Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Opportunities with Grains for Health: Breeding and Production

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Winnipeg, Manitoba, Canada
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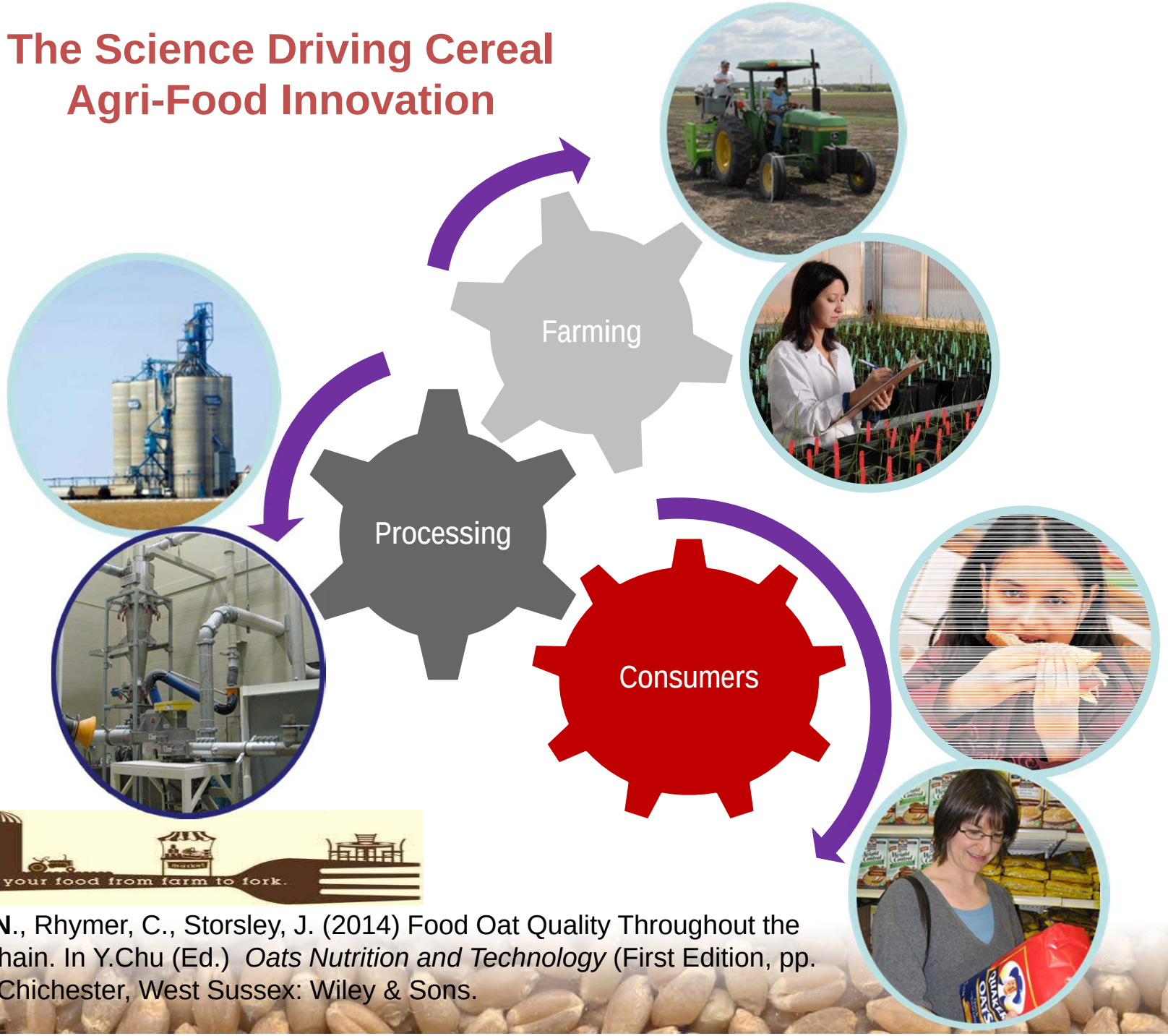
Canada

The Science Driving Cereal Agri-Food Innovation



Ames, N., Rhymer, C., Storsley, J. (2014) Food Oat Quality Throughout the Value Chain. In Y.Chu (Ed.) *Oats Nutrition and Technology* (First Edition, pp. 33-70). Chichester, West Sussex: Wiley & Sons.

Justification for Increased Consumption of Whole Grains

- Health benefits of whole grains and specific compounds found in whole grains have been substantiated
  - Glycemic control (diabetes and obesity)
  - Cholesterol lowering (coronary heart disease)
  - Reduced risk of cancer

Whole grains are a natural vehicle for providing health promoting nutrients to a growing population

Fibre-Related Claims for Grain Foods

Nutrient Content Claims (Canada & US): based on total fibre content

Canadian Approved Health Claims:

Oat Products and Blood Cholesterol Lowering

Contain at least 0.75 g β-glucan oat fibre per reference amount and per serving of stated size from the eligible sources. The label reads as 25% of daily requirements. (Daily amount 3 g β-glucan oat fibre)

Barley Products and Blood Cholesterol Lowering

Contain at least 1 g of β-glucan from barley grain products per reference amount. (Daily amount 3 g of barley β-glucan). The Label reads as 35% of daily requirements

FDA Approved Health Claims:

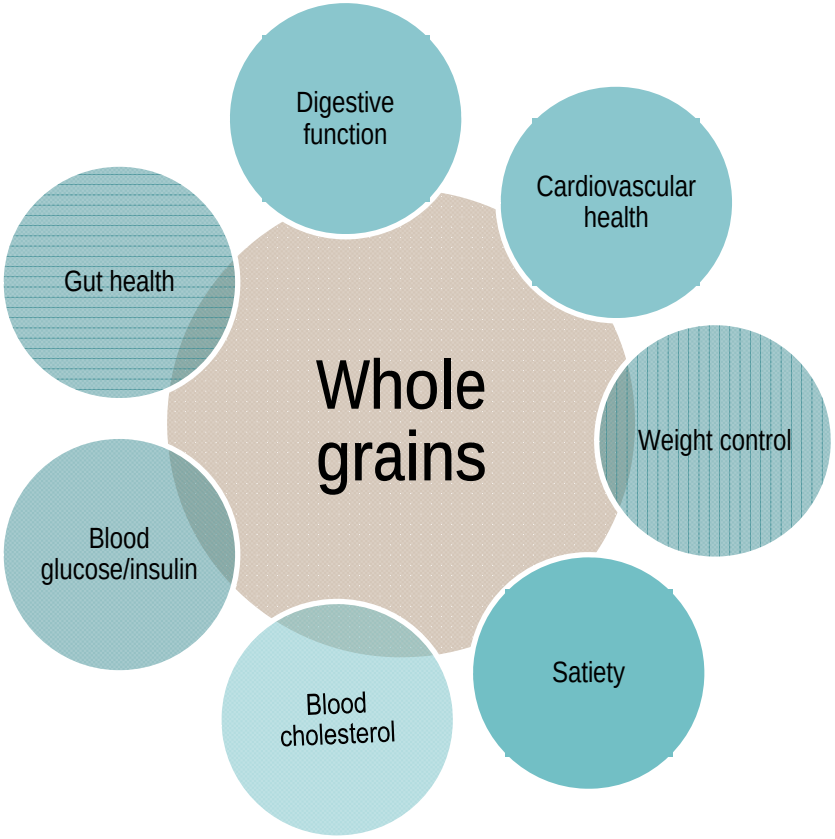
Soluble fiber from fruit, vegetables and grain for reducing coronary heart disease: 0.6 g soluble fiber per reference amount

