody>
</table>
### Table 10 Training meetings (co-) organised by HEALTHGRAIN

<table>
<thead>
<tr>
<th>Meeting date</th>
<th>Meeting title (attendance)</th>
<th>Organisers HEALTHGRAIN Partners and others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 19-21/5/'08 Kaunas University of Technology, Lithuania</td>
<td>European Young Cereal Scientists &amp; Technologists Workshop (35)</td>
<td>Cerchem, Cereals &amp; Europe, Kaunas Univ.</td>
</tr>
<tr>
<td>2 8-10/12/'08, Budapest Budapest University of Technology and Economics (BUTE), Hungary</td>
<td>Food safety and analytical challenges in the cereal based food chain&quot; (30)</td>
<td>BUTE, ICC FP6 Network of Excellence MoniQA</td>
</tr>
<tr>
<td>3 20-24/4/'09, HCTU Hacettepe University, Ankara, Turkey</td>
<td>Building Skills on the Analysis of Components Formed during Thermal Processing of Foods&quot;(22)</td>
<td>ICC Hacettepe University, MoniQA</td>
</tr>
<tr>
<td>4 3-5/8/'09, Viterbo, Italy</td>
<td>European Young Cereal Scientists &amp; Technologists Workshop (28)</td>
<td>University of Tuscia, ICC, Cereals &amp; Europe</td>
</tr>
<tr>
<td>5 23-27/11/'09 Theory part: Warsaw University of Life Sciences Practical part: Inst of Plant Breeding &amp; Acclimatization, Radzików, Poland</td>
<td>Measurement of Dietary Fibre and Small Bioactive Components of Cereals (32 theory, 20 practice)</td>
<td>Institute of Plant Breeding and Acclimatization, ICC</td>
</tr>
<tr>
<td>6 17-19/4/'10 Budapest, BUTE University, Hungary</td>
<td>European Young Cereal Scientists and Technologists Workshop (30)</td>
<td>BUTE Budapest University, ICC Cereals &amp; Europe</td>
</tr>
</tbody>
</table>
Five modules in the meeting in Cork, Ireland, January 2008

Module 1

Module 2

Module 3
Module 4

Module 5

Kaisa and Riitta with the five module leaders
Whole grain definition

Introduction
The term ‘grain’ applies to the genera and species of the grass family (*Poaceae*) and includes the pseudocereals and other cereal grains, as set out in Table 1. Pulses, nuts and seeds are not included. All the grains of the *Poaceae* family are related both structurally and biochemically. Typical grains are energy dense and can vary in starch content (typically 50–80%), depending on the species, origin and environmental growing conditions. Cereal grains are those that are typically included in the bread and cereal groups in dietary guidance in most countries. This whole grain definition is expected to be useful in the context of nutrition recommendations and guidelines and nutrition claims. Health claims, on the other hand, must be based on documentation of specific effects of grains or grain components in the diet.

Table 1. Whole grain sources

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td></td>
</tr>
<tr>
<td>Wheats, including spelt, emmer, faro, einkorn, kamut, durums</td>
<td><em>Triticum</em> spp.</td>
</tr>
<tr>
<td>Rice</td>
<td></td>
</tr>
<tr>
<td>Barley including hull-less or naked barley but not pearled</td>
<td><em>Oryza</em> spp.</td>
</tr>
<tr>
<td>Maize (corn)</td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td></td>
</tr>
<tr>
<td>Oats, including hull-less or naked oats</td>
<td><em>Hordeum</em> spp.</td>
</tr>
<tr>
<td>Millets</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td></td>
</tr>
<tr>
<td>Teff (tef)</td>
<td></td>
</tr>
<tr>
<td>Triticale</td>
<td></td>
</tr>
<tr>
<td>Canary seed</td>
<td></td>
</tr>
<tr>
<td>Job’s tears</td>
<td></td>
</tr>
<tr>
<td>Fonio, black fonio, Asian millet</td>
<td><em>Phalaris arundinacea</em> and <em>P. canariensis</em></td>
</tr>
<tr>
<td>Wild rice</td>
<td></td>
</tr>
<tr>
<td>Pseudocereals</td>
<td></td>
</tr>
<tr>
<td>Amaranth</td>
<td></td>
</tr>
<tr>
<td>Buckwheat, Tartar buckwheat</td>
<td></td>
</tr>
<tr>
<td>Quinoa</td>
<td></td>
</tr>
<tr>
<td><em>Amaranthus caudatus</em></td>
<td></td>
</tr>
<tr>
<td><em>Fagopyrum</em> spp.</td>
<td></td>
</tr>
<tr>
<td><em>Chenopodium quinoa</em> Wild. is generally considered to be a single species within the Chenopodiioideae</td>
<td></td>
</tr>
</tbody>
</table>
Whole grain definition

- Whole grains shall consist of the intact, ground, cracked or flaked kernel after the removal of inedible parts such as the hull and husk. The principal anatomical components - the starchy endosperm, germ and bran - are present in the same relative proportions as they exist in the intact kernel.
- Small losses of components - i.e. less than 2% of the grain/10% of the bran - that occur through processing methods consistent with safety and quality are allowed.

