Has intensive breeding resulted in changes in the composition of wheat grain and flour?

Peter R Shewry

Rothamsted:
- Alison Lovegrove, Till Pellny, Amy Plummer, Abby Wood, Alice Bellisai, Jane Ward

University of Bristol
- Sacha Allen, Amanda Burridge

ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

Strategy

1. Select 39 varieties released 1790-201
    - all bred and/or adapted to UK
    - All grown for significant time or over large area
2. Field trials for 3 years, 3 randomised replicates
3. Determine composition of WHITE FLOUR:
    - dietary fibre (arabinoxylan and β-glucan)
    - polar metabolites (include sugars, amino acids, organic acids, methyl donors)

ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

The 39 Cultivars

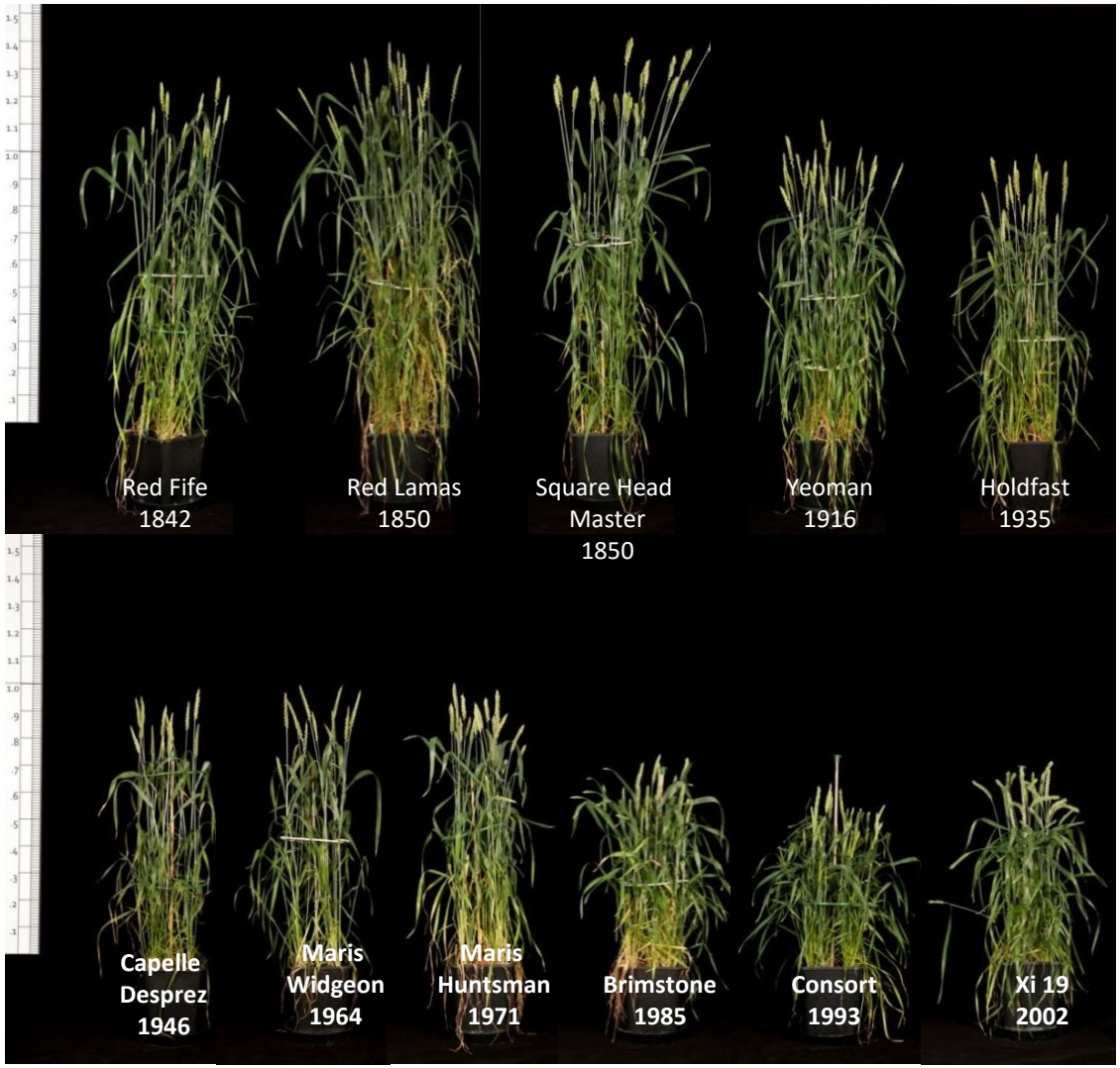
Date	Variety	Allele RhtB1	Allele RhtD1	Rht Phenotype	Country of Origin (if not UK)
1790	Chidham White Chaff				
1838	April Bearded				
1842	Red Fife				Canada
1844	Browick				