Soluble fiber from certain foods for reducing coronary heart disease - Oats, Barley, Psyllium
0.75 g β-glucan soluble fiber from oats, barley per reference amount

Fiber from Grains, Fruit & Vegetables for Reduced Risk of Cancer

Whole Grain Foods Reduce the Occurrence of Coronary Heart Disease and Cancers of the Lung, Colon, Esophagus, and stomach (at least 51% of product by weight must contain whole grain)

European Food Safety Authority



http://www.efsa.europa.eu/en/efsajournal/pub/1766.htm

European Food Safety Authority health claims

(Source: Healthgrains Forum)

Material	Health claim	Conditions of use	EFSA opinion reference
Rye fibre	Normal bowel function	Foods should be high in that fibre (i.e. fibre ≥ 6g/ 100g product) and daily intake ≥ 10g is required	2011;9(6):2258
Barley grain fibre	Increase in faecal bulk		2011;9(6):2249
Oat grain fibre	Increase in faecal bulk		2011;9(6):2249
Wheat bran fibre	Increase in faecal bulk		2010;8(10):1817
Wheat bran fibre	Accelerated intestinal transit	Foods should be high in that fibre and daily intake ≥ 10g is required	2010;8(10):1817

European Food Safety Authority health claims

(Source: Healthgrains Forum)

Material	Health claim	Conditions of use	EFSA opinion reference
β-glucans (Bg)	Maintenance of normal cholesterol levels (Article 13.1 claim)	Daily intake of 3 g required Food with ≥ 1 g of Bg per quantified portion.	2009;7(9):1254 , 2011;9(6):2207
Oat β-glucan	Oat (respectively barley) beta-glucan has been shown to lower/reduce blood cholesterol. High cholesterol is a risk factor in the development of coronary heart disease *Article 14.(1)(a) claim (disease reduction claim)*	Daily intake of 3 g required Foods which provide at least 1g of oat (respectively barley) per portion	Q-2008-681
Barley β-glucan			Q-2011-00798 *and* Q-2011-00799

European Food Safety Authority health claims

(Source: Healthgrains Forum)

Material	Health claim	Conditions of use	EFSA Opinion Reference
Arabinoxylan produced from wheat endosperm	Reduction of blood glucose rise after a meal	Daily intake ≥ 8g AX rich fibre	2011;9(6):2205
β-glucans from oats and barley		Intake ≥ 4g / 30g digestible carbs	2011;9(6):2207
Resistant starch (RS)		RS Content ≥ 14% of total starch	2011;9(4):2024

How can breeding and production enhance the healthfulness and consumer acceptance of whole grains?

Genotype (G) x Environment (E) x Processing (P)

Health effects

Breeding: Developing cultivars with enhanced nutrition and consumer appeal

- Increase levels and efficacy of bioactive compounds
  - E.g. increase soluble fibre and viscosity; reduce available carbohydrate
  - Increase mineral uptake based on growing location; genes affecting mineral remobilization
- Improved whole grain end-product quality
  - E.g. increase dough strength to accommodate increased bran and germ fractions (i.e. focus on protein quality)
  - Remove astringent flavour compounds present in bran
- Altered physical grain characteristics
  - E.g. Increase bran layer and separation
  - Change kernel morphology and fractionation properties (particle size)
  - Higher test weight
- Develop new methodologies for screening early generation breeding lines
  - E.g. rapid screening of traits for better whole grain bread
  - *In vitro* testing of physiological outcomes

Environmental Effects on Nutritional Quality

- G x E and G x E x P Studies
  - starch properties; nutritional components; end product texture
  - E.g. collaboration with China to study phenolics, avenanthramides and antioxidant activity
- Effects of disease, sprouting, agricultural practices and applications
  - E.g. collaborations to investigate application of fungicides and glyphosate on grain quality

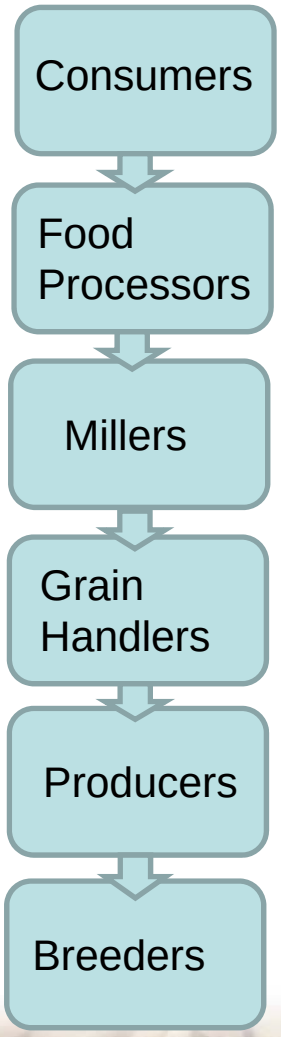
May, W., **Ames, N**., Irvine, B. Kutcher, H.R., Lafond, G.P. and Shirtliffe, S.J. (2014) Are fungicide applications to control Crown Rust in oat beneficial? Canadian Journal of Plant Science, 94(5): 911-922.

Yan, W., Mitchell Fetch, J.W., Frégeau-Reid, J.A., Rossnagel, B.G., and **Ames, N.P.** (2011). Genotype × location interaction patterns and testing strategies for oat in the Canadian prairies. *Crop Science, 51*(5), pp. 1903-1914.

Rhymer, C., **Ames, N.**, Malcolmson, L., Brown, D., Duguid, S. (2005). Effects of Genotype and Environment on the Starch Properties and End-Product Quality of Oats. Cereal Chem. 82(2): 197-203.

Tekauz, T., McCallum, B**., Ames, N.** and Mitchell Fetch, J. (2004). Current status of Fusarium head blight of oat in western Canada. Can. J. Plant Pathol. 26:473-479.