Milling and processing

- Whole grain foods are almost universally processed to make them edible and safe for human consumption.
- Whole grain includes grains that have been subjected to processing but only if, after processing, the germ, endosperm and bran are present in the same, or virtually the same proportions, as in the original grain.
- Temporary separation of whole grain constituents during processing for later recombination is acceptable, provided the proportions of the germ, endosperm and bran are the same or virtually the same as in the original grain.
- Recombination of bran, germ and endosperm from the same type and variant of grain in which a component (bran, germ or endosperm) has been stabilised is allowed, provided that the three components are in the correct proportions.
- Removal of the very outer bran layer - up to 10% of the bran or 2% of the grain - is acceptable for minimising levels of undesirable substances such as bacteria, moulds, agrochemicals and heavy metals.
- Recombination of the endosperm, bran and germ takes into account that there are variations in the ratio of endosperm, bran and germ between kernels in one ear and between varieties of one type of grain. Recombination per grain and per variety will result in some fluctuations in the ratios of endosperm, bran and germ between batches of flour and products. There should, however, be no significant nutritional losses, and differences should be no greater than normally found from season to season or between varieties.
- Virtually all the cereals are made into flours that can be used to bake breads and other cereal-based products, including breakfast cereals. Production of those flours and products must follow appropriate quality systems (e.g. Good Manufacturing Processes, GMP etc.) in compliance with food safety regulations in the European Union.
- Storage conditions and shelf-life of whole grain flours, breads and cereal-based products vary according to the nature and composition of the product. Shelf-life stability information should be provided on product labels in compliance with European legislation.
Whole grain definition

On behalf of the HEALTHGRAIN Consortium, February 2010
Nils-Georg Asp - Swedish Nutrition Foundation, Sweden
Kaisa Poutanen, VTT and University of Kuopio, Finland
David P. Richardson - DPR Nutrition Ltd, UK
Jan-Willem van der Kamp, TNO Quality of Life, The Netherlands
HEALTHGRAIN is more …
…than science and research

Memorable moments of the HEALTHGRAIN Consortium away from the lab and the computer…

HEALTHGRAIN is...Celebration

Celebrating at VTT, after completing the first Annual Report of HEALTHGRAIN in July 2006.

Kaisa Poutanen, HEALTHGRAIN Coordinator, Riitta Kervinen, Project Manager Päivi Vahala, Secretary and Irmeli Koskinen, Financial Manager, ....all feeling happy and relieved.

HEALTHGRAIN is...Good Food

HEALTHGRAIN First Annual Meeting in Helsinki Finland, June 2006.

Special Guest, the HEALTHGRAIN Scientific Officer of the European Commission, Daniele Tissot, here with Inger Björck.

By boat the HEALTHGRAIN Team goes out to dinner.
...drinks and good food after the first year’s work in the HEALTHGRAIN project make the First Annual Meeting in Helsinki 2006 a great networking event...

HEALTHGRAIN is...Cultural Exchange

Flamenco in Madrid at 3rd HEALTHGRAIN Annual Meeting in June 2008...
HEALTHGRAIN is...Sun and Beach

Business lunch in the harbour of La Grande Motte, South of France, at the 4th HEALTHGRAIN Annual Meeting in June 2009...

....and beach party after happy hour...

...happy faces in La Grande Motte...after a hard working day, with drinks, sweets and music!
HEALTHGRAIN is...Exercise

Polish Polonaise Dancing at the Half Year Working Meeting in Warsaw Poland in January 2009.

...sometimes a confusing business for cereal scientists...

HEALTHGRAIN is...Peace and Quiet

In freezing Lapland, Finland, at the Half Year working Meeting in January 2010.
Enjoying Lapland's solitude and beauty by...
...riding reindeer sledges...
...cross country skiing...
...snowmobiling...

HEALTHGRAIN was there...
...been there...
...seen it...
....done it...

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