Exploiting Natural And Induced Variation To Improve The Content And Composition Of Dietary Fibre In Wheat Grain

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Improving the quality of staple foods to deliver health benefits.

Topic 2.1 Enhanced Health Benefits

DFW

Wheat eaten from one side of the globe to the other

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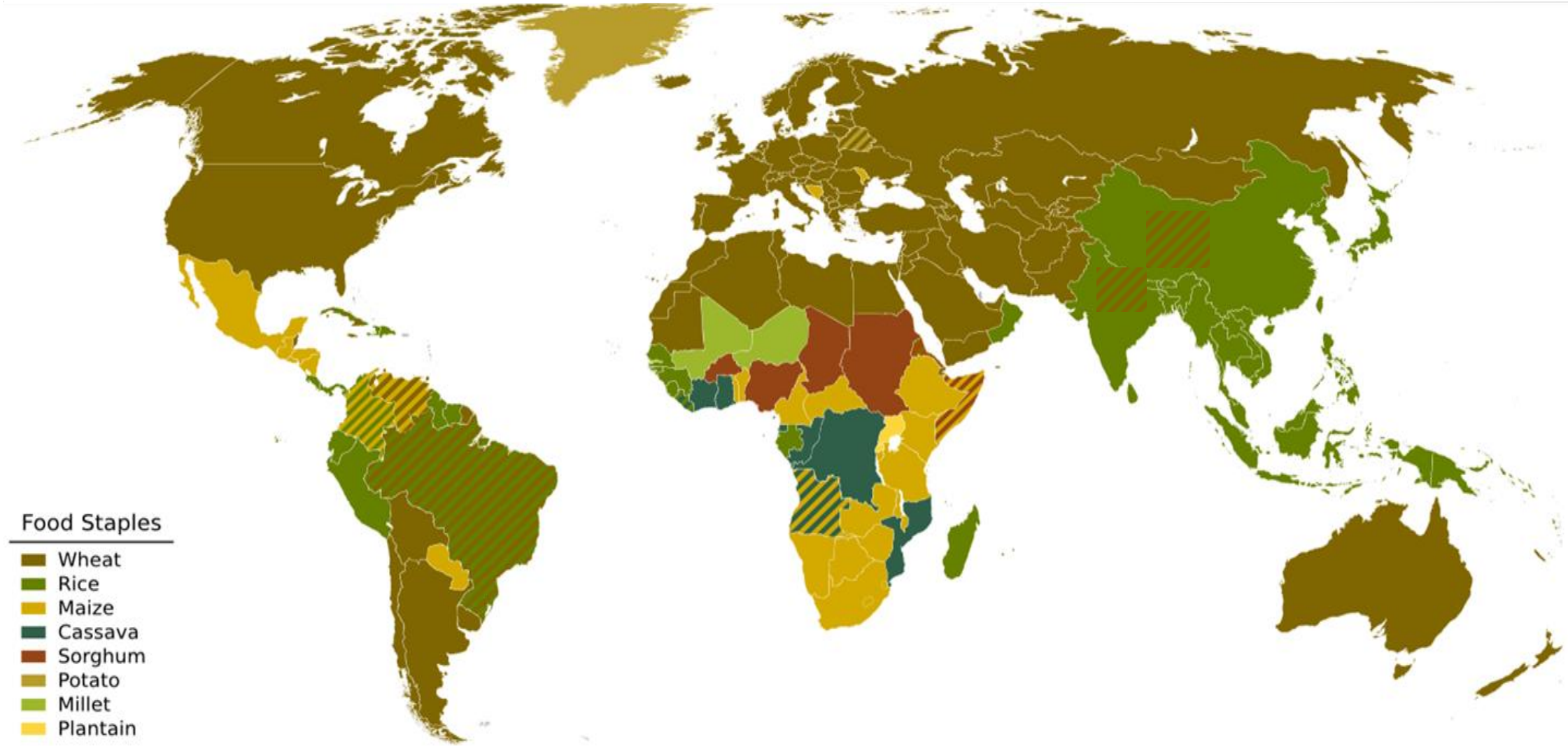

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Bread

Percentage contributions of bread to average daily intake of some essential nutrients in the UK

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	Children (4-18 years)		Adults (19-64 years)	
	Male	Female	Male	female
Energy	11	11	12	10
Protein	12	10	11	11
Dietary Fibre	18	17	21	18
Folates	12	11	12	12
Iron	16	15	16	15
Zinc	11	11	12	12

(NDNS Data Released 14/05/2014).

....not just empty calories

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Accepted Health Claims of **Cereal** Fibre

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FDA

Whole grains

- Risk of **heart disease** and **some cancers**
- Qualified claim for risk of **type 2 diabetes**
- Soluble fibre (β-glucan), **serum cholesterol** and **Coronary Heart Disease**

EFSA

1. Wheat

- **Arabinoxylan and reduced post-prandial glycaemic response**
- Bran fibre and reduced intestinal transit time
- Bran fibre and increased faecal bulk

2. Oat and barley

- Fibre and increased faecal bulk
- **β-glucans** and **reduced post-prandial glycaemic response**
- **β-glucans** and reduced blood cholesterol and **risk of heart disease**

3. Rye

- Fibre and “normal bowel function”

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Consumption of dietary fibre in the UK is below national guidelines… and pretty much everywhere else too!

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fibre intake UK (2015)

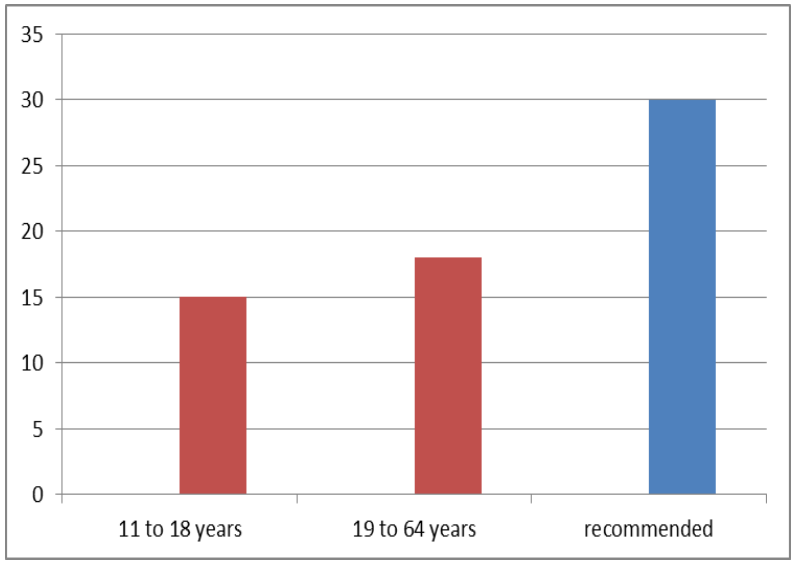

Table 4 Adult fiber recommendations and average intakes in selected countries

Country/Region		Recommended fiber intake (g/day)	Median intake (g/day)	Body issuing the requirement
US and Canada	Males	38	16.5-19.4	North America – Jointly use the IOM report from the National Academy of Sciences
	Females	25	12-15	
France	Males	30	21	*Agence française de sécurité sanitaire des aliments* (French food safety agency)
	Females	25	17	
Germany	Males	30	24	German Nutrition Society
	Females	30	21	
Japan	Males	30	17	Japanese Ministry of Health
	Females	25	17	
UK	Males	18*	15.2	UK Department of Health
	Females	18*	12.6	
FAO/ WHO		>25		WHO/FAO
		>20		

*Lower requirements due to use of the NSP method.

Jones Nutrition Journal 2014, 13:34
http://www.nutritionj.com/content/13/1/34

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Importance

NON-COMMUNICABLE DISEASES

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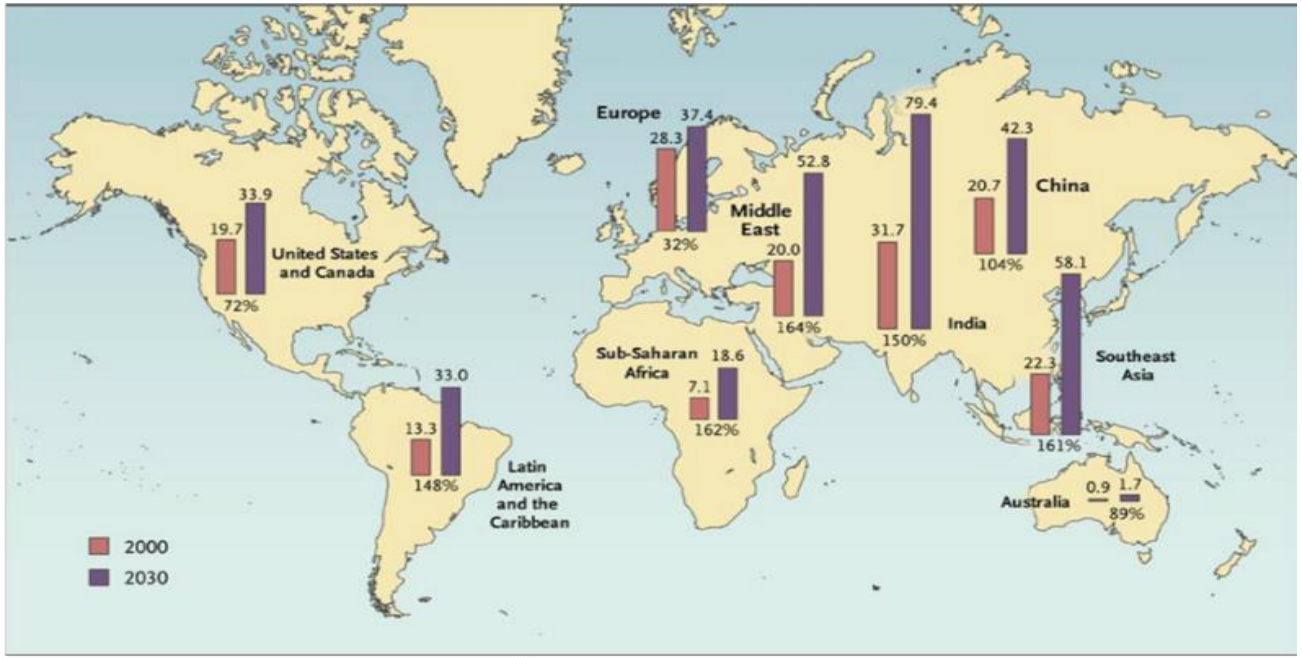
NCDs kill 40 million people each year, equivalent to 70% of all deaths globally

Diabetes



Millions of Cases of Diabetes in 2000 and Projections for 2030, with Projected Percent Changes.