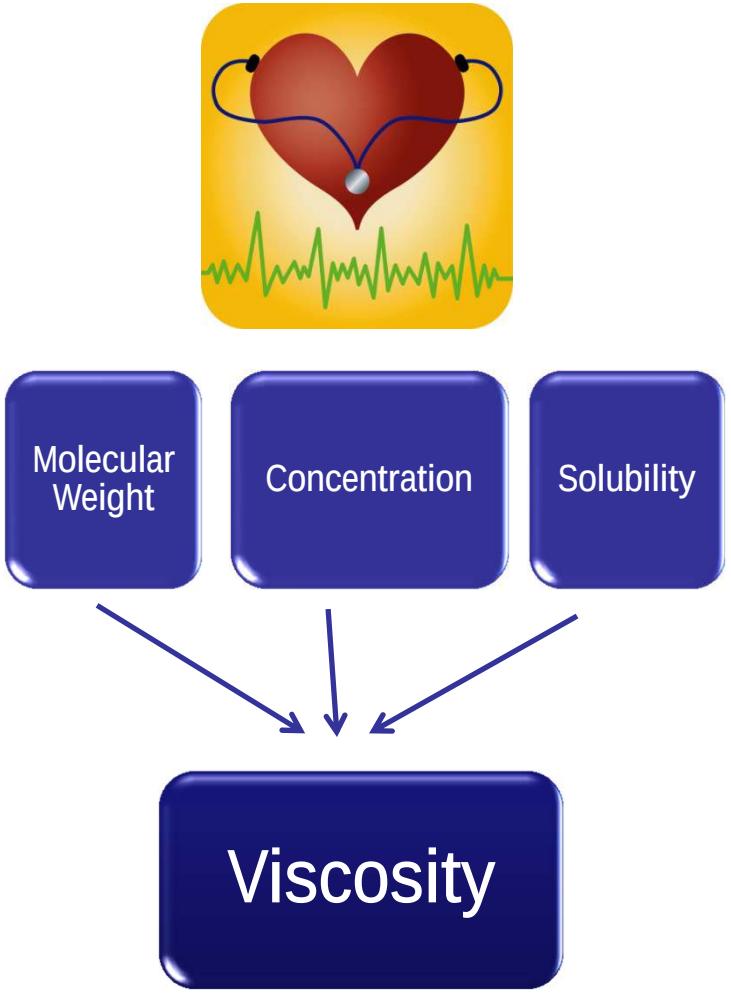
Oat beta-glucan health benefit:
Example of successful uptake along the value chain



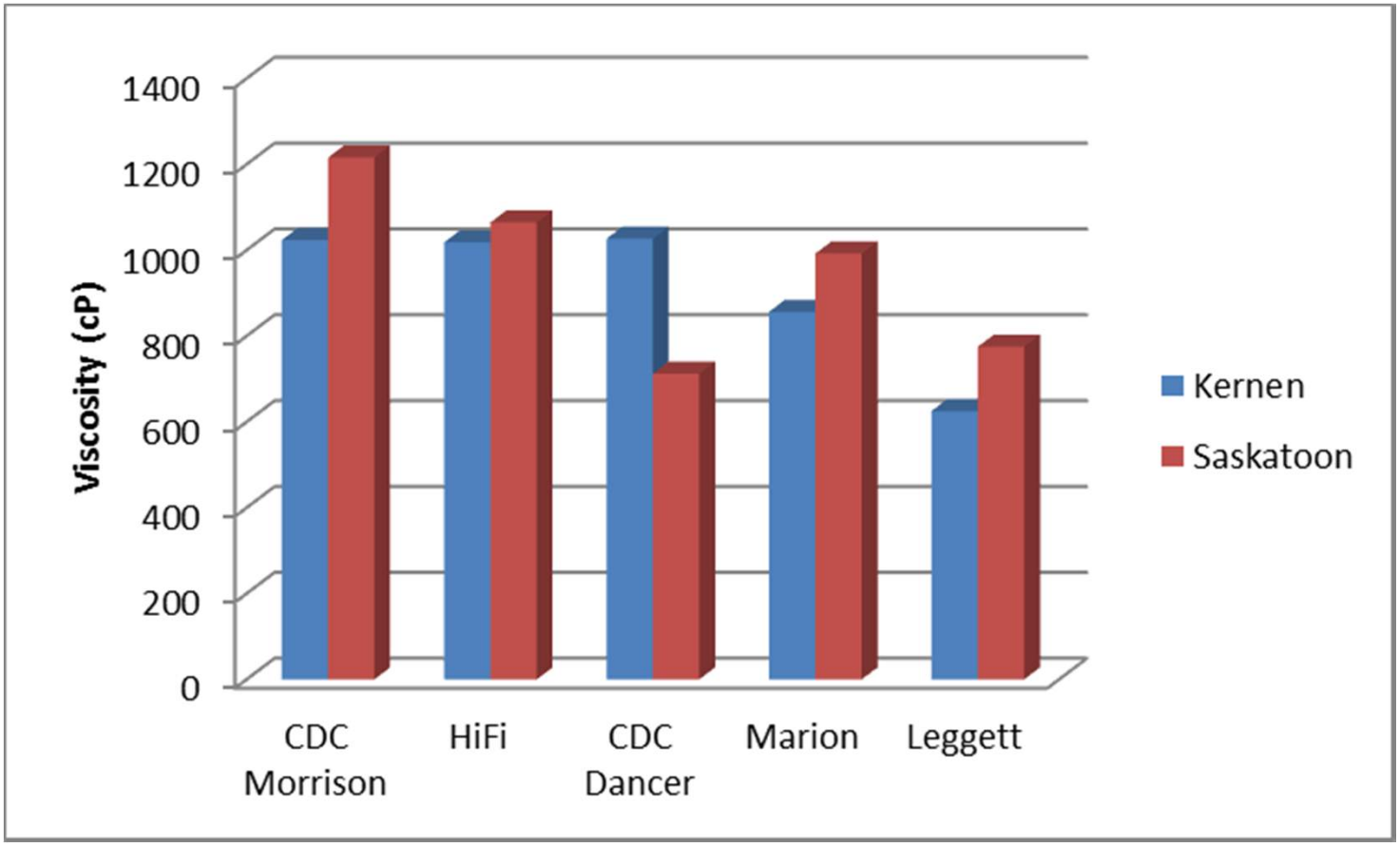
- Consumers look for foods to lower cholesterol (3g BG per day health claim)
- Processors put health claim on eligible oat product labels (0.75g/serving)
- Millers need to meet ingredient specifications for high beta-glucan content (flakes, flour, oat bran, etc. 4 - 20% BG)
- Grain handlers source oats from millers' "preferred variety" lists (>4% BG)
- Producers choose varieties that are believed to be marketable (opportunities for contract growing of healthier oats)
- High BG is a quality trait in breeding (variety registration requires >4% BG)