1850	Red Lammas				
1905	Red Standard				
1908	Little Joss				
1911	Squareheads Master				
1916	Yeoman				
1935	Holdfast				
1942	Gartons 60				
1946	Cappelle Desprez				France
1947	Victor				
1949	Flanders				Belgium
1952	Steadfast				
1954	Masterpiece				
1956	Viking				
1957	Dominator				
1958	Milfast				
1964	Maris Widgeon				
1971	Maris Huntsman				
1972	Maris Ploughman				
1980	Avalon	Rht-B1a	Rht-D1b	Rht2	
1983	Galahad	Rht-B1a	Rht-D1b	Rht2	
1984	Apollo	Rht-B1a	Rht-D1a	WT	Germany
1985	Mercia	Rht-B1a	Rht-D1b	Rht2	
1985	Brimstone	Rht-B1a	Rht-D1b	Rht2	
1989	Hereward	Rht-B1a	Rht-D1b	Rht2	
1991	Spark	Rht-B1a	Rht-D1a	WT	
1992	Cadenza	Rht-B1a	Rht-D1a	WT	
1993	Consort	Rht-B1a	Rht-D1b	Rht2	
1995	Flame	Rht-B1a	Rht-D1b	Rht2	
1997	Malacca	Rht-B1a	Rht-D1b	Rht2	
2002	Solstice	Rht-B1a	Rht-D1b	Rht2	
2002	Xi 19	Rht-B1a	Rht-D1b	Rht2	
2003	Robigus	Rht-B1b	Rht-D1a	Rht1	
2007	Einstein	Rht-B1a	Rht-D1b	Rht2	
2009	Gallant	Rht-B1a	Rht-D1b	Rht2	
2012	Crusoe	Rht-B1a	Rht-D1b	Rht2	

ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

The 12 wheat varieties grown at Rothamsted since 1843

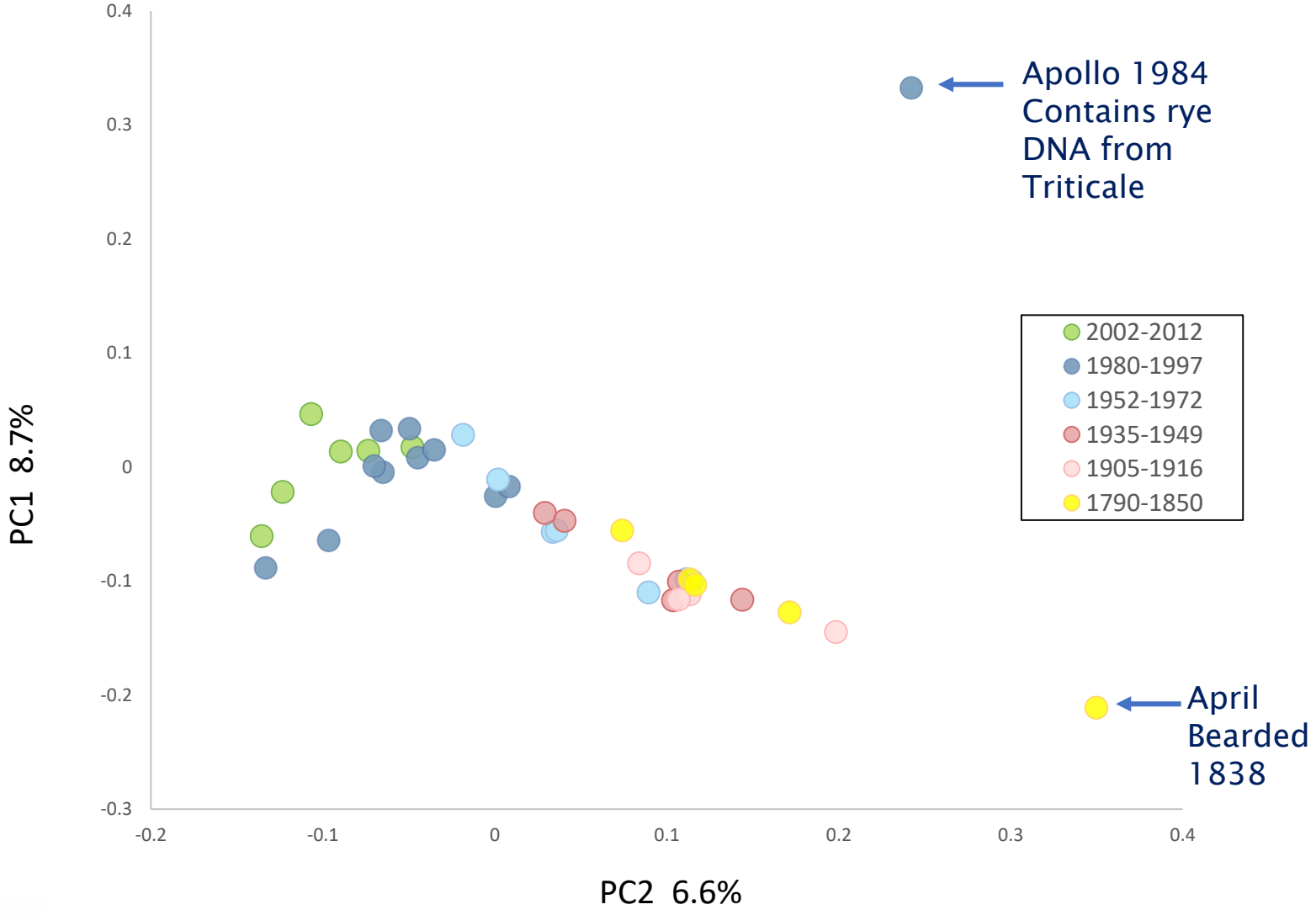


ROTHAMSTED RESEARCH

DFW

BBSRC
bioscience for the future

PCA of genetic diversity using the Axiom HD Array.