Data are from Wild et al.[3]

CVD

Cancer

Respiratory disorders

Type-2 diabetes

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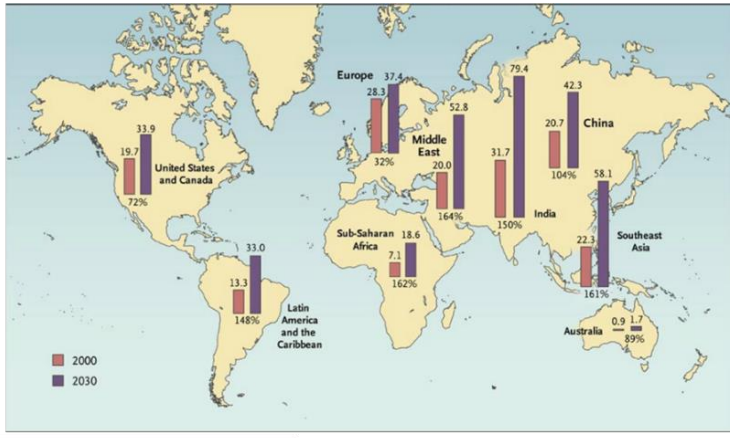
Why is this happening?

- Rapid urbanisation and economic development
- Adoption of unhealthy western diet
- Sedentary lifestyle
- Change from traditional crops and foods to ‘white’ grains



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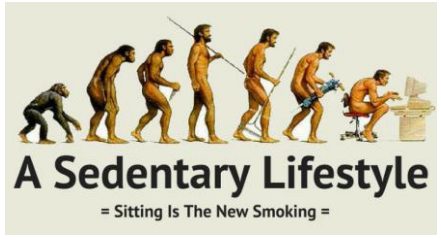

77% OF PEOPLE WITH DIABETES LIVE IN LMIC COUNTRIES

- Diabetes UK

77%

Biomedical Engineering
The Partnership for Global Health Technologies

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Program Experience About Us Apply Now Blog Solve Challenges

Diabetes: Leading Cause of Death in Mexico

The World Health Organization released that as of 2016, diabetes was the leading cause of death in Mexico, being responsible for with 14.7% of Mexico's deaths and thus seizing over 76,000 lives that year. The percent of the population that died to diabetes has tripled since 1990, and by 2050, scientists predict that half of Mexico's population will suffer from diabetes.

The rise of the epidemic started in the 1970s-1980s, when more efficient methods of producing many crops was introduced. Due to these advancements in agriculture, while much more food was being produced, there was a smaller variety of crops. Farmers tended to produce crops that were cheaper and easier to grow, are staples of the Mexican diet (such as corn), thus resulting in a diet that's high in carbs and fat, and low in protein. Also, the introduction and widespread accessibility of fast food has added to this problem. Mexico is the world's largest consumer of soda- with each person consuming an average of 500 cans annually. Also, selling at just one pesos per bottle, carbonated beverages tend to be significantly cheaper than healthier alternatives. For many, soda is a part of their everyday routine. Also, as for many of the people in Mexico who work long hours every day and need a meal that they can eat on the go, fast food and street vendors are a regular and cheap source of meals.

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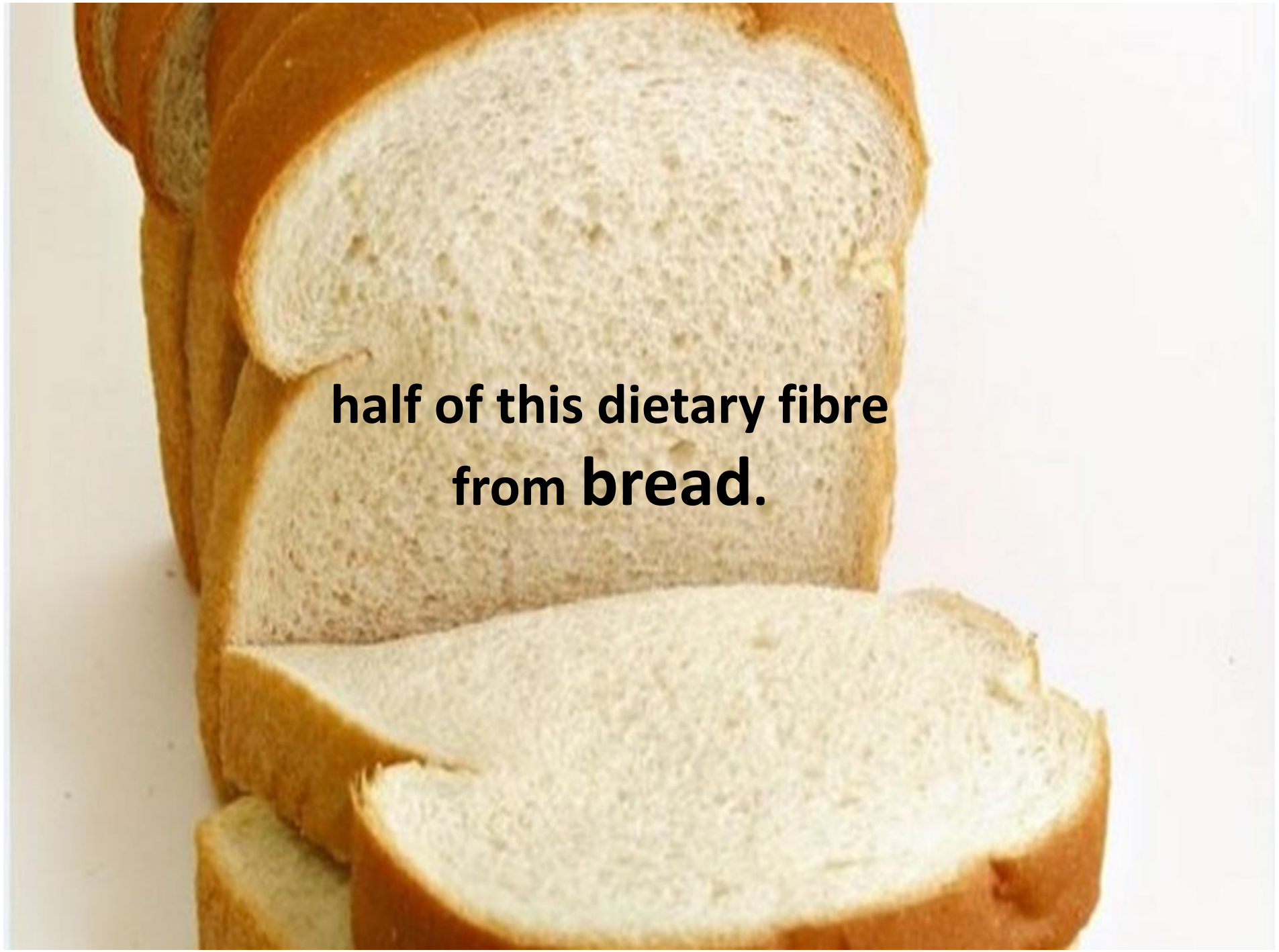
40%


half of this dietary fibre
from bread.

Cell wall composition of wheat

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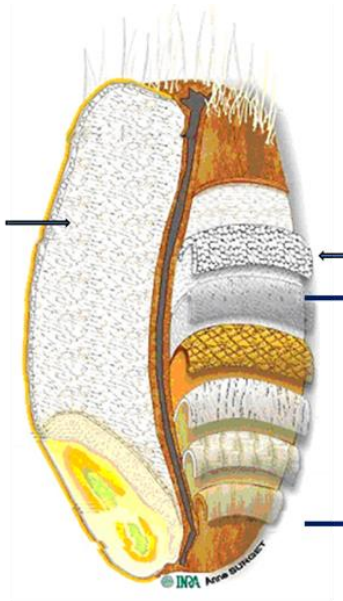
Dietary fibre composition of wheat grains

White flour
2–3% TDF

Cell Walls
70% AX
20% BG
10% other



Aleurone
60 AX
29% BG
11% other

Pericarp
60% GAX
30% cellulose
10% lignin

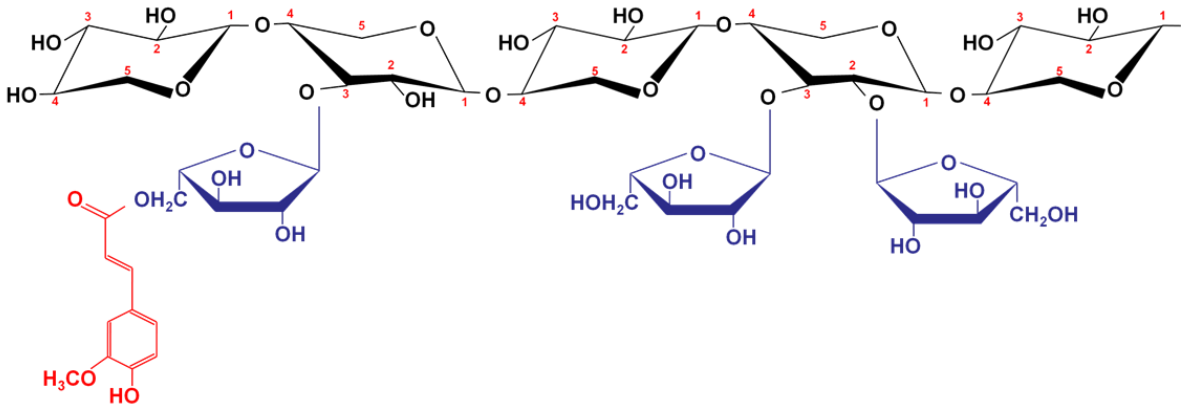
Embryo
AX
BG

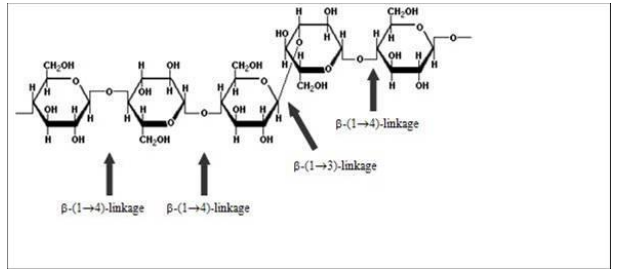
Bran
45–50
%TDF

ALSO
Fructans
Raffinose
Resistant Starch

Fibre content in different cereal fractions (g/100 g DM):

Fraction	Wheat	Rice
Whole grain	12	4
Bran	43	21
Starchy endosperm	2.7	2
Germ	13	-





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The contents of soluble and total AX fibre vary widely in bran and white flour of 150 wheat lines

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150 wheat lines and 50 other cereals grown in Hungary in 2004–5

130 winter wheats
20 spring wheats
5 spelt
10 durum wheat
5 *T. monococcum*
5. *T. dicoccum*
10 rye
10 barley
5 oats

26 wheat lines grown in Hungary in 2005–6 and in the UK, France, Hungary, Poland in 2006–7

data from 6 environments

Allows determination of
1. Range of variation in wheat compared with related cereals
2. Heritability in wheat

HEALTH·GRAIN

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Chinese wheat (Yumai-34) highest dietary fibre

