Variability and required level of characterisation of complex foods

for studies of their physiological responses & for labelling purposes

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International Symposium on Health Benefits of Foods - From Emerging Science to Innovative Product
6 October 2011
Foods are complex by nature

Food

(Bioactive) fraction

(Bioactive) extract

Singe compound

Multiple signals & targets, long exposure

Single target, shorter exposure
Complex vs. simple foods?

- Composition = chemistry
  - Small molecular weight compounds
  - Biopolymers
  - Lipids

- Structure = physics
  - Different structural levels from nano to makro
  - Rheological properties
  - Interactions of constituents
  - Water dynamics
Required level of characterization of food?

- For research
  - to assess food digestibility and bioaccessibility of components?
  - to understand how food properties determine acute physiological outcomes?
  - to show effects of dietary changes in longer-term interventions?
  - to define diets in epidemiological studies?

- For labelling
  - for consumer communication of nutritional properties?
  - for health claims?

- For safety assessment?
Epidemiology

Long time health effects at population level

Dietary recommendations

Hypotheses for food properties and mechanisms

Animal models

In vitro

Mechanisms

Validation

Human meal studies

Human intervention studies

Biomarkers
Processing influences food digestibility, nutrient signaling and health

**FOOD**
- Release of compounds
- Absorption
- Fermentative bioconversions
- Absorption
- Excretion

**NUTRITION**
- Diet / gene interactions
- Effects on cellular metabolism
- Cytotoxicity

**HEALTH**
- Obesity
- Metabolic syndrome
- Diabetes
- CVD
- ……

**PHYSIOLOGICAL RESPONSES**
- Raw material- & process- induced changes on food
  - Composition
  - Structure
  - Sensory quality
  - Stability
  - Safety

**EFFECTS ON DISEASE RISK**
Whole grain -> quality of cereal food -> health outcome?
Sterols
Minerals
Phytic acid
Vitamins
Phenolic compounds
(Micronutrients, phyto-estrogens, antioxidants, enzyme inhibitors..)

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Cell wall poly-saccharides and lignin (Dietary fibre)</td>
<td>10-15 %</td>
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<tr>
<td>Starch</td>
<td>50-60 %</td>
</tr>
<tr>
<td>Protein</td>
<td>10-20 %</td>
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<tr>
<td>Fat (Energy-providing macronutrients)</td>
<td>5-10 %</td>
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</tbody>
</table>
Whole Grain, Bran, and Germ Intake and Risk of Type 2 Diabetes: A Prospective Cohort Study and Systematic Review

Jeroen S. L. de Munter¹,², Frank B. Hu¹,³,⁴, Donna Spiegelman³,⁵, Mary Franz¹, Rob M. van Dam¹,²,⁴*

¹ Department of Nutrition, Harvard School of Public Health, Boston, Massachusetts, United States of America, ² Institute of Health Sciences, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands, ³ Department of Epidemiology, Harvard School of Public Health, Boston, Massachusetts, United States of America, ⁴ Channing Laboratory, Department of Medicine, Brigham and Women’s Hospital and Harvard Medical School, ⁵ Department of Biostatistics, Harvard School of Public Health, Boston, Massachusetts, United States of America


Based on pooled data for six cohort studies including 286,125 participants and 10,944 cases of type 2 diabetes, a two-serving-per-day increment in whole grain consumption was associated with 21% decrease in risk of type 2 diabetes after adjustment for potential confounders and BMI.
An analysis of the data of seven population studies with 149 000 people showed that those who consumed 2.5 dosages of whole grain foods had 21% lower risk of getting cardiovascular disease than those who ate 0.2 dosages daily.
CONCLUSIONS:
Our results support the favourable association of whole-grain intake with fasting glucose and insulin and suggest a potential interaction between variation in GCKR and whole-grain intake in influencing fasting insulin concentrations.
Epidemiological evidence on effects of foods on disease risk

Tailored raw materials

Design of food properties

Effects of specific foods on health-relevant biomarkers
We should open the "black boxes"

Nutrition science
We should open the "black boxes"

Food technology
Harvard school of public health, nurses´health study, diet and supplement use question index