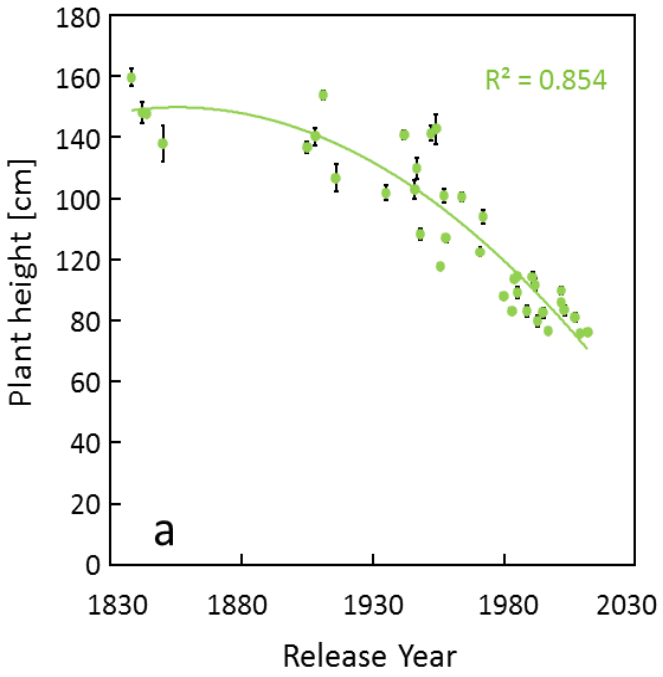
ROTHAMSTED RESEARCH

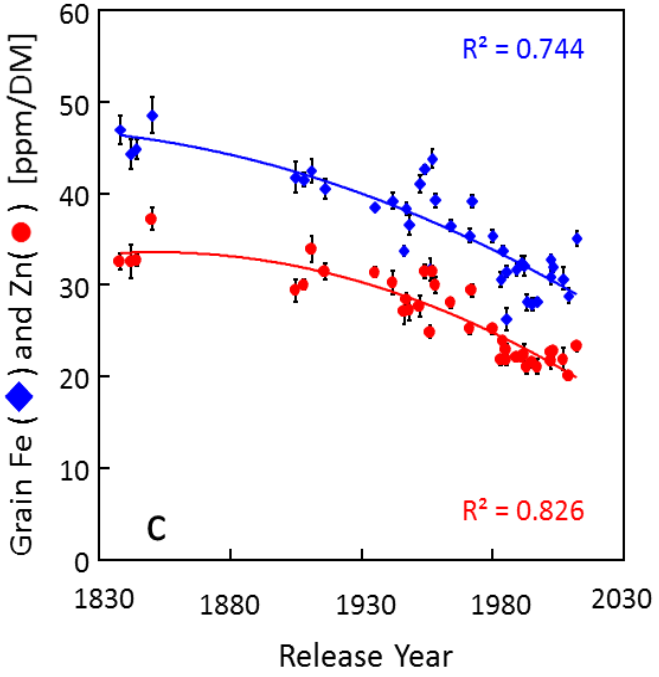
DFW

BBSRC bioscience for the future

Reduced plant height is associated with lower contents of minerals in whole grains of historical wheats

Data from replicate field trials for two years at Rothamsted





PUBLISHED: 1 JULY 2016 | ARTICLE NUMBER: 16097 | DOI: 10.1038/NPLANTS.2016.97

comment

Is modern wheat bad for health?

Prolonged and intensive breeding of wheat has produced varieties that would be unrecognizable to our ancestors. Such artificial selection can risk prioritizing traits of value to producers over those of importance to consumers. So is there evidence that crop improvement has left modern wheat nutritionally impoverished?