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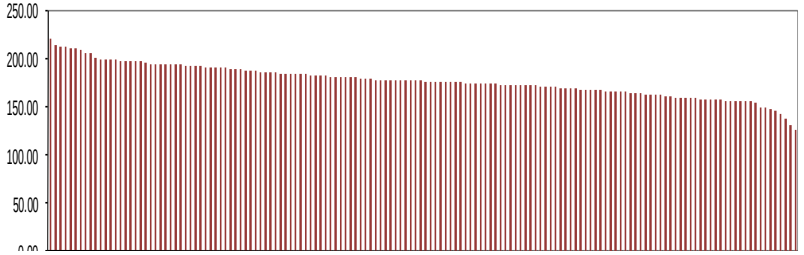
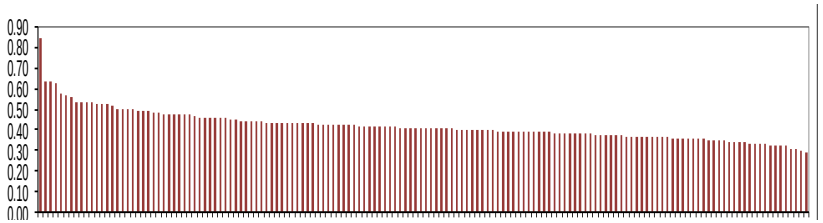
BRAN

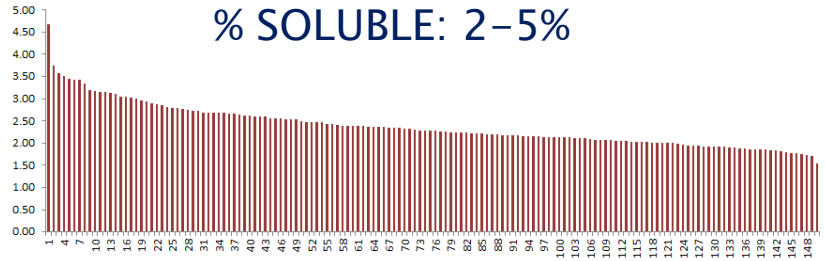
TOTAL: 12.7–22.1%



SOLUBLE: 0.3–0.85%

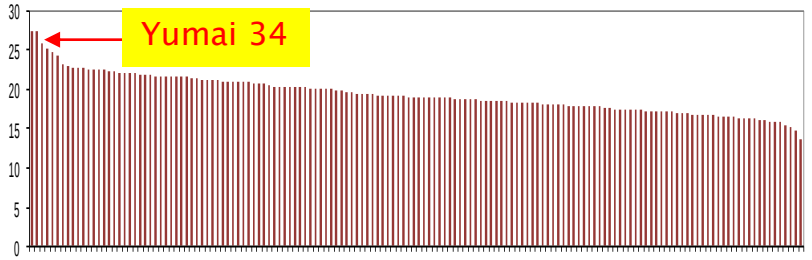


% SOLUBLE: 2–5%

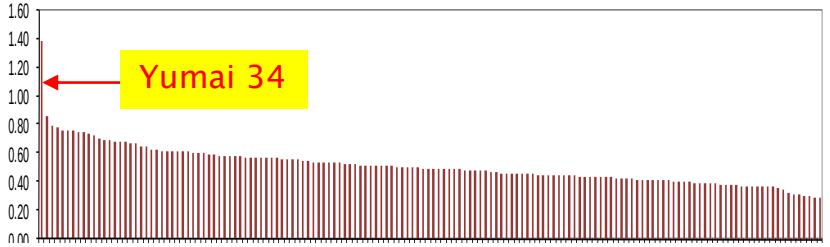


FLOUR

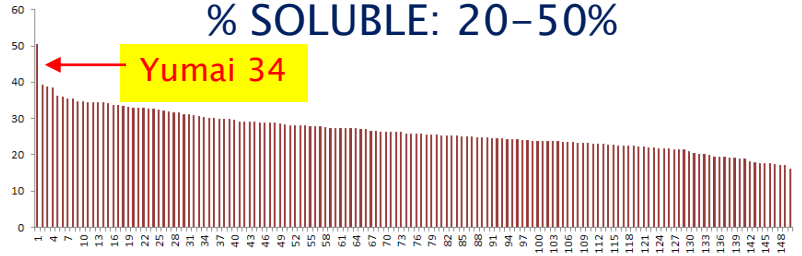
TOTAL: 1.35–2.75%



SOLUBLE: 0.3–1.4%



% SOLUBLE: 20–50%



Data of Kurt Gebruers, Christophe Courtin and Jan Delcour (KU Leuven)

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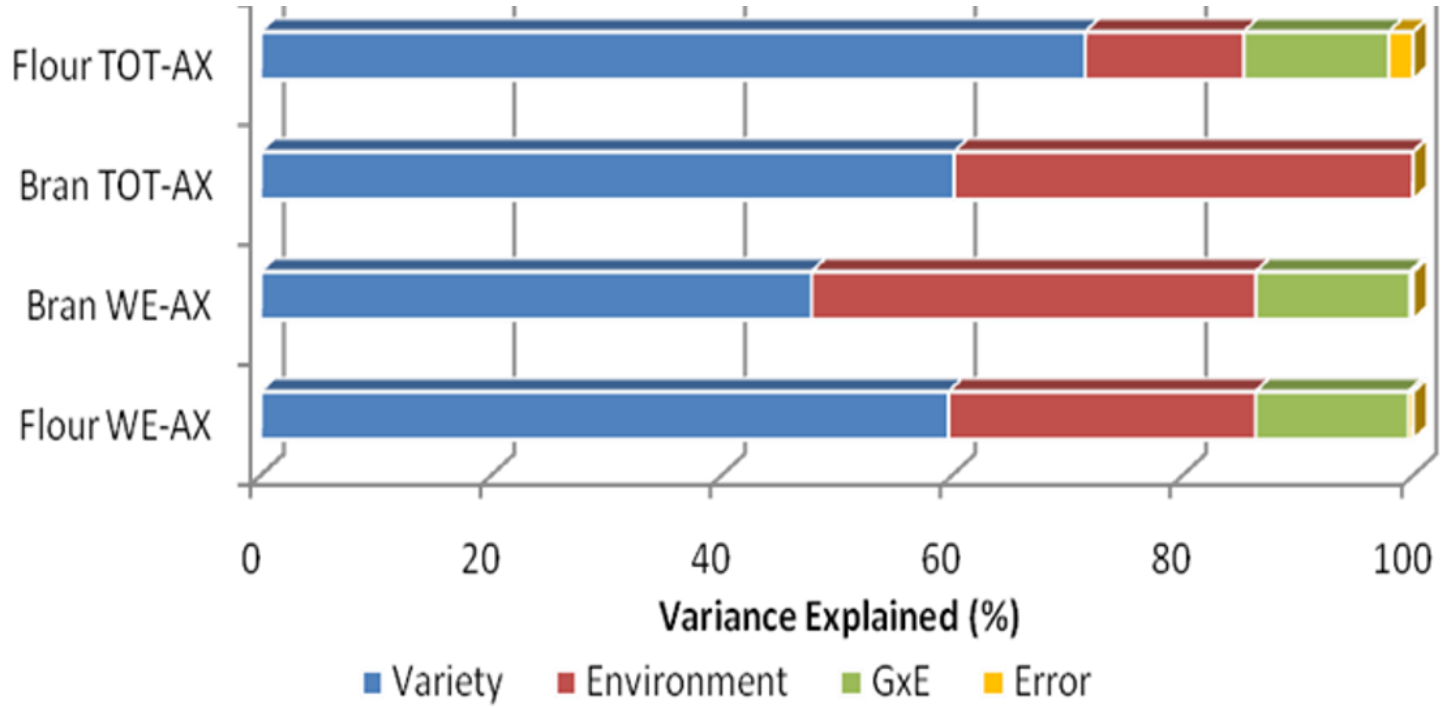
AX content in flour and bran is **highly heritable**.



Identification of novel genetic sources of variation

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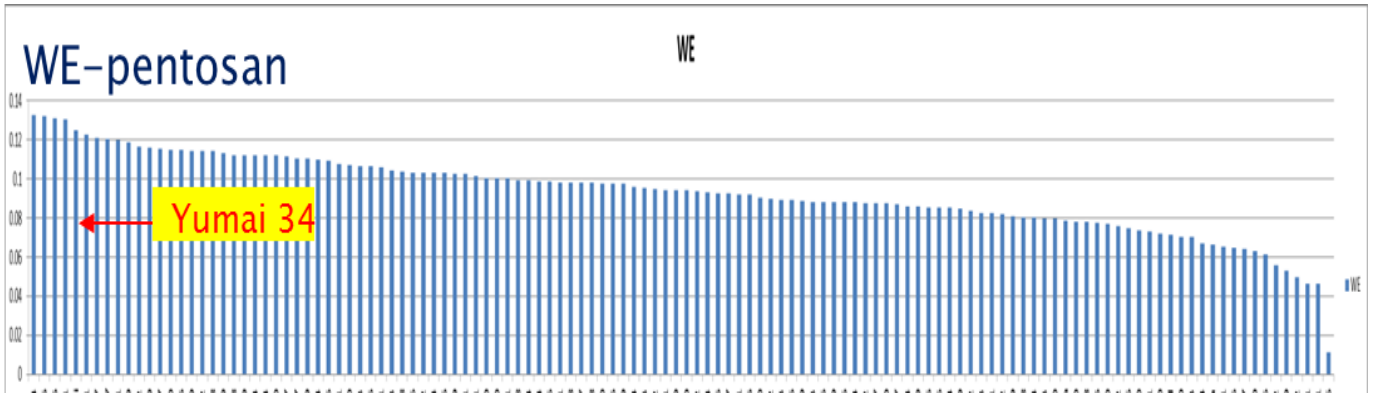
The Watkins collection of wheat landraces



Amount and composition, polymer size, viscosity

- A E Watkins, University of Cambridge
- 1920s and 30s
- Board of Trade asked Embassies to obtain samples
- From farmers, markets and researchers
- Several thousand lines but now 1300
- 34 countries
- Held at JIC, duplicated in Australia
- Core genetic collection of about 120 lines

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Identification of novel genetic sources of variation