- Other supplements (ie cod liver oil, brewer's yeast, etc)
- How many days a week do you have breakfast?
- How many times a day do you eat? (include meals & snacks)
- Wat percent of your noon and evening meals are prepared at home? (exclude commercially prepared meals)
- How many times do you eat meat (beef, pork, lamb) per week?
- How is it cooked (ie roasted, panfried, broiled, bbq'd, or boiled/stewed)
- What do you do with the visible fat on your meat?
- What kind of fat do you use for frying or sauteing?
- What kind of fat do you use for baking
- What form of margarine do you use?
- How often do you eat food that is fried at home? (excluding PAM spray)
- How often do you eat fried food away from home?
- How many teaspoons of sugar do you add to your food each day?
- What type of cooking oil do you usually use?
- What type of cold breakfast cereal do you usually use?
- Are there any other important foods that you usually eat at least once a week? (specify)
- How many shakes of salt do you add to your food per day?
- How much salt is added during cooking of these foods: meat, veg, staples (rice), soup
- In a typical week, number of days you have any form of alcoholic beverage
- In a typical month during the last year, what was the largest number of drinks you had in one day?
- ETC
Harvard school of public health, health professionals’ follow-up study, part of questionnaire (http://www.hsph.harvard.edu/hpfs/pdfs/06L.pdf)
Harvard school of public health, health professionals´ follow-up study, part of questionnaire (http://www.hsph.harvard.edu/hpfs/pdfs/06L.pdf)

<table>
<thead>
<tr>
<th>SWEETS, BAKED GOODS, MISCELLANEOUS</th>
<th>Never, or less than once per month</th>
<th>1-3 per month</th>
<th>1 per week</th>
<th>2-4 per week</th>
<th>6-6 per week</th>
<th>1 per day</th>
<th>2-3 per day</th>
<th>4-5 per day</th>
<th>6+ per day</th>
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<tr>
<td>Milk chocolate (bar or pack), e.g., Hershey’s, M&amp;M’s</td>
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<td>Dark chocolate, e.g., Hershey’s Dark or Dove Dark</td>
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<td>Candy bars, e.g., Snickers, Milky Way, Reeses</td>
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<td>Candy without chocolate (1 oz.)</td>
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<td>Cookies (1)</td>
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<td>Fat free or reduced fat</td>
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<td>Other ready made</td>
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<td>Home baked</td>
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<td>Brownies (1)</td>
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<td>Doughnuts (1)</td>
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<td>Cake, homemade or ready made (slice)</td>
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<td>Pie, homemade or ready made (slice)</td>
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<td>Jams, jellies, preserves, syrup, or honey (1 Tbs)</td>
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<td>Peanut butter (1 Tbs)</td>
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<td>Popcorn (3 cups)</td>
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<td>Fat free or light</td>
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<td>Sweet roll, coffee cake or other pastry (serving)</td>
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<td>Fat free or reduced fat</td>
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<td>Pretzels (1 small bag or serving)</td>
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<td>Peanuts (small packet or 1 oz.)</td>
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<td>Walnuts (1 oz.)</td>
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<td>Other nuts (small packet or 1 oz.)</td>
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<td>Oat bran, added to food (1 Tbs)</td>
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<td>Other bran, added to food (1 Tbs)</td>
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</tbody>
</table>
FDA Health claim 1999

“Diets rich in whole grain foods and other plant foods and low in total fat, saturated fat, and cholesterol may reduce the risk of heart disease and certain cancers”.

US Dietary recommendations 2010

- Consume 3 or more ounce-equivalents of whole-grain products per day, with the rest of the recommended grains coming from enriched or whole-grain products.
- In general, at least half the grains should come from whole grains.
Definition of whole grain

- **AACCI 1999**: Whole grains shall consist of intact, ground, cracked, or flaked caryopsis, whose principal anatomic components – the starchy endosperm, germ, and bran – are present in the same relative proportions as they exist in the intact caryopsis.

- **FDA 2006** “Whole grain" includes "cereal grains that consist of the intact and unrefined, ground, cracked or flaked fruit of the grains whose principal components -- the starchy endosperm, germ and bran -- are present in the same relative proportions as they exist in the intact grain." Examples include: barley, buckwheat, bulgur, corn, millet, rice, rye, oats, sorghum, wheat and wild rice.

- **Healthgrain 2010**: Whole grains consist of 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.

  - Temporary separation of whole grain constituents during processing for later recombination is acceptable.
Whole grain food, whole meal food?

- USA (FDA, 1999) whole grain foods must contain \( \geq 51\% \) whole grain ingredients by wet weight.

