

Whole Grain Matters: Mechanisms and New Insights

Satellite Symposium Programme at FENS

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Symposium chairs: Professor Kaisa Poutanen and Professor Chris Seal

*Many countries now have recommendations to eat more foods made with whole grain but their populations are a long way from achieving them. This symposium focused on the scientific basis for the recommendations and highlighted new and emerging evidence on the role of whole grain in weight management and the reduction of metabolic risk factors. The chairs concluded that priorities should be to identify the many active compounds and their mechanisms and to study the impact of food structure and processing techniques. However, evidence is clear enough to be able to advocate **at least three servings per day** of foods containing whole grain, regardless of the type of cereal grain normally consumed.*

Introducing the symposium, Professor Kaisa Poutanen from VTT and the University of Eastern Finland and Chair of the HEALTHGRAIN Forum, reminded us that grains are the basis of most diets, yet whole grain in particular deserves a new focus as we have learned more in the past 10 to 15 years about the importance of bioactive compounds common to whole grains, fruit and vegetables. Today, we are moving from epidemiology to mechanisms and from there to foods with substantiated effects and then eventually to tailored raw ingredients.



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Definition of whole grain and recommendations for consumption

How do we define whole grain?

Dr Jan Willem van der Kamp (TNO, the Netherlands) explained the whole grain definition developed by the HEALTHGRAIN consortium to provide a common basis for recommendations. This includes products made by separating the main components of grain kernels (bran, germ and endosperm) and then recombining in the original proportions, although there is allowance to remove up to two per cent of the grain to minimise levels of undesirable substances on the surface (e.g. mycotoxins). More details can be found at: http://www.healthgrain.org/regulatory_issues/whole_grain.

What amount is recommended?

Recommendations for whole grain consumption have been issued by many authorities and range from a typical 48g per day whole grain (dry matter), the equivalent to three 30g slices of wholemeal bread, to 75g per day per 10MJ (Denmark) and even 100g per day (Netherlands). The typical recommendation is based mainly on epidemiological studies consistently showing that people who eat at least 48g of whole grains per day have a 20 to 40 per cent lower risk of coronary heart disease and diabetes.^{1,2} Dr van der Kamp argued that to take into account a recommended fibre intake of >25g,³ three servings per day is too modest. Assuming that whole grain should provide one third of fibre intake, six servings per day would be necessary to achieve the higher fibre recommendation of 35g issued by the Netherlands, he said.

How much are we consuming?

Currently, most populations need to increase their consumption considerably. In Britain an estimated one third of adults never eat whole grain foods,⁴ while in Denmark only six per cent consume the recommended amount (75g/d).⁵ In the USA current intakes are estimated to average only 15 per cent of those recommended.⁶ However, for many countries, published data are lacking with regard to current intake of foods made from whole grain.

Can a diet rich in whole grains help with weight management?

In the second presentation, Dr Nicola McKeown, a scientist in the Nutritional Epidemiology Program at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University, USA, reviewed evidence linking whole grains to body weight, including some exciting new research on abdominal obesity. Even modest weight loss of five to 10 per cent of body weight can translate into substantial health improvements in metabolically at-risk individuals, including a 58 per cent reduction in the incidence of new diabetes over four years.⁷ One effective strategy may be the substitution of refined-grain foods with whole grain equivalents such as recommended in 2010 Dietary Guidelines for Americans⁸ (<http://health.gov/DietaryGuidelines>). A variety of mechanisms have been postulated (see **Table One**) although evidence is still partial.

Weight control: evidence from cross-sectional and prospective studies

The majority of cross-sectional studies demonstrate an inverse association between intake of whole grains and BMI (after adjustment for potential confounders) and at least two prospective studies observed that higher whole grain intake was associated with less weight gain in adults. More studies are needed that examine fatness (as opposed to BMI) and central obesity in particular. Using Dual-emission X-ray absorptiometry scans to determine abdominal fat in older adults, Dr McKeown found that those who consumed about three servings of whole grain daily (top

quartile) had a significant lower percentage of abdominal fat (absolute difference 4%) than low consumers (<0.5 servings/day).⁸ More recently, in a study on individuals from the Framingham study who underwent Multidetector Computed Tomography scans, Dr McKeown and colleagues found that visceral adipose tissue (VAT) volume was 10 per cent lower among adults consuming three or more servings of whole grain, compared to non-consumers, even after adjusting for lifestyle and dietary factors. Conversely, high intake of refined grain products was associated with higher VAT.⁹