New Opportunities: Beta-Glucan Viscosity

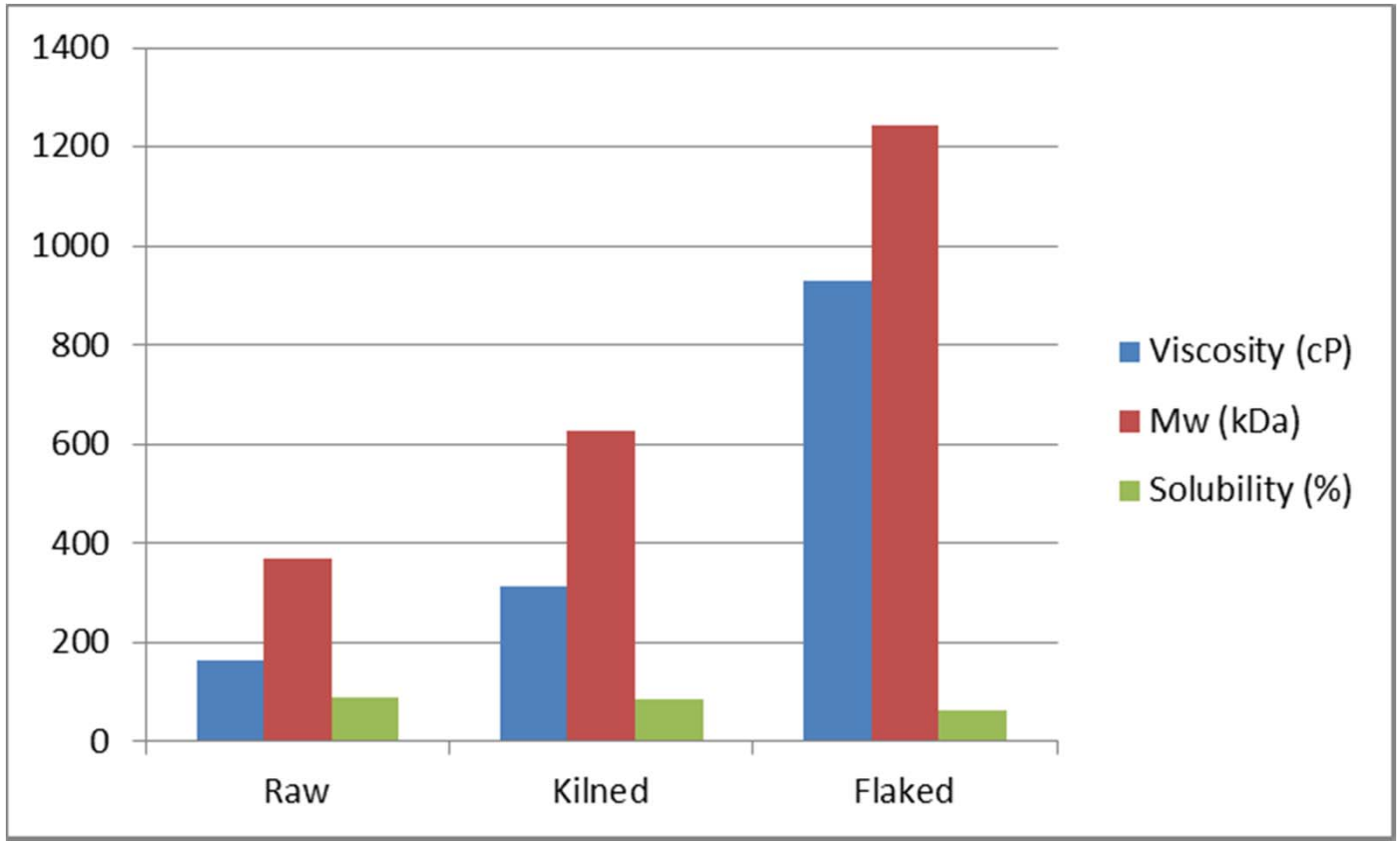
- Highly viscous nature of beta-glucan is thought to impart its health benefits
  - e.g. oat and barley studies show that viscosity of beta-glucan affects glucose response, cholesterol lowering and gut microbiota in humans
- Physicochemical properties contribute to viscosity
- External factors affecting one or more of these BG properties therefore have potential to influence physiological efficacy