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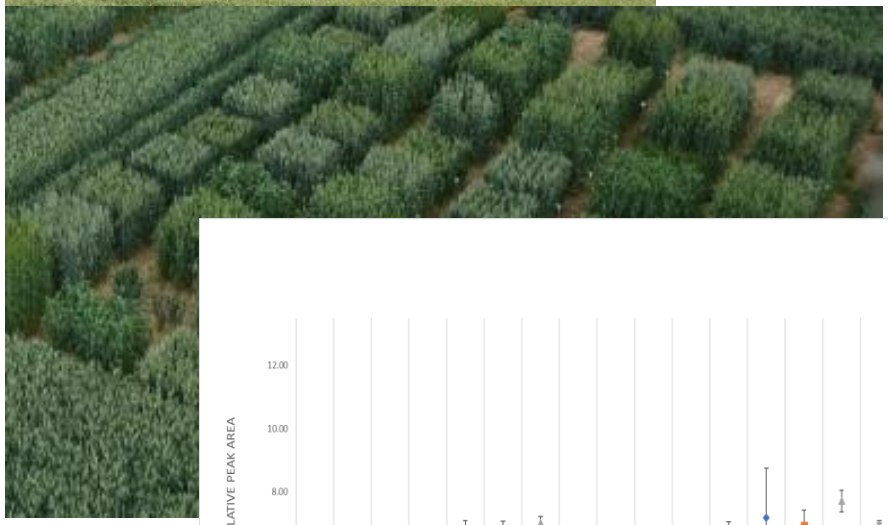
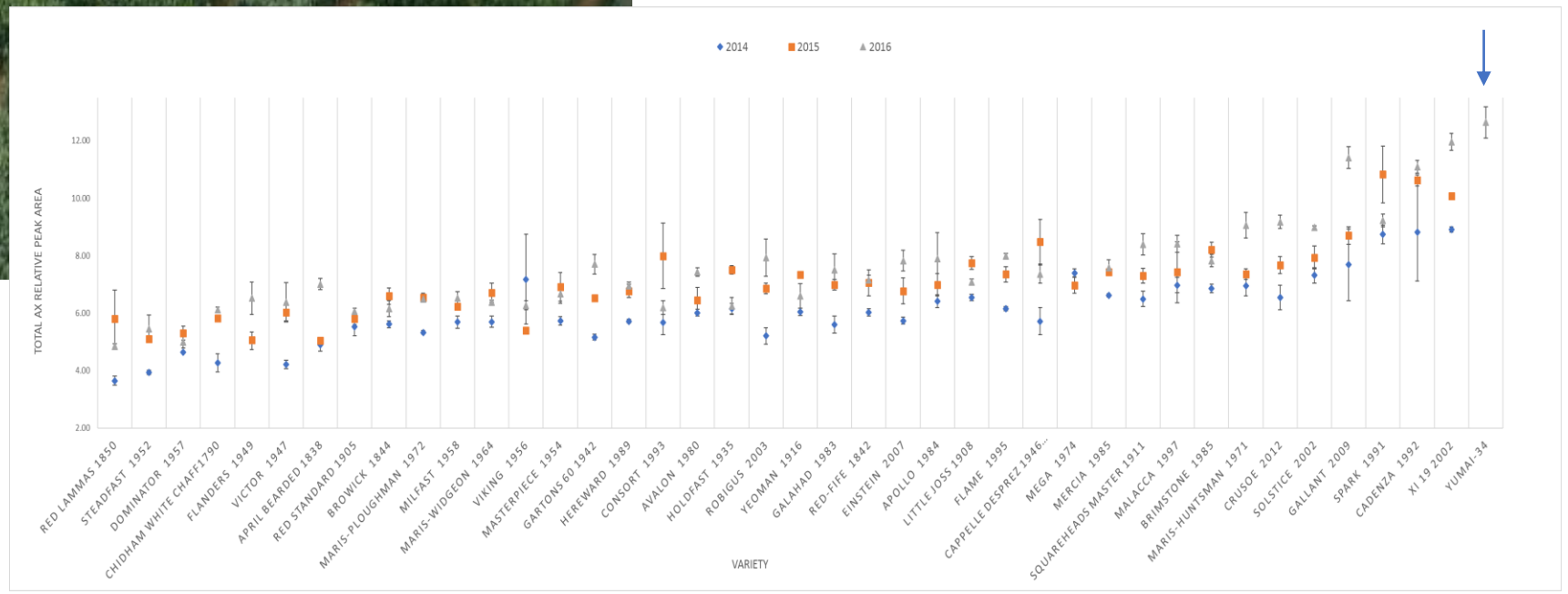
The Heritage Collection 1790-2012





"Looking back to the Future"

1790	Chidham White Chaff
1838	April Bearded (Spring)
1842	Red Fife (Canadian spring)
1844	Browick
1850	Red Lammas (Lammas?
1905	Red Standard
1908	Little Joss
1911	Squareheads Master
1916	Yeoman
1935	Holdfast
1940	Warden
1942	Gartons 60
1947	Victor
1946 (1953 UK)	Cappelle Desprez
1952	Steadfast
1954	Masterpiece
1956	Viking
1957	Rampton Rivet (turgidum)
1957	Dominator
1958	Milfast
1964	Maris Widgeon
1971	Maris Huntsman
1972	Maris Ploughman
1974	Mega
1980	Avalon
1983	Galahad
1984	Apollo
1985	Mercia
1985	Brimstone
1986	Flanders
1989	Hereward
1991	Spark
1992	Cadenza
1993	Consort
1995	Flame
1997	Malacca
2002	Solstice
2002	Xi 19
2003	Robigus
2009	Gallant
2012	Crusoe

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Identification of novel genetic sources of variation

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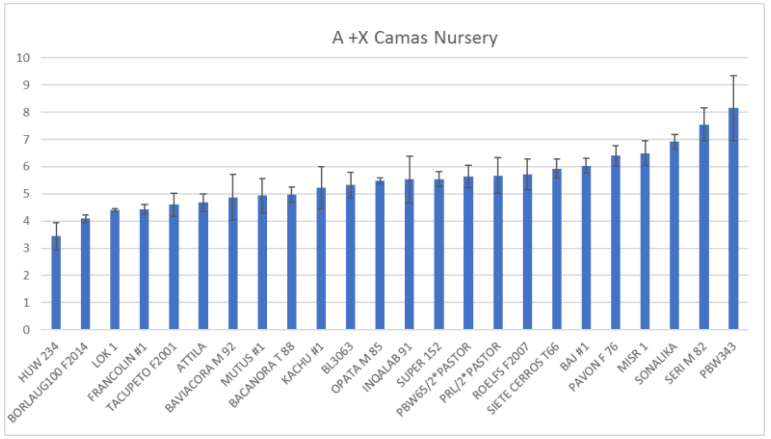
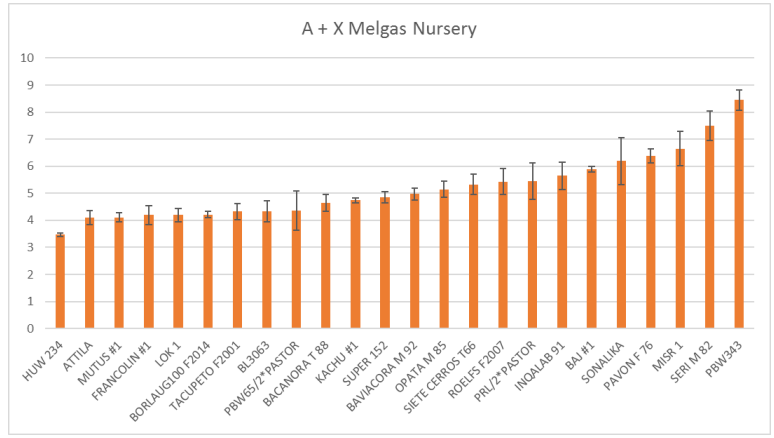
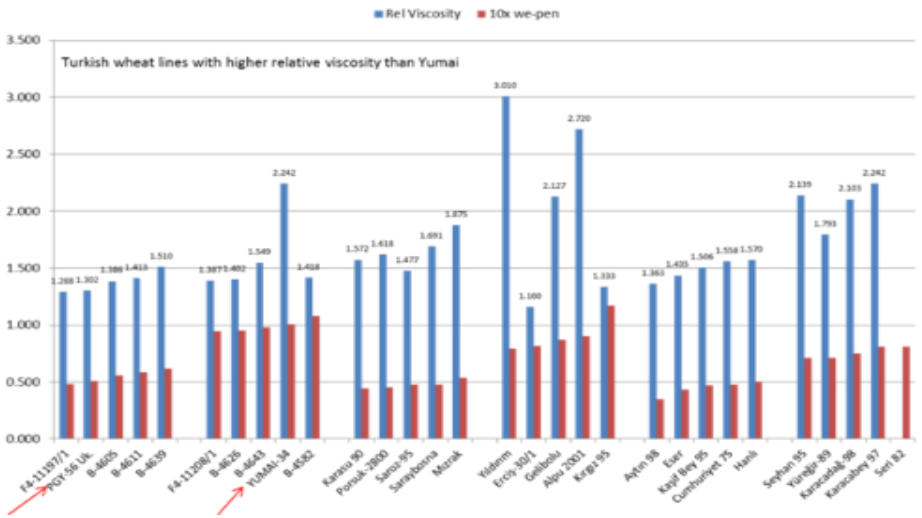
Exotic bread wheats





CIMMYT

Turkish wheat lines



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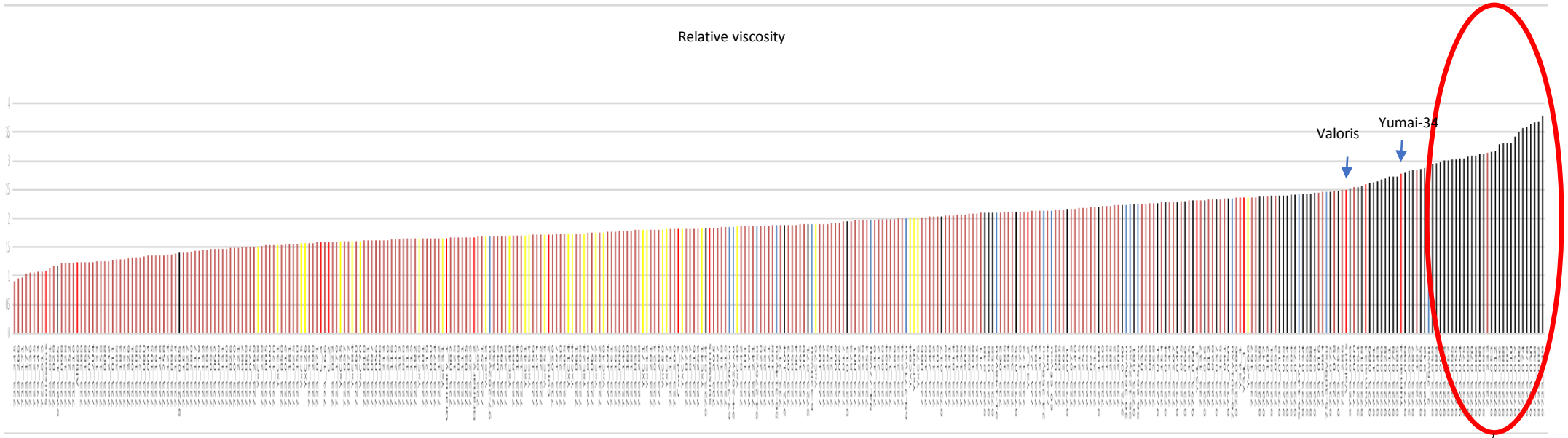
Segregating populations developed for the discovery of gene/s controlling high fibre content in Yumai 34

Populations Yumai 34 x	Population type	Developers	Genotyping platform
Ukrainka	RIL	CARHAS (HU)	KASP
Valoris	DH	INRA (FRA)	Axiom 35K
Altigo	DH	INRA (FRA)	Axiom 35K
Claire	RIL	DFW (GBR)	KASP