Peter R. Shewry, Till K. Pellny and Alison Lovegrove

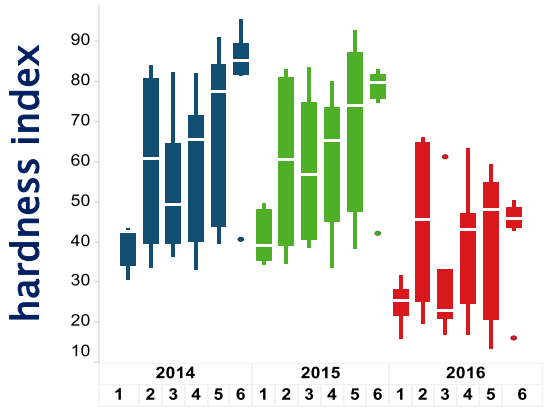
ROTHAMSTED RESEARCH

DFW

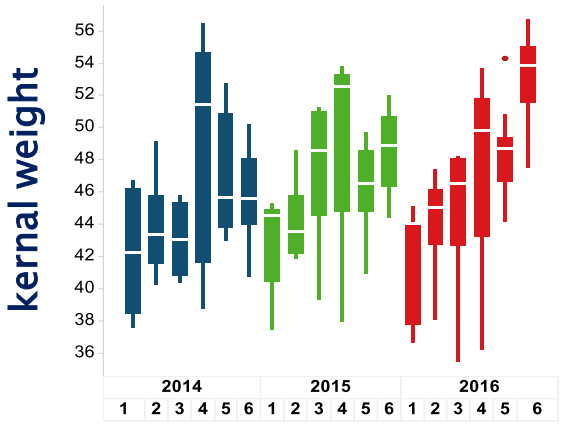
BBSRC bioscience for the future

Variation in Grain Parameters

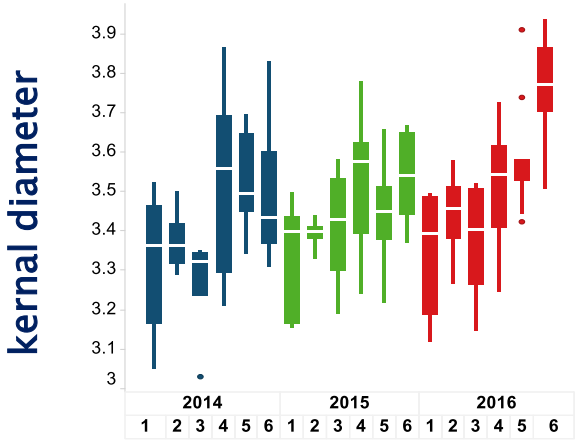
Boxes delineate the upper and lower quartile.
Whiskers represent upper and lower values
Means are represented by a solid line within boxes.
Small squares represent statistical outliers.



Age group, Growth year



Age group, Growth year



Age group, Growth year

ROTHAMSTED RESEARCH

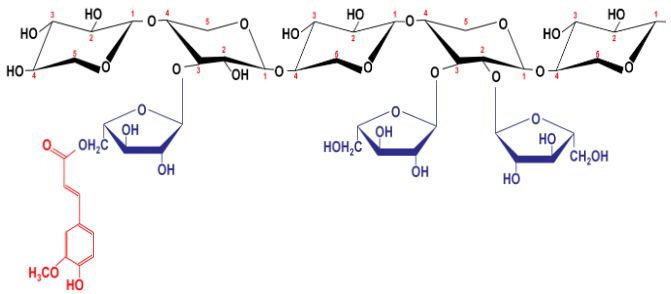
DFW

BBSRC bioscience for the future

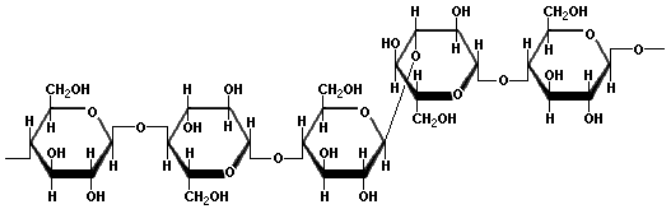
White flour is a major source of dietary fibre in the UK diet