Weight control: evidence from intervention studies

Dietary intervention studies, of which there are relatively few, have yielded mixed results. Two hypocaloric studies comparing whole grain vs. refined grain diets found similar weight loss but greater reduction in abdominal fat¹⁰ or waist circumference¹¹ on the whole grain regimen. On the other hand, the WHOLEheart study¹² observed no changes in body weight or body composition in healthy, overweight adults consuming three or six servings per day of whole grain over 16 weeks, possibly because the intervention groups tended to add whole grains to their diet despite instruction to exchange them for refined grains. While these studies suggest that changes in overall body weight may be modest, it is possible that inclusion of foods containing whole grain into the diet may alter body fat distribution independently of weight loss, but longer, well-controlled interventions, with body composition measures, are needed to study this further. Other gaps in the knowledge base include evidence

Table One: Potential Mechanisms for Weight Control by Whole Grains

- Increased satiety (greater chewing and slower gastric emptying – greater feeling of fullness)
- Delayed starch digestion or absorption, resulting in a lower post-prandial glycaemic response and insulin demand
- Effects on plasma glucose and insulin concentrations resulting in oxidation of substrate rather than storage
- Effects on secretion of gut hormones that influence satiety, especially:
 - Glucagon-like-Peptide 1 in the GI tract inhibits gastric emptying and in the central nervous system promotes satiety and weight loss
 - Peptide YY, produced mainly by the colon in proportion to the amount of calories ingested may play a physiological role in appetite by signaling the end of a meal at the level of the hypothalamus
 - Cholecystokinin, a peptide hormone secreted by upper small intestine after ingestion of food is believed to influence post-prandial glycaemic response
 - Ghrelin, (hunger hormone) released from the stomach and suppressed by food



relating to weight gain and adiposity in ethnic groups, adolescents and children. Moving forward, intervention studies with whole grains as part of the diet regime should include biomarkers of intake to assess adherence. Also identified was a need for better characterisation of whole grain and to express intake in grams rather than number of servings.

Benefits of whole grain in insulin resistance and cardiometabolic risk

Evidence of a prebiotic mechanism based on meal studies

Meta-analyses of prospective cohort studies indicate a substantial reduction in Type 2 diabetes with higher intake of whole grain, yet the mechanisms for health benefits remain largely unknown. The next speaker, *Professor Inger Björck, Lund University, Sweden*, reported insight from acute and second meal studies focusing on glycaemic regulation and on the potential influence of colonic fermentation on cardio-metabolic risk markers.

In a series of overnight studies involving whole grain barley kernel products compared with white bread (both containing 50g available starch), Professor Björck reported benefits on glucose tolerance after a standardised breakfast.¹³ This appears to be mediated through colonic fermentation, with production of short chain fatty acids such as butyrate.¹⁴ Compared with the white bread control, in the whole grain barley group plasma free fatty acid concentrations fell (high FFA levels are a marker of insulin resistance), as did levels of interleukin-6 (IL-6), an inflammatory cytokine. With barley there was also a rise in adiponectin, a hormone which increases insulin sensitivity by increasing tissue fat oxidation and which also suppresses inflammatory processes in the vascular endothelium. Whole grain barley also increased concentrations of glucagon-like peptide-1 (GLP1), an antidiabetic and satiating hormone. The prebiotic effect appears to be linked to a number of components in the barley including dietary fibre and resistant starch.

Recently, Professor Björck and colleagues have tested whether these benefits were

observed in a more realistic eating situation involving a test evening meal followed by *ad libitum* breakfast and lunch, and found similar results (Johansson E, Nilsson A, Östman E, Björck I, to be published). An evening meal containing boiled barley kernels (as opposed to white bread) increased GLP-1 concentrations over the course of breakfast and lunch the subsequent day, and reduced hunger and energy intake. In addition, higher concentrations of adiponectin the following day suggest a beneficial effect on insulin sensitivity and inflammation.

Evidence further suggests that certain rye products, including pumpnickel bread, induced rapid colonic fermentation in the postprandial phase (measured as increase in breath hydrogen) possibly explained by the presence of arabinoxylans, fructans, and other fibre components of low molecular weight. Breath hydrogen correlated with lower late-postprandial free fatty acid concentration and an improved glycaemic profile (lower peak and longer duration above fasting level), suggesting increased glucose tolerance in the postprandial phase. Rye kernels induced high postprandial subjective satiety and also promoted satiety at a subsequent meal. Professor Björck concluded that colonic fermentation of indigestible carbohydrates in foods containing whole grains might contribute to the metabolic benefits seen in observational studies. However, she said it was important that future long-term studies should consider the prebiotic potential (and glycaemic index and glycaemic profile) of included foods, as well as possible synergies with prebiotics in the 'background' diet.