Segregating populations- for gene discovery



Yumai x Ukrainka

Yumai x Claire

Yumai x Altigo

Yumai x Valoris

Transgressive segregation in Y x V population

Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences

UMR 1095 Génétique Diversité et Ecophysiologie des Céréales

Major QTL identified for relative viscosity on distal portion of 1BL

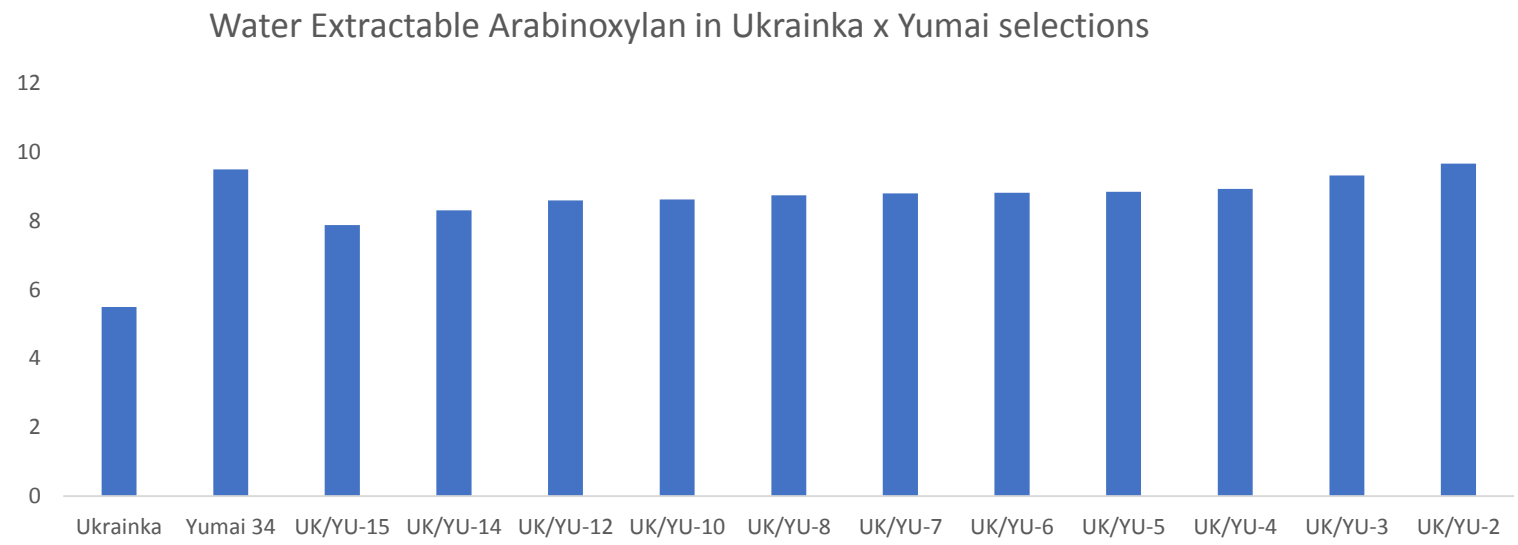
Population	LOD	Population mean	Substitution effect
Yumai 34 x Altigo	12.6	2.98	1.1
Yumai 34 x Valoris	7.8	4.53	1.8

Physical location of QTL peak markers

Data only shown from INRA populations

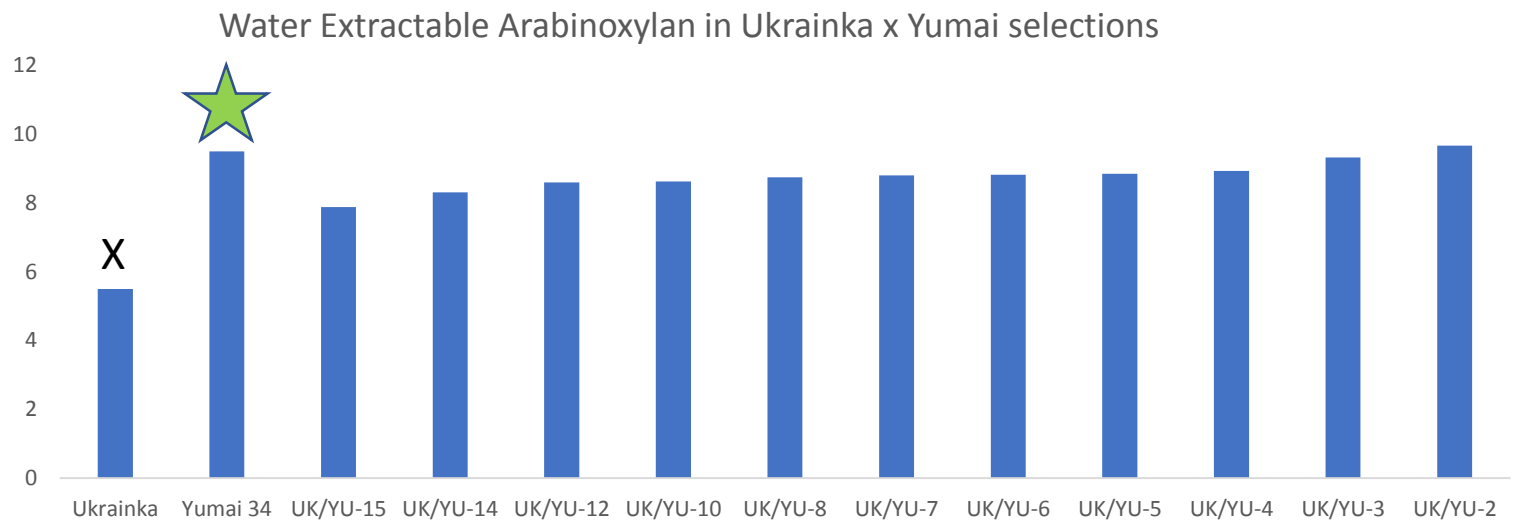
Genes in this region were used to develop KASP markers

Direct selection for high fibre progeny in Hungarian-produced, locally adapted lines with fibre content as high as Yumai 34



Tremmel-Bede, K., Láng, L., Török, K., Tömösközi, S., Vida, G., Shewry, P.R., Bedő, Z. and Rakszegi, M., 2017. Development and characterization of wheat lines with increased levels of arabinoxylan. *Euphytica*, *213*(12), p.291.

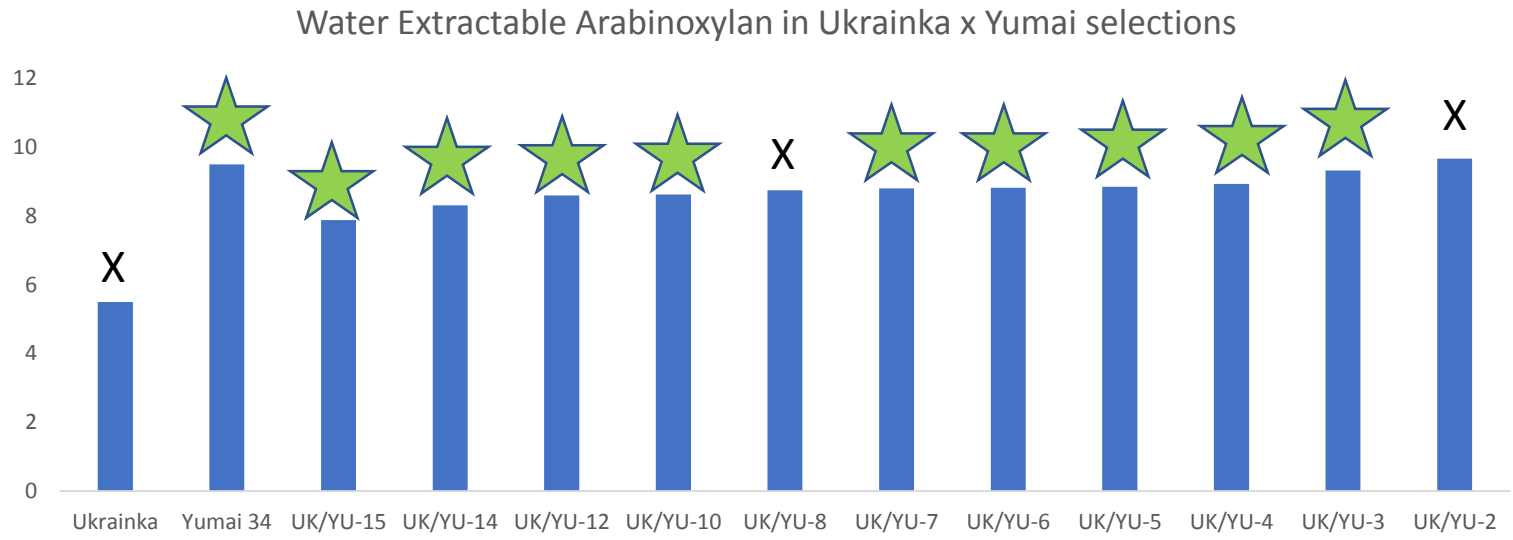
Ukrainka and Yumai 34 are polymorphic for the KASP assay developed from the Yumai 34 x Valoris/Altigo analysis



Yumai 34 1BL KASP allele

X Valoris, Altigo, Claire, Ukrainka allele

The high fibre Yumai 34 x Ukrainka progeny are significantly enriched for the Yumai 34 1BL allele



Why are the lines not fixed for 1BL allele?

- The current marker is 2-3cM away from QTL peak, these might be recombinants.
- Minor QTL for increased fibre where detected in Yumai 34 and Ukrainka, they might be stacked favourably in UK/YU-2 and UK/YU-8

Exploiting natural variation in AX fibre: Yumai 34

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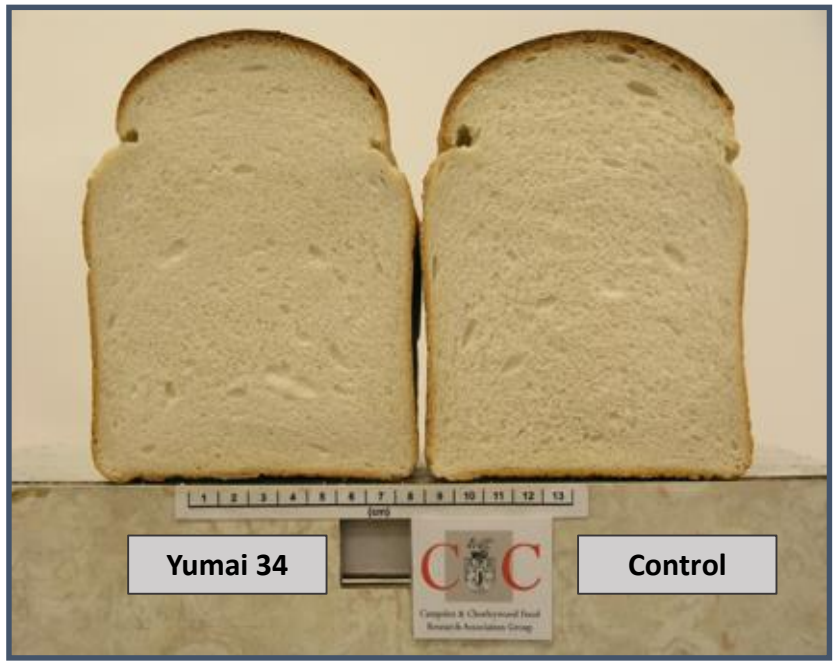
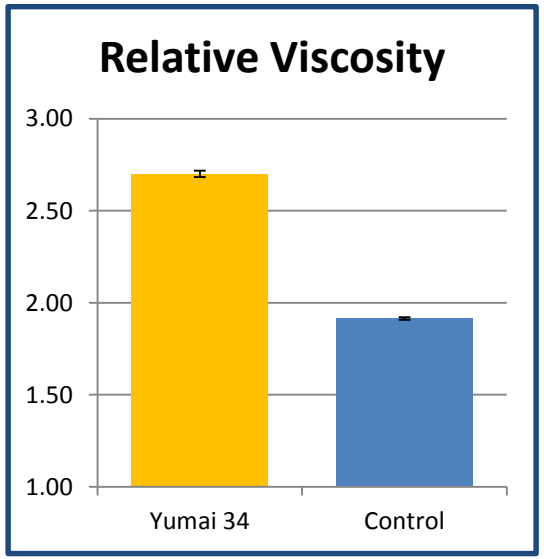
- A Chinese wheat variety released in 1998 in Henan province
- High fibre content (total and soluble)
- High viscosity of aqueous extracts
- Good bread making quality