Genotypic and Environmental Variation in BG Viscosity from Oat Flakes

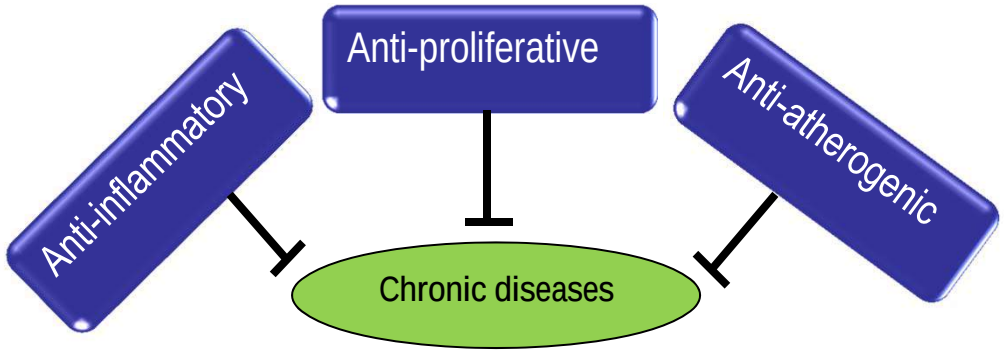


Effect of Pilot Scale Oat Processing on Beta-Glucan Properties

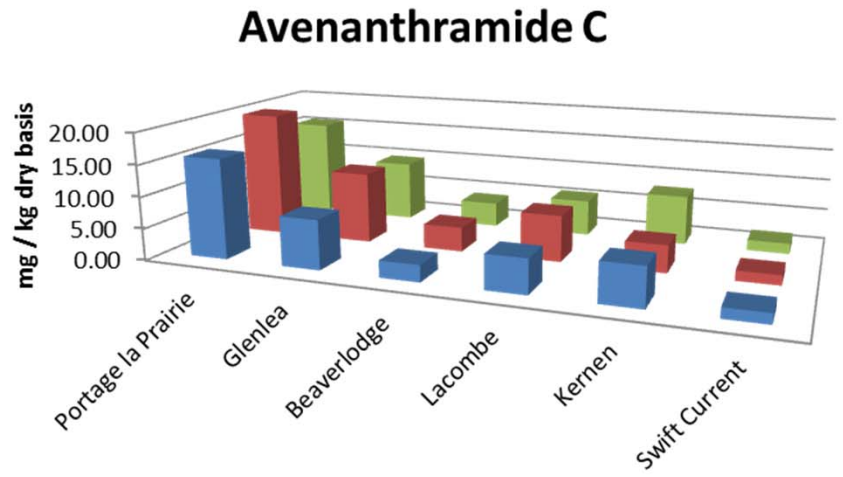


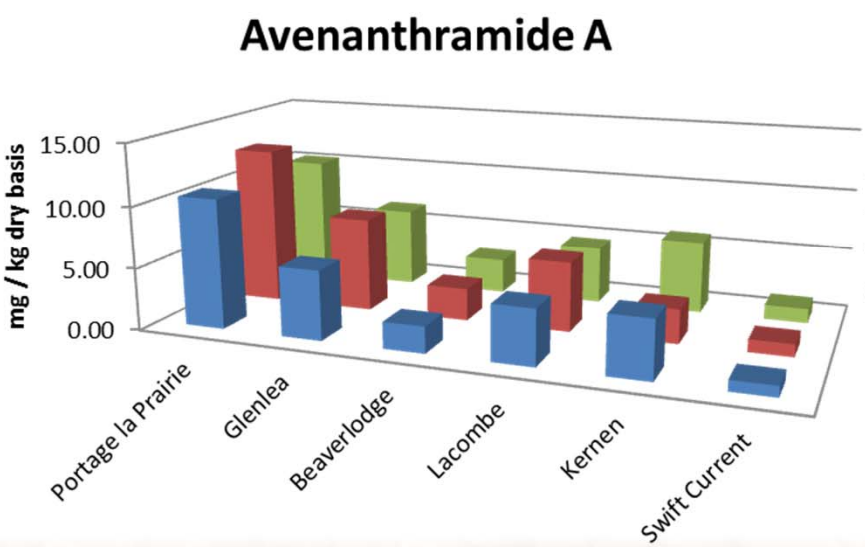
Avenanthramides - polyphenols unique to oats

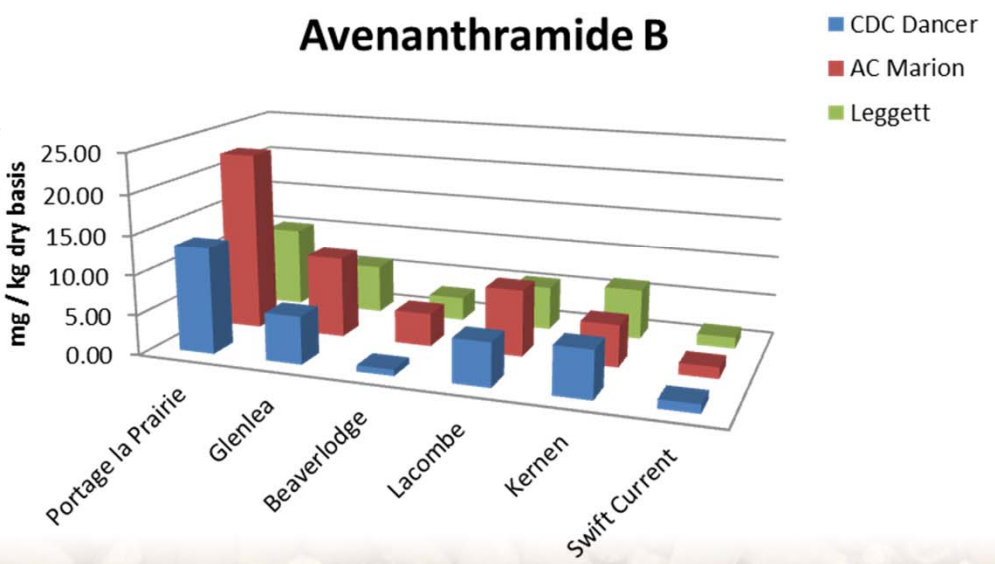
- Low-molecular-weight, soluble phenolic compounds.
- Anti-pathogenic molecules (phytoalexins) produced by the plant in response to various pathogens such as fungal infection.
- More than 20 different forms are present; the three major forms are A, B, and C.
- Has shown broad range of health benefits in *in-vitro* and *in-vivo* settings.



Effect of GxE on Avenanthramide Compounds







Research in Support of Breeding for Healthier Wheat

- New analytical tools suitable for plant breeding (NIR equations for fibre components; Electronic Nose)
- Discovery of bioactives and variability in wheat germplasm (arabinoxylan, lutein, betaine, fibre)
- Validation of physiological effects in animal and human models

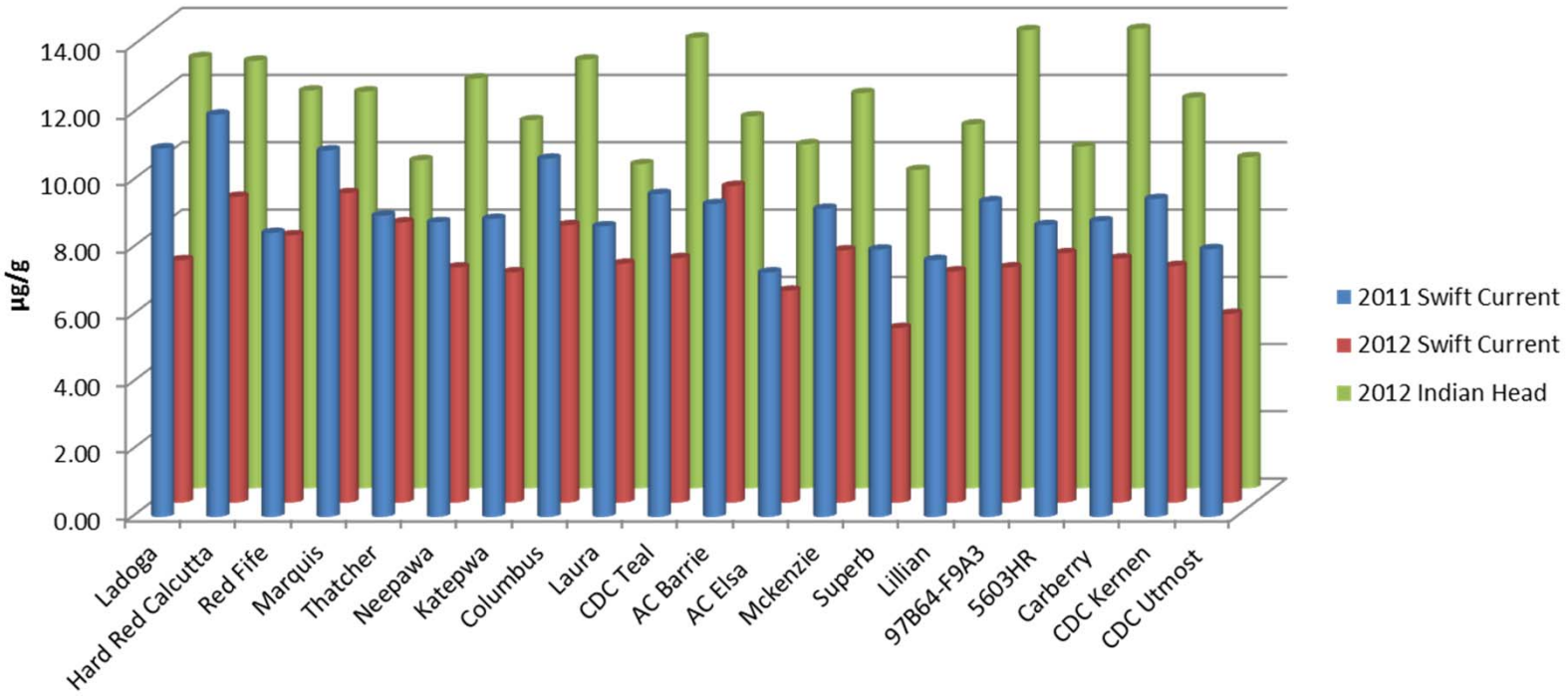
- Investigating claims regarding functional and nutritional differences in modern vs. heritage wheats.