Metabolic syndrome and the role of whole grain cereals

Continuing on the theme of metabolic disease and inflammation, the last speaker *Professor Chris Seal from Newcastle University, UK*, presented some new data on the potential role of whole grain in metabolic syndrome (MS). As a cluster of risk factors rather than a disease in itself, metabolic syndrome has varying diagnostic criteria. Diagnosis is broadly based on an individual showing three or more risk factors, which include insulin resistance, elevated blood glucose and uric acid concentrations, dyslipidaemia (elevated LDL cholesterol; lowered HDL cholesterol and higher

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triglycerides), higher blood pressure, and central obesity. Prothrombotic and proinflammatory states are also often observed in people with MS, but these are not yet considered part of the diagnostic process despite their association with CVD risk.

Many cross-sectional studies show reduced risk of MS or its components with higher whole grain consumption,^{15, 16, 17} yet prospective studies are sparse¹⁸ and evidence from interventions is inconclusive.

In regard to inflammation, there is some evidence that adults with high whole grain consumption (median 2 servings daily) have significantly lower plasma concentrations of Plasminogen activator inhibitor-1 (PAI-1) (an inhibitor of fibrinolysis and associated with thrombosis) and C-reactive protein (CRP) (an acute-phase protein associated with the inflammatory response).¹⁹ In a sample of healthy young women, as little as one or more whole grain servings a day was associated with 12 per cent lower CRP concentrations (P = 0.02) compared with non-consumers.²⁰ Of the intervention studies, only two showed evidence of an effect on inflammatory markers. In individuals with impaired glucose metabolism, a diet high in whole grain products (with or without the addition of fatty fish and bilberries) significantly reduced levels of CRP over 12 weeks compared with no change in the control group.²¹ In adults with MS a hypocaloric diet with whole grains gave greater decreases in CRP (and in abdominal fat) than a diet that included refined grains.¹⁰

There is no doubt, said Professor Seal, that higher whole grain consumption is associated with improvement in some CVD risk factors. Higher intakes of both foods made with whole grains and cereal fibre are associated with less progression of coronary atherosclerosis in postmenopausal women with established coronary artery disease.²² In relation to blood pressure and vascular risk, prospective data from the Health Professionals follow-up study found a 19 per cent lower relative risk of hypertension among highest consumers (median 46g whole grain/d) vs. lowest consumers (3g/d).¹⁸ In a randomised controlled trial in healthy adults, groups eating three servings whole grain foods (either wheat or wheat and oats) reduced systolic blood pressure by 6mm Hg compared with

the control group, which could translate to a 15 per cent and 25 per cent decrease in the incidence of coronary artery disease and stroke, respectively.²³ He also presented data from a recent pilot study, which found that 48 g/d of whole grain consumed as bread rolls for three weeks reduced systolic blood pressure by 2 mmHg, although weight did not change, while SBP rose among controls.²⁴ Professor Seal concluded that foods containing whole grains may elicit a series of small improvements in several risk markers, which in combination may be associated with a benefit.

Points arising from the Question Session and Panel Discussion

Panelists were agreed that there is an urgent need to identify the components of whole grain and how they are acting. Food structure also has an important effect and needs defining better in studies, while synergistic effects between whole grain with other dietary components have also received insufficient attention. Identifying mechanisms and active substances is essential, but it is important that dietary advice should encourage consumption of whatever type of whole grain cereal is preferred in that population, probably by advocating stepwise changes that move people toward the desired goal. Health professionals might consider how best to communicate the whole grain message: not only advocating 'eating foods as nature intended' but also demystifying 'processing', which can have benefits in increasing bioavailability. The industry is responding by producing a variety of palatable foods containing whole grain in varying proportions (over 3200 new product launches in 2010). Nevertheless, as the consumption statistics show, there is a long way to go to achieve recommended levels. People with metabolic abnormalities or obesity should arguably consume more than the standard recommendation. However, it is worth emphasising that most of the beneficial effects are seen when whole grain is used as substitute for refined grain cereal products, rather than as a supplement to them.

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