- Sweden, Denmark \( \geq 50\% \) whole grain ingredients by dry weight.
Whole grain seals by www.wholegrainscouncil.org

At least 8 grams of whole grain per labeled serving

At least 16 grams of whole grain per labeled serving

At least 16 grams of whole grain per labeled serving. No refined grain
All whole grains are not equal

<table>
<thead>
<tr>
<th>Wheat</th>
<th>Rye</th>
<th>Oats</th>
<th>Barley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Rice</td>
<td>Sorghum</td>
<td>Buckwheat</td>
</tr>
</tbody>
</table>

?
Suggested beneficial physiological effects assisting in health maintenance

- Magnesium, chromium: Improved insulin sensitivity
- Phytoestrogens
- Lignans
- Alkylrecorcinols: Antioxidants
- Tocopherols & trienols: Antioxidants, reduce LDL oxidation
- Phytosterols: Cholesterol-lowering
- Phytate: Antioxidant
- Dietary fibre: Improved glucose and lipid metabolism
- Ferulic acid: Antioxidant
- Oligo-Saccharides: Prebiotic
- Folate: Choline, betaine: Methyl donors
- Tocopherols & trienols: Antioxidants, reduce LDL oxidation
Biochemical markers: Efficient tools for the assessment of wheat grain tissue proportions in milling fractions

Youna Hemery\textsuperscript{a}, Valérie Lullien-Pellerin\textsuperscript{a}, Xavier Rouau\textsuperscript{a}, Joël Abecassis\textsuperscript{a}, Marie-Françoise Samson\textsuperscript{a}, Per Åman\textsuperscript{b}, Walter von Reding\textsuperscript{c}, Cäcilia Spoerndli\textsuperscript{c}, Cécile Barron\textsuperscript{a,*}

Biochemical markers chosen were

- Ferulic acid trimer
- Alkylresorcinols
- Para-coumaric acid
- Phytic acid
- Starch
- Wheat germ agglutinin
- Outer pericarp,
- Intermediate layer
- Aleurone cell walls
- Aleurone cell contents
- Endosperm
- Germ
Biomarkers of intake would be useful

Plasma AR concentrations are correlated with intake assessed by food records, which suggests that Ars are selective nutritional biomarkers for the intake of whole-grain wheat and rye.

AJCN 2008, 87:832-8
Some *suggested* mechanisms for metabolic benefits of whole grain foods (HEALTHGRAIN project)

**Whole grain (WG) intake**

- **Dietary fibre**
- **Oligosaccharides, RS**
- **Bioactive components**

**Colonic fermentation**

- (Viscosity/food structure)
- (e.g. SCFA, phenolic metabolites)

**Antioxidant/anti-inflammatory status**

- (e.g. Mg)

**Insulin resistance**

**Blood lipids**

**Type 2 diabetes**

**CVD**

**Homocysteine**

**Dietary fibre**

**Whole grain (WG) intake**

**Bioactive components**

- (Betaine, choline, folate)

**Insulin resistance**

**Blood lipids**

**Type 2 diabetes**

**CVD**
Whole grain and grain dietary fibre foods
- Origin and type
- Effects of processing

Decreased risk of type 2 diabetes

SCFA=short chain fatty acids, ↑=increases, ↓=decreases

Based on Jenni Lappi et al in press
Bran: the grain fraction high in dietary fibre and associated phytochemicals, minerals and vitamins

• An important DF ingredient

• Due to structural complexity at different levels poses challenges for food uses

• Effects of structure on gastrointestinal physiology not well known
The section has been stained with Acid Fuchsin and Calcofluor Protein (red), Cell walls (blue), Lignified cell walls (orange)

Fruit coat (pericarp)

Seed coat (testa)

Aleurone layer

Starchy endosperm
Microstructure of unstained rye (R) and wheat (W) brans (Kamal-Eldin et al 2009)

Bar=500 µm = 0,5 mm
Influence of structural modification on functionality?

Rye bran

Chemical structure of polymer
Polymer structure
Polymer size
Type and amount of associated compounds
Cell wall structure
Particle size, shape
Rheological properties

Bio-processed rye bran
- Mostly insoluble cell walls and associated compounds
  - Highly resistant structures
  - Particle size depends on processing
  - Effects on food matrix structure and mechanical properties

- Polymeric extractable arabinoxylan and beta-glucan
  - High viscosity
  - Effects on food matrix structure

- Fructans

- Partially depolymerized arabinoxylan and beta-glucan and oligosaccharides thereof?
Effect of cryogenic grinding on coarse wheat bran (Healthgrain project)

Grinding made at INRA Montpellier.
Structure in food processing and gastrointestinal digestion

Food components

- Native structure
- Structuring
- Engineered structure
- De-structuring
- Ultimate structure
- Mastication
- Perceived structure