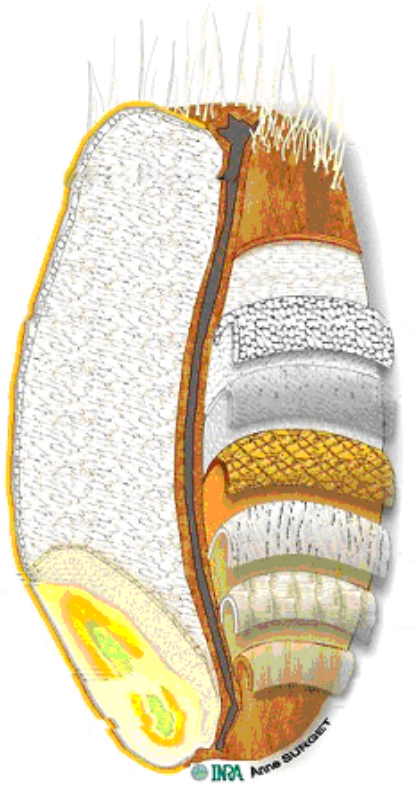
White flour
2–3% total dietary fibre

70% arabinoxylan



20% β-glucan





% contribution to daily intake of TDF

All bread	20
White bread	11
Wholemeal bread	5

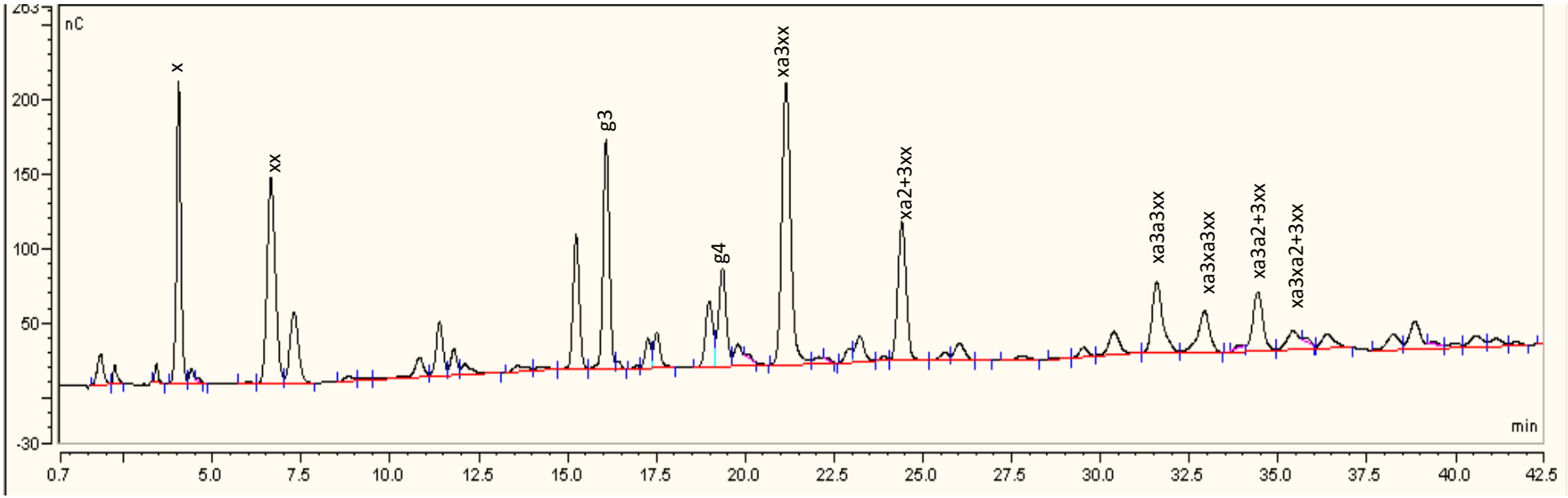
Steer et al., Proc. Nutr. Soc. 2008, 67, E363

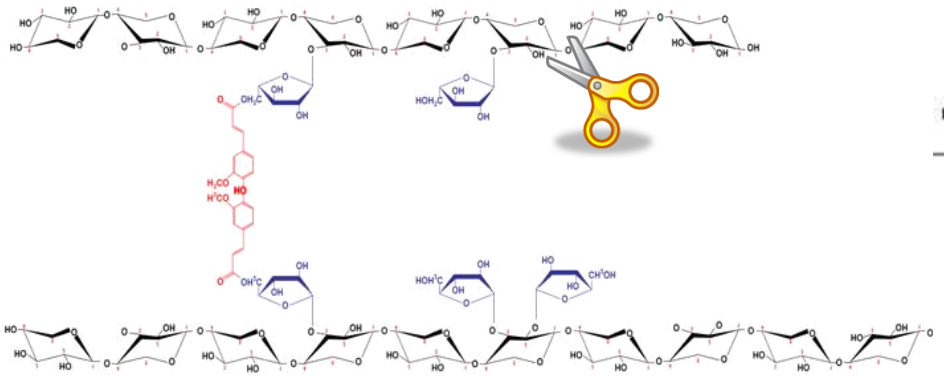
ROTHAMSTED RESEARCH

DFW

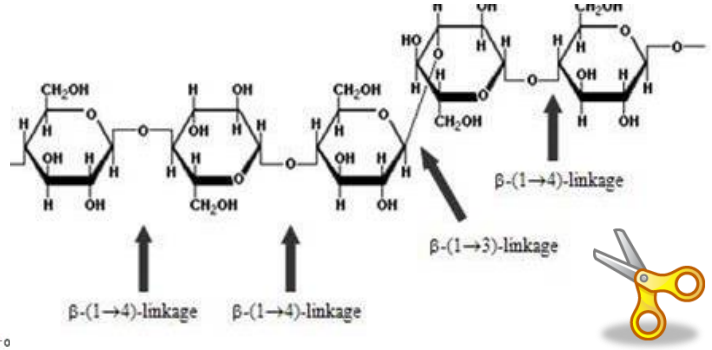
BBSRC bioscience for the future

Fingerprinting of AX and β-glucan by HPAEC-PAD





endo-1,4- β -xylanase



endo-1,3(4)-β-glucanase (lichenase)