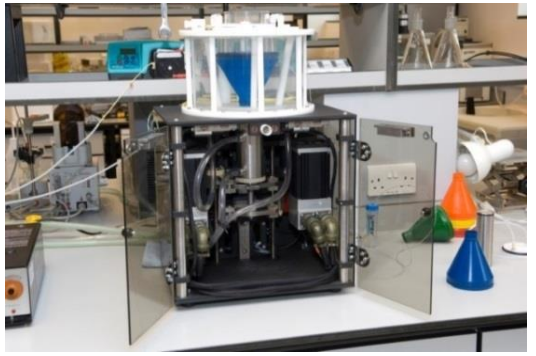




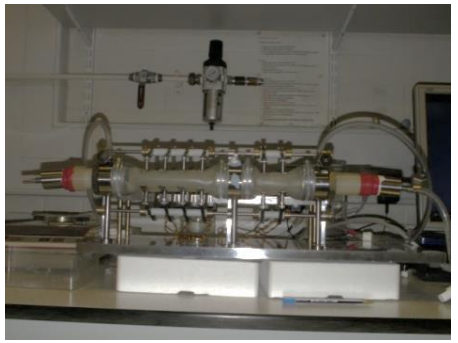
DFW

Mining Diversity in Cereal (Wheat) Fibre to Improve the Nutritional Quality of Bread

Yumai-34 Control



The Dynamic Gastric Model



The Dynamic Duodenum

White bread has a GI/GL similar to sucrose

Any reduction in white bread GI could have significant health benefits

Hypothesis:

1. Chyme **viscosity** effects 'digestion'...mixing…and mass transfer
2. Simulated glucose adsorption using *in-silico* and *in-vitro* model
3. Bread formulations can significantly alter the viscosity of the chyme

Release of reducing sugars from high fibre white bread (Yumai 34) compared to other breads and porridge in a model duodenal system

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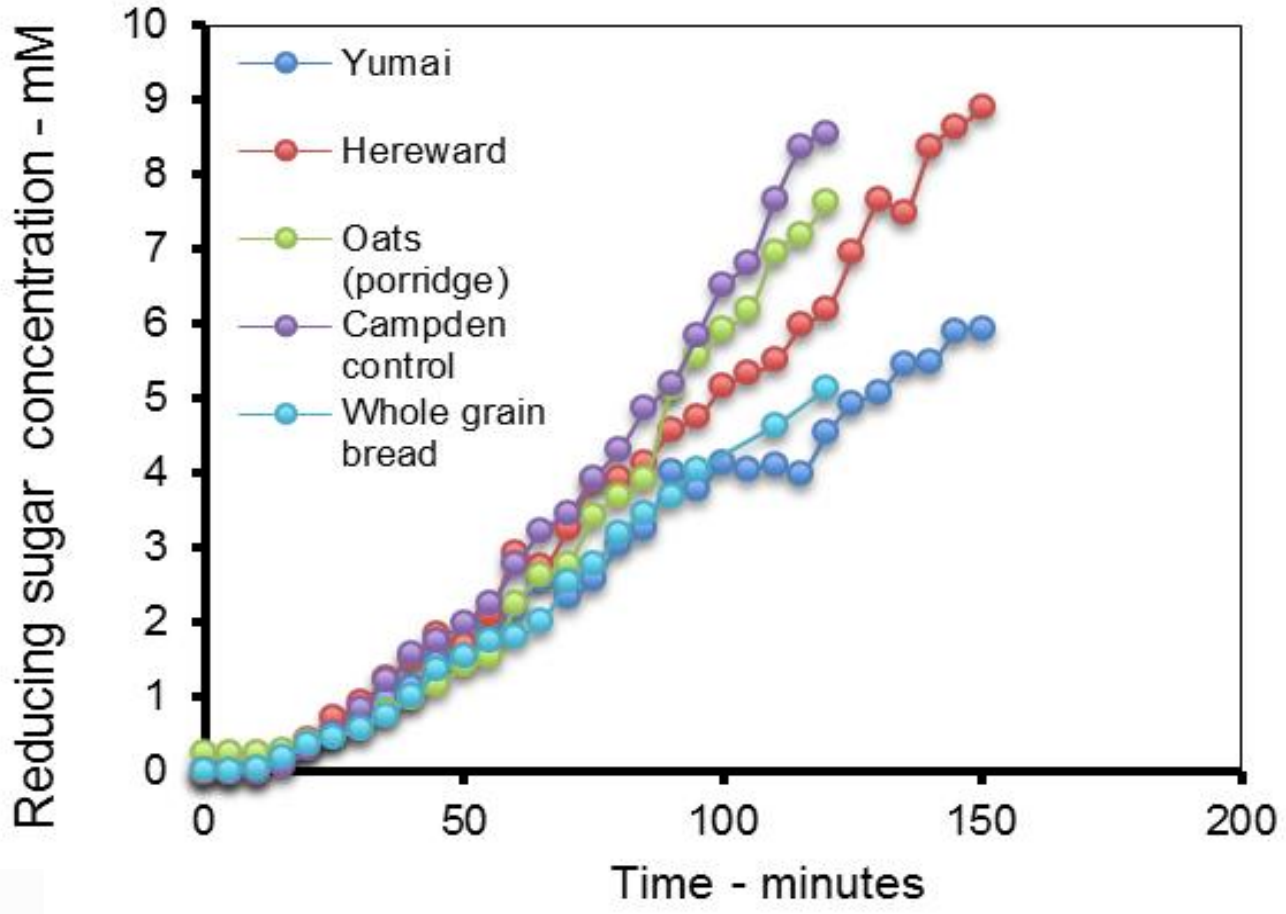

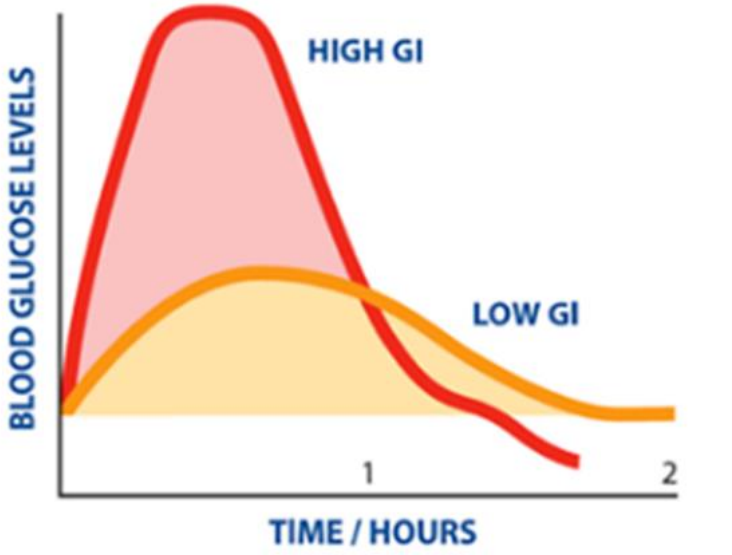

UNIVERSITY OF BIRMINGHAM

Serafim Bakalis, Peter Fryer

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Yumai 34 x Ukrainka

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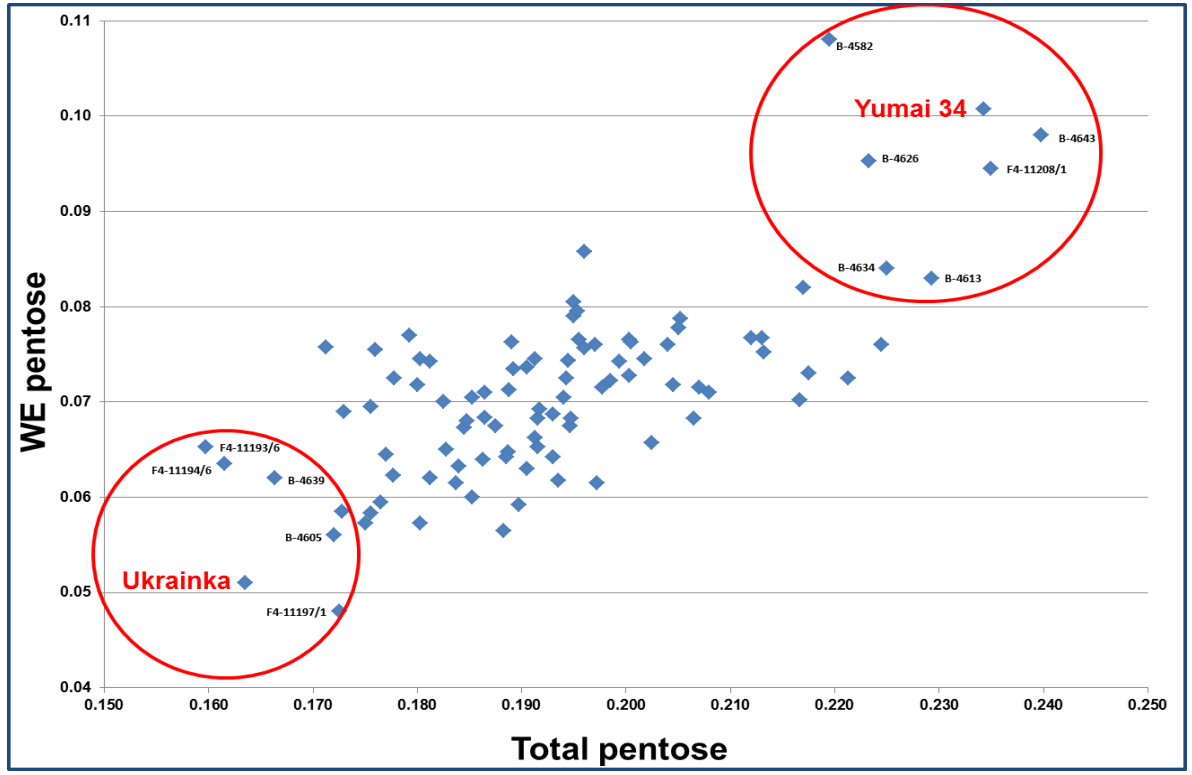
- 96 F6 lines + parents



Recombinant inbred lines

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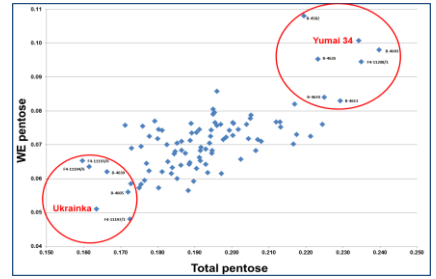
Yumai 34 x Ukrainka bread



a supermarket

Bread on a stick!