Structure of bolus

Swallowing

Heat
Mass
Shear

Degradation and hydrolysis in stomach

Structure of digesta

GI Enzymes

Small intestinal degradation and absorption

GI Microbes

Structure and quantity of digesta

Large intestinal degradation and fermentation

Structure and amount of faeces
List of allowed nutrition claims in the EU regulation 1924/2006

- Low energy
- Energy-reduced
- Energy-free
- Low-fat
- Fat-free
- Low-saturated fat
- Saturated fat-free
- Low sugar
- Sugar-free
- With no added sugar
- Low sodium/salt
- Very low sodium/salt
- Sodium-free or salt-free

- Source of fibre
- High fibre
- Source of protein
- High protein
- Source of (name of vitamin/s) and/or (name of mineral/s)
- High (name of vitamin/s) and/or (name of mineral/s)
- Contains (name of the nutrient or other substance)
- Increased (name of the nutrient)
- Reduced (name of the nutrient)
- Light/lite
- Naturally/natural
EU Fibre definition
Commission directive 2008/100/EC

- Fibre means carbohydrate polymers with three or more monomeric units, which are neither digested nor absorbed in the human small intestine and belong to the following categories*:
  - Edible carbohydrate polymers naturally occurring in the food as consumed;
  - Edible carbohydrate polymers which have been obtained from food raw material by physical, enzymatic or chemical means and which have a beneficial physiological effect demonstrated by generally accepted scientific evidence;
  - Edible synthetic carbohydrate polymers which have a beneficial physiological effect demonstrated by generally accepted scientific evidence.
EU Fibre definition
Commission directive 2008/100/EC

- The carbohydrate polymers of plant origin that meet the definition of fibre may be closely associated in the plant with lignin or other non-carbohydrate components such as phenolic compounds, waxes, saponins, phytates, cutin, phytosterols.

- These substances when closely associated with carbohydrate polymers of plant origin and extracted with the carbohydrate polymers for analysis of fibre may be considered as fibre.

- However, when separated from the carbohydrate polymers and added to a food these substances should not be considered as fibre.
Beneficial physiological effects of dietary fibre (EU def.)

- Decreasing of intestinal transit time
- Increasing of stool bulk
- Fermentability by colonic microflora

- Attenuation of blood total cholesterol
- Attenuation of blood LDL cholesterol
- Attenuation of postprandial blood glucose
- Attenuation of blood insulin levels
**Claims on cereal fractions and dietary fibre on EFSA positive list of generic health claims**

<table>
<thead>
<tr>
<th>Food constituent</th>
<th>Claimed effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat and barley grain fibre</td>
<td>Gut health (increase in faecal bulk)</td>
</tr>
<tr>
<td>Rye Fibre</td>
<td>Changes in bowel function</td>
</tr>
<tr>
<td>Wheat bran fibre</td>
<td>Increase in faecal bulk</td>
</tr>
<tr>
<td>Wheat bran fibre</td>
<td>Reduction in intestinal transit time</td>
</tr>
<tr>
<td>Beta-glucans from oats and barley</td>
<td>Reduction of post-prandial glycaemic responses</td>
</tr>
<tr>
<td>Beta-glucan</td>
<td>Maintenance of normal blood cholesterol concentrations</td>
</tr>
<tr>
<td>Arabinoxylan produced from wheat endosperm</td>
<td>Reduction of post-prandial glycaemic responses</td>
</tr>
<tr>
<td>Glucomannan</td>
<td>“Cholesterol” and “cholesterol level”</td>
</tr>
<tr>
<td>Glucomannan</td>
<td>Reduction of body weight</td>
</tr>
</tbody>
</table>
Food design for physiological functionality

- Food research
  - Food prototypes
    - In vivo studies
  - In vitro models
  - Metabolomics analyses of in vivo & in vitro samples

Knowledge on the physiological functionality of food

Bioinformatic analyses
Data alignment
Identification + integration
In vitro methodologies
A bridge between food technology and human nutrition

**IN VITRO ENZYMATIC DIGESTION**
- Starch hydrolysis rate
- Quantification of dietary fibre
- Bioaccessibility of phenolics compounds

**HUMAN GASTRO-INTESTINAL TRACT**

**IN VITRO COLON FERMENTATION**
- Fermentability of dietary fibre
- Metabolite formation
- Bioconversions of phenolic compounds
DF and WG- rich foods are parts of a healthy diet

How can we help them to replace refined foods –
labelling and consumer motivation –
risk-benefit assessment

Emerging scientific knowledge
about structure-function relationships,
biomarkers etc
Thank you for your attention!
Kaisa.Poutanen@vtt.fi