Antioxidants and Phenolics in Wheat

- The average antioxidant activity of wheat exceeds most fruits and vegetables.
- Most fruits are around 1200 Trolox equivalents and wheat can range from 2000 to 3500 TE/100g.
- Form of the ferulic has a big effect on availability and free or soluble have higher bioavailibility compared to bound .

Measurement of the phenolic acid variations and antioxidant activities (chemically/physiologically) will enable the wheat breeders to optimise the environment and cultivar to improve the levels of wheat bio-actives.

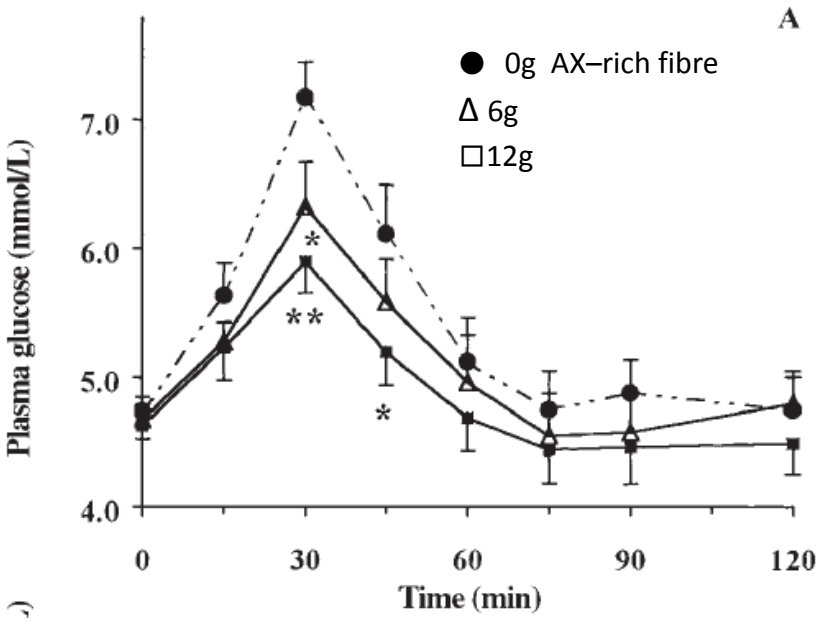
Genotypic and Environmental Variation in Caffeic Acid



Arabinoxylan

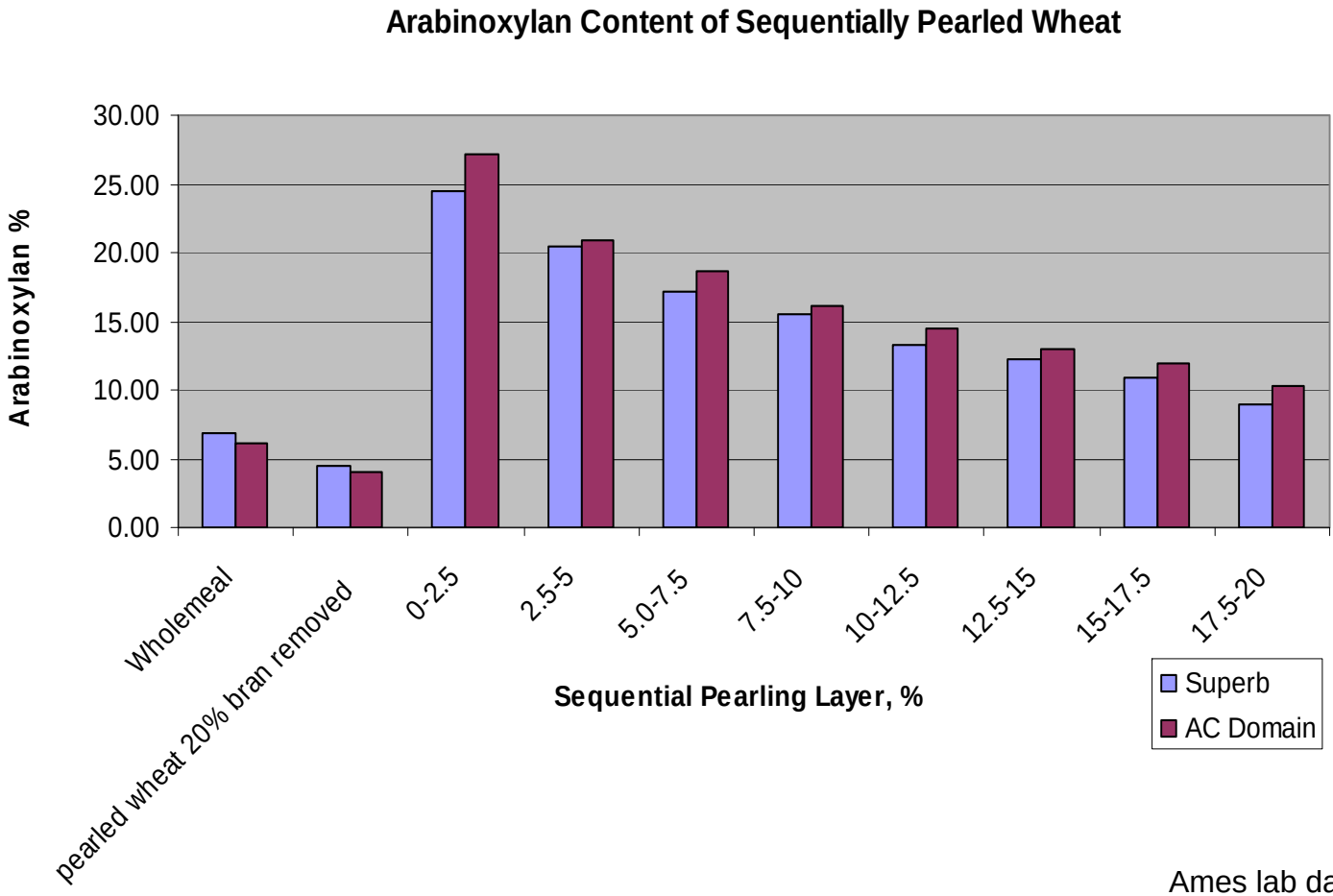
- A hemicellulose found in plant cell walls; component of dietary fibre