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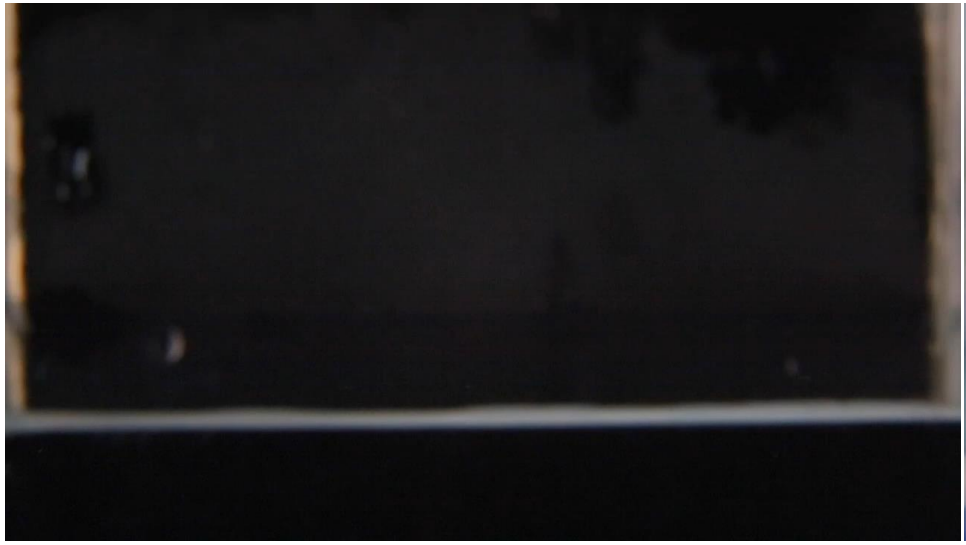
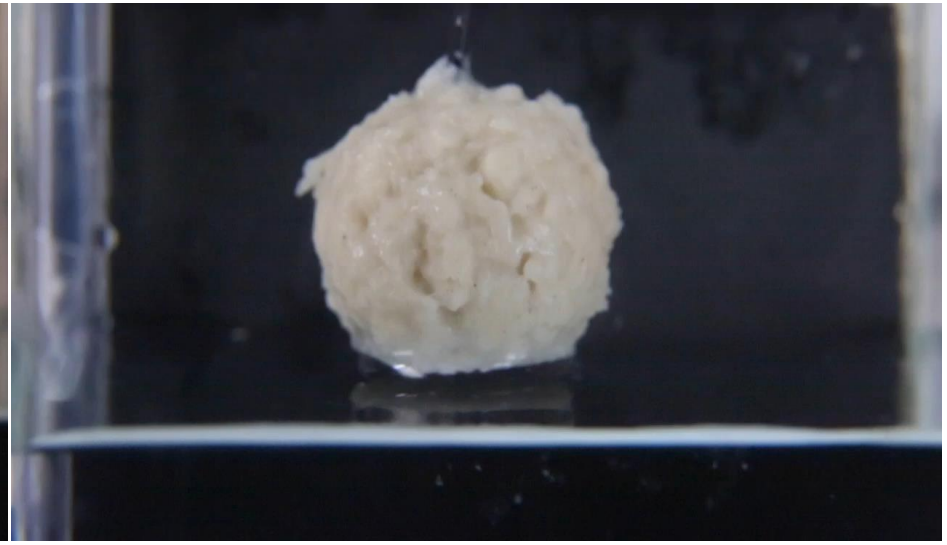
Endogenous fibre important





Low AX

High AX

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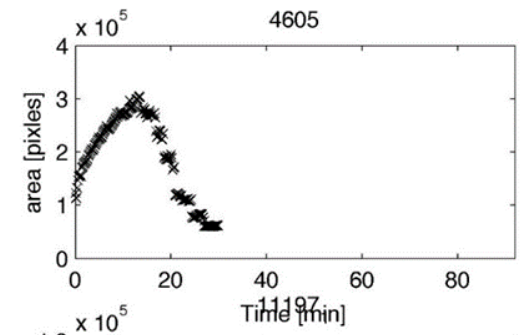
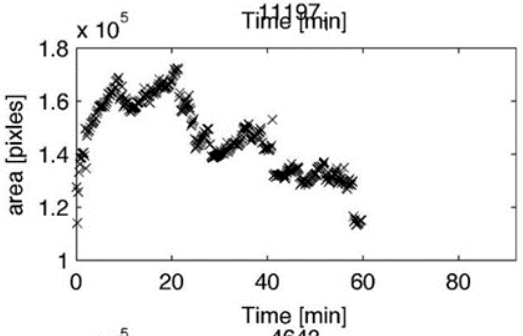
Endogenous Fibre and starch digestion

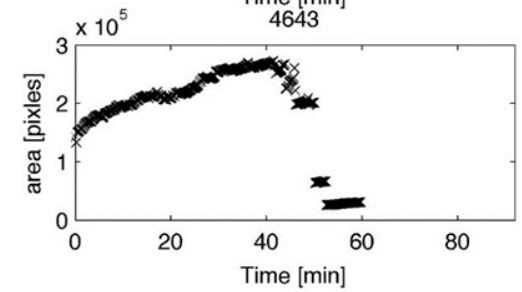
ROTHAMSTED RESEARCH

Bread disintegration graphs

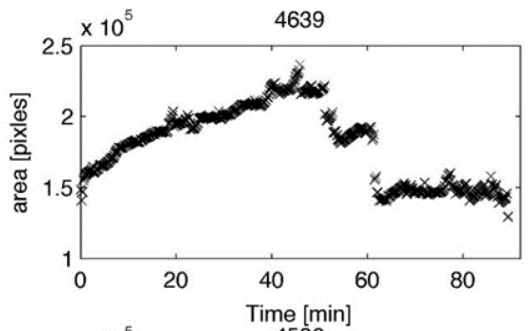
Low

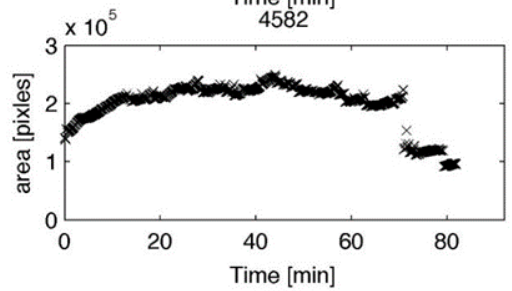


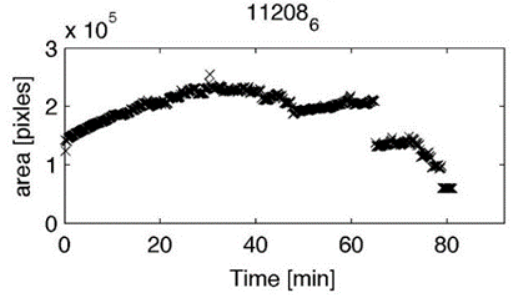




High







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‘and another thing…’

AX is a prebiotic

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AX as a prebiotic

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"Dietary fibres that improve human health by selectively stimulating the growth or activity of beneficial microorganisms in the colon".

Enhanced growth of 'good bacteria' compared to 'bad bacteria'

University of Reading

Suzanne Harris

Dimitris Charalampopoulos, Glenn Gibson and Bob Rastall (UoR).

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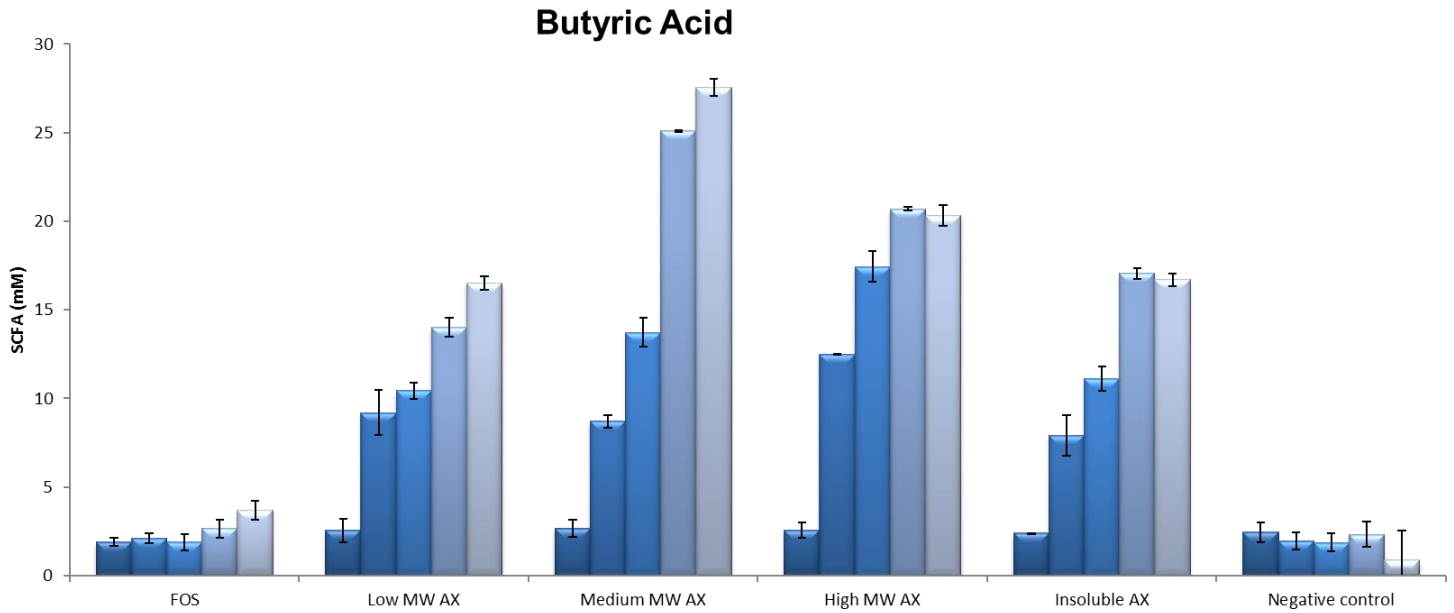
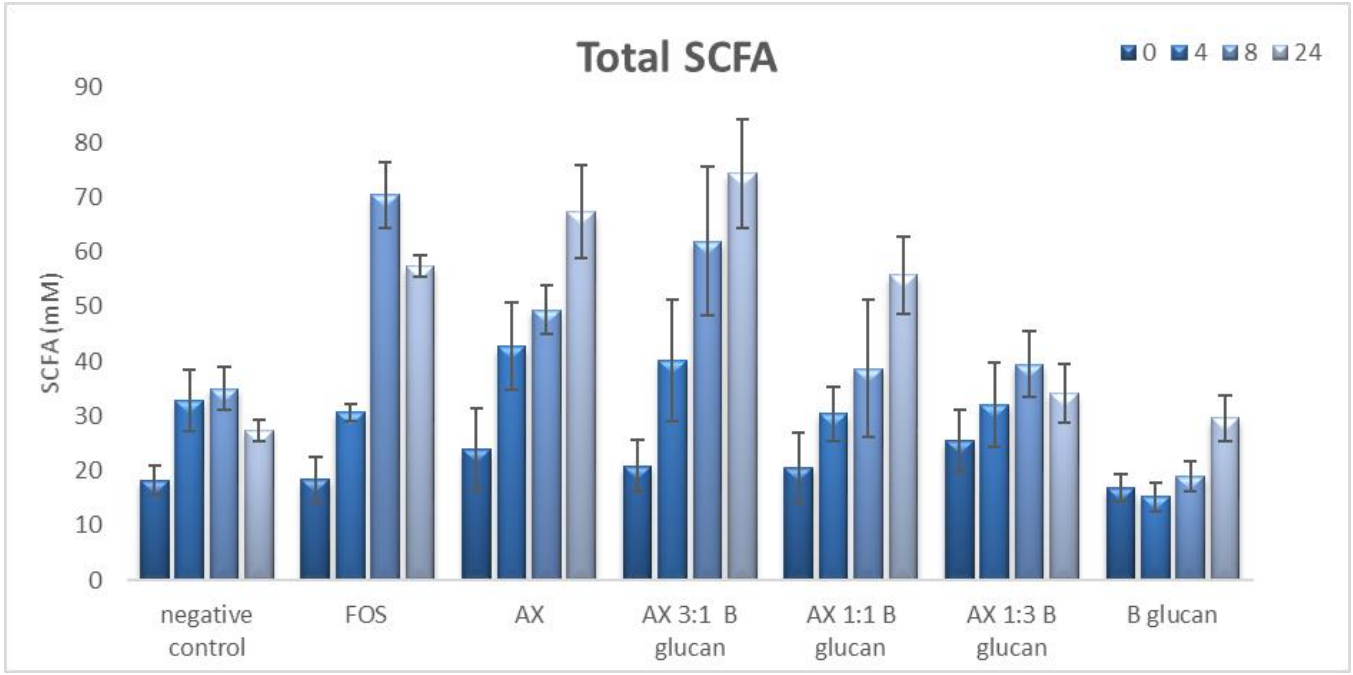
AX of different mass