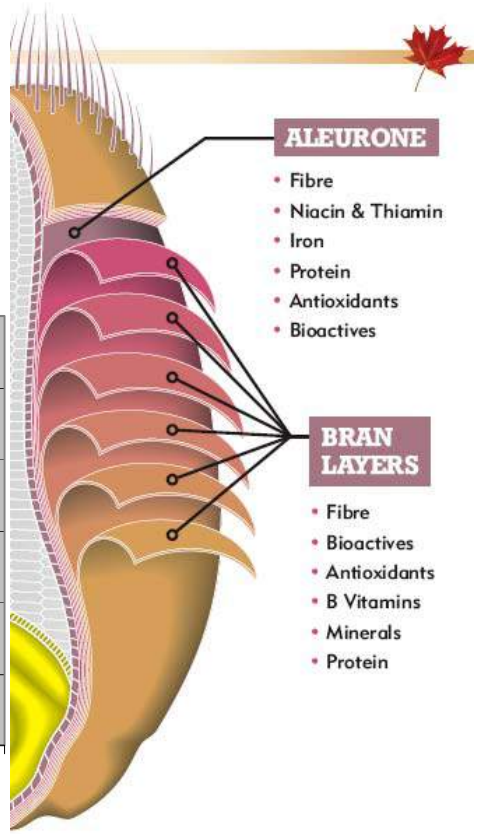
- Consumption of wheat arabinoxylan lowered post-prandial glucose and insulin response to a test meal in a dose dependant manner in healthy humans (Lu et al, *AJCN,* 2000)



- 5-week consumption of arabinoxylan enriched bread and muffins significantly lowered fasting glucose and plasma glucose and insulin after an oral glucose challenge in 14 Type 2 Diabetics. (Lu et al. *EJCN,* 2004)