Suzanne Harris

Dimitris Charalampopoulos, Glenn Gibson and Bob Rastall (UoR).

Wheat AX and β-glucan are prebiotics



Suzanne Harris

Dimitris Charalampopoulos, Glenn Gibson and Bob Rastall (UoR).

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‘and another thing…’

-processing for health

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Phenols and a human feeding trial

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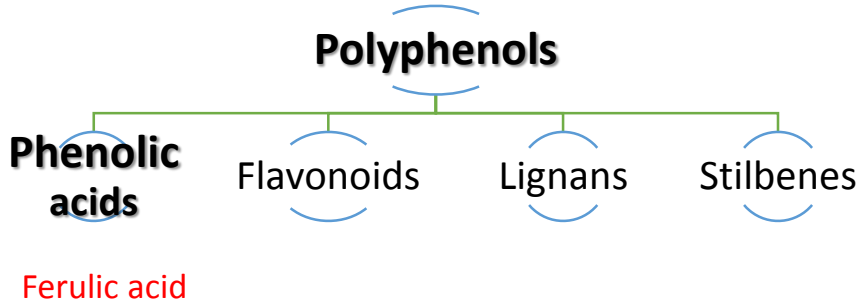
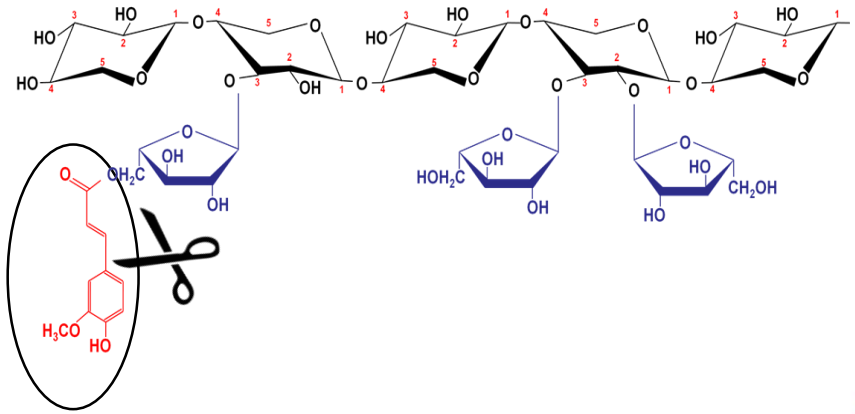
Numerous studies show positive relationship between polyphenols and prevention of heart disease.



Ferulic acid



Ferulic acid

University of Reading

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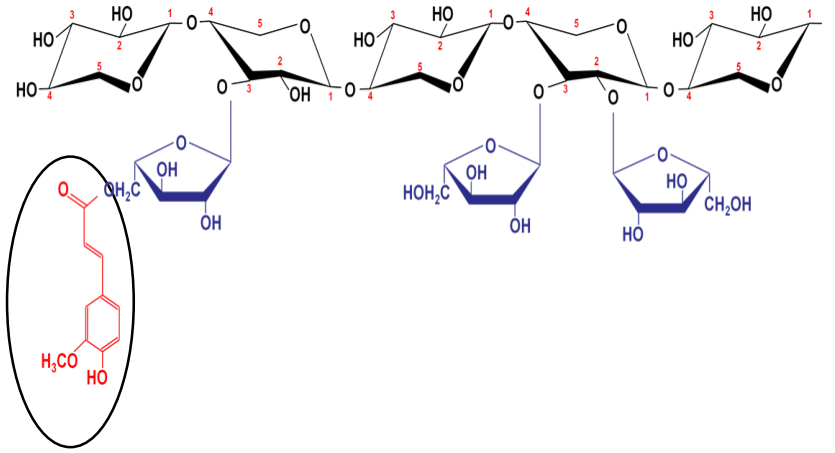
Release of free ferulic acid

Flatbreads produced, with added feruloyl esterase to release ferulic acid early in GI tract.



more **free** ferulic acid

Free, conjugated, bound and total ferulic acid content of treated and non-treated flatbread products				
Flatbread	**Free µg/g**	**Conjugated µg/g**	**Bound µg/g**	**Total FA µg/g**
White	5.41 ± 0.1	0.11 ± 0.3	10.07 ± 4	15.59
Whole-grain	25.86 ± 3.7	14.81 ± 2.0	169.11 ± 16.2	209.78
Whole-grain active	158.24 ± 3.3	3.46 ± 6.1	94.45 ± 10.6	256.15

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Randomised, controlled, cross-over human intervention trial

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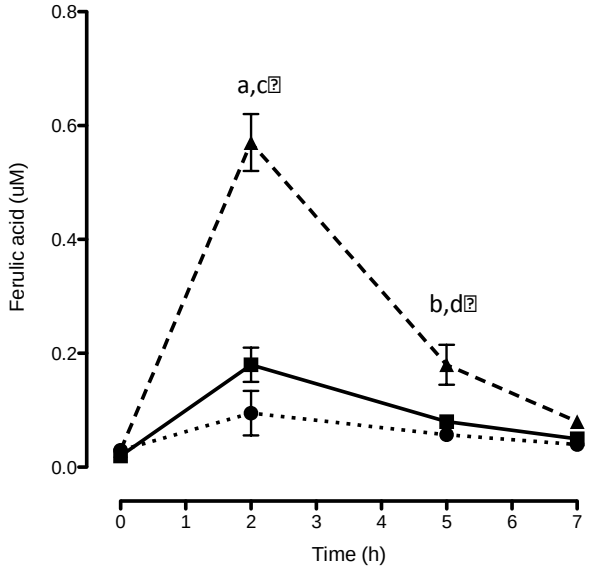
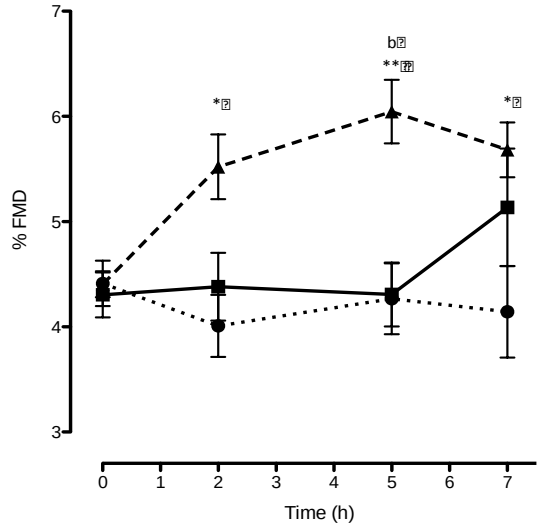
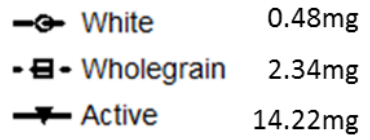
Fed to 20 volunteers in a human trial.



ferulic acid detected in blood





free ferulic

arterial dilation

Increased blood flow
Relaxation of blood vessels
Improved endothelial function

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As good a blueberries or champagne

ROTHAMSTED RESEARCH

Total polyphenols **1791mg**=80g freeze dried blueberry powder

Total polyphenols **1278**mg=56g freeze dried blueberry powder

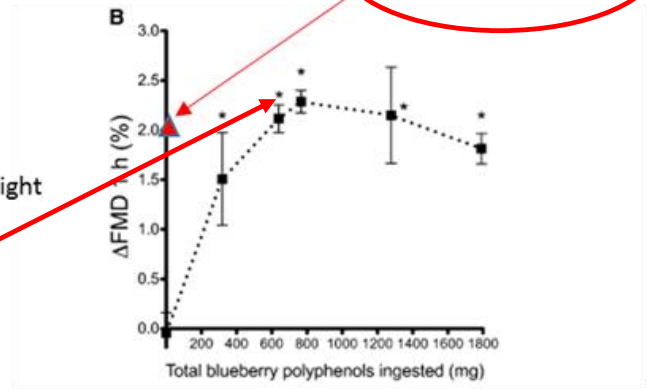
Total polyphenols **766**mg=34g freeze dried blueberry powder

3.7 tubs 560g fresh weight

2.6 tubs 400g fresh weight

1.6 tubs 240g fresh weight

22.71mg total ferulic acid
90g of flatbread



AJCN. First published ahead of print September 4, 2013 as doi: 10.3945/ajcn.113.066639.

Intake and time dependence of blueberry flavonoid–induced improvements in vascular function: a randomized, controlled, double-blind, crossover intervention study with mechanistic insights into biological activity[1–3]

Ana Rodriguez-Mateos, Catarina Rendeiro, Triana Bergillos-Meca, Setareh Tabatabaee, Trevor W George, Christian Heiss, and Jeremy PE Spencer

University of Reading

Alice Turner, Jeremy Spencer

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Conclusions

Cereals are an important source of key components for human health including fibre, minerals and vitamins.

Arabinoxylan, the main DF component of wheat grain

- effects on glycaemic load/index
- (pre-biotic)
- (AX/ferulic acid effects on endothelial function)

Wheat is immensely diverse in composition, due to the effects of genotype and environment.

Highly heritable traits, such as fibre content, can be exploited by breeders.
Processing may permit enhancement of quality traits

Rothamsted Research

where knowledge grows

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