Arabinoxylan Distribution Within the Bran

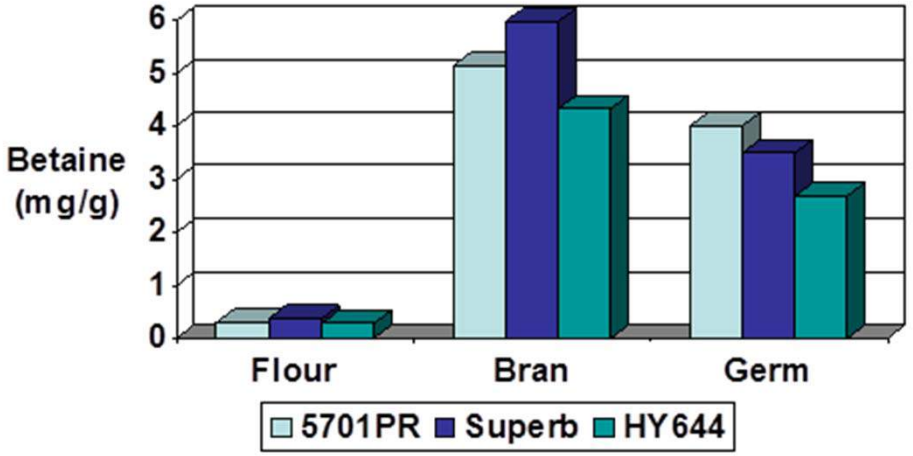




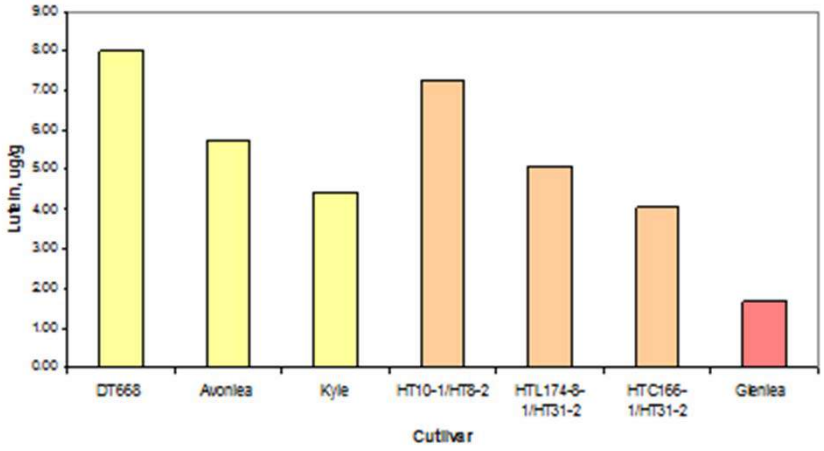
Ames lab data

Wheat Genotypic Variation

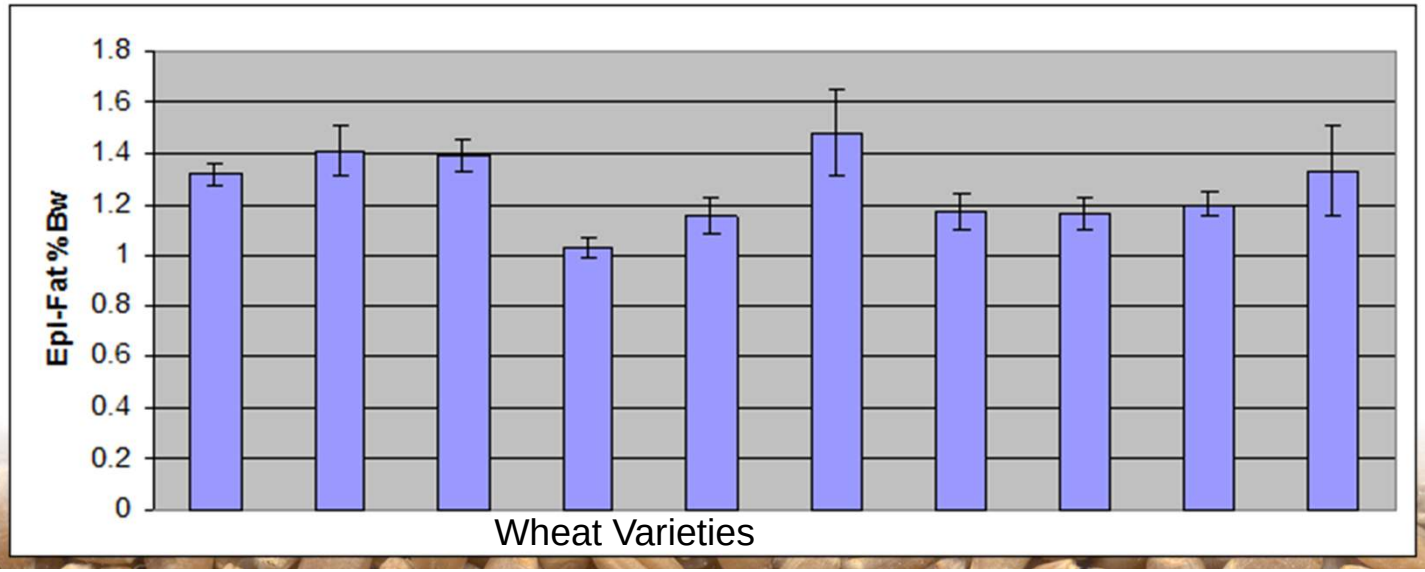
Betaine



Lutein



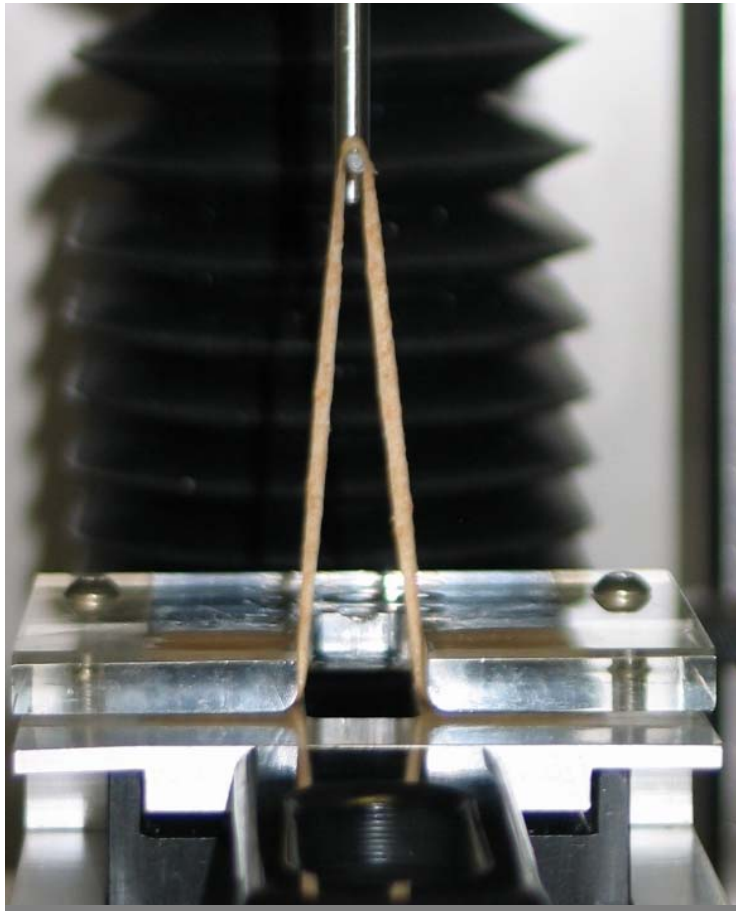
Mammalian Metabolism



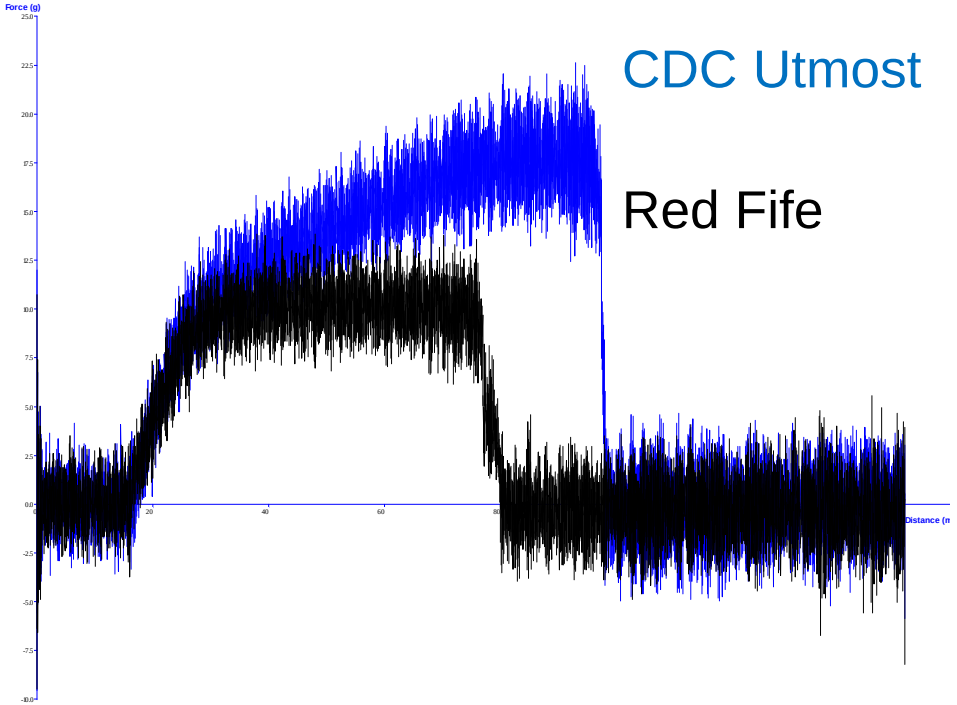
Animal Trial results: Rats fed a wheat bran fraction diet had a **27% reduction in epididymal adipose mass** compared to the control group.

Ames lab data

Whole Wheat Flour Dough Extensibility



TA.XT2 Texture Analyser Kieffer Rig



Desirable Quality:

- High resistance to extension (peak force at limit)
- High extensibility (distance at rupture)
- Good ratio between peak force and extension

Whole Grain Functionality: Rapid Screening Tools

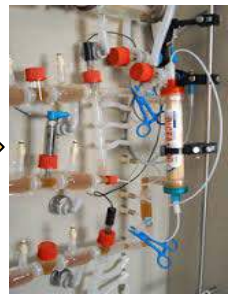
Glycemic response *in vitro*

Static *in vitro* digestion system

Cardiovascular health *in vitro*

Cardiac cell culture screening assay

Physico-chemical properties *ex-vivo*



Gut viscosity, digestibility, and glucose release by TIM-1

Gut/microbiota health *ex-vivo*

Fibre fermentability, prebiotic index etc. by TIM-2

Summary

- Cereal grains contain fibre and other health promoting compounds, making them ideal ingredients for functional foods that target outcomes such as cholesterol reduction and glycemic control.
- Genotype and growing environment can vary the levels of bioactive compounds in cereal grains, which presents opportunities for breeders, producers, grain handlers and processors to select for improved nutritional quality.
- Processing can also play an important role in potential health benefits of cereal grain ingredients
  - e.g. impact on oat and barley beta-glucan bioactivity by altering the molecular weight and solubility, resulting in altered viscosity.
- New methodologies such as cell culture, *in vitro* digestion assays and model stomach systems offer new opportunities for rapid screening of bioactive components and predicating physiological outcomes of whole grains.


THANK YOU

Canada