AX fractions identified by MS and NMR

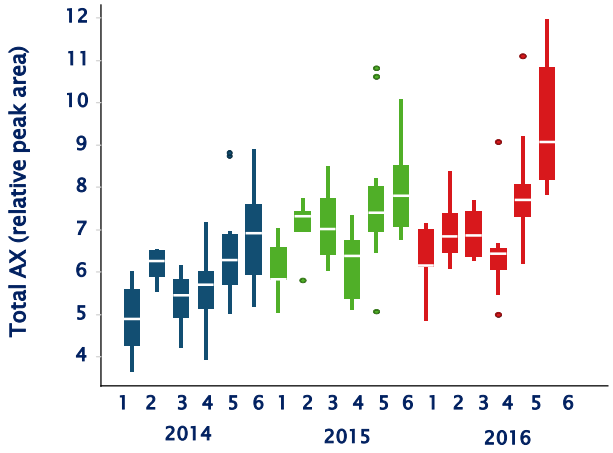
ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

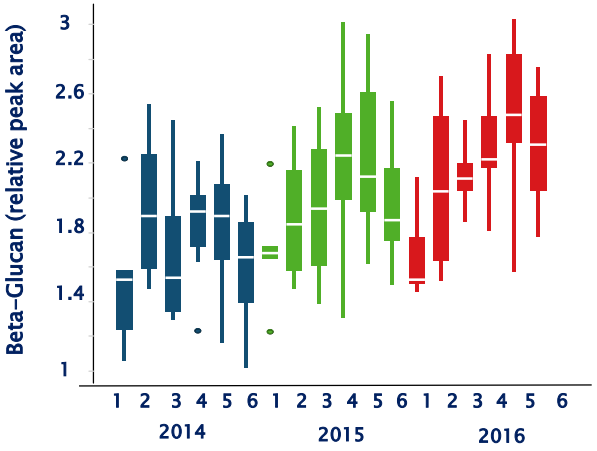
Variation in dietary fibre components in white flour

Arabinoxylan

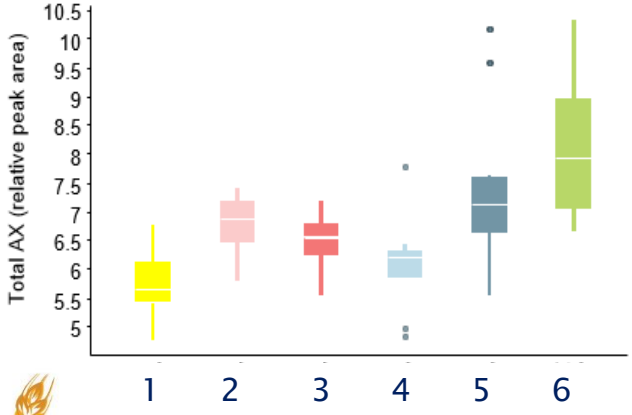


Age group, growth year

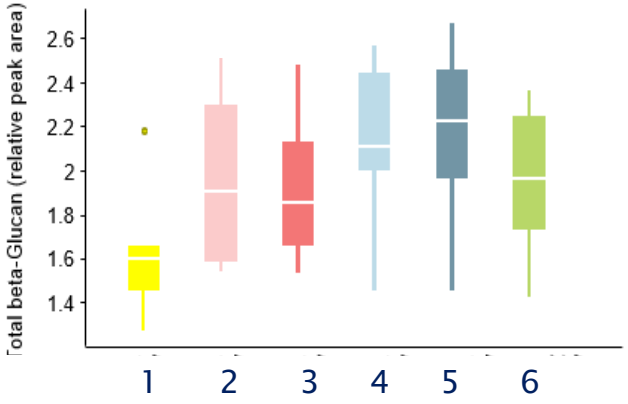
β-glucan



Age group, growth year



Age group, means of growth years



Age group, means of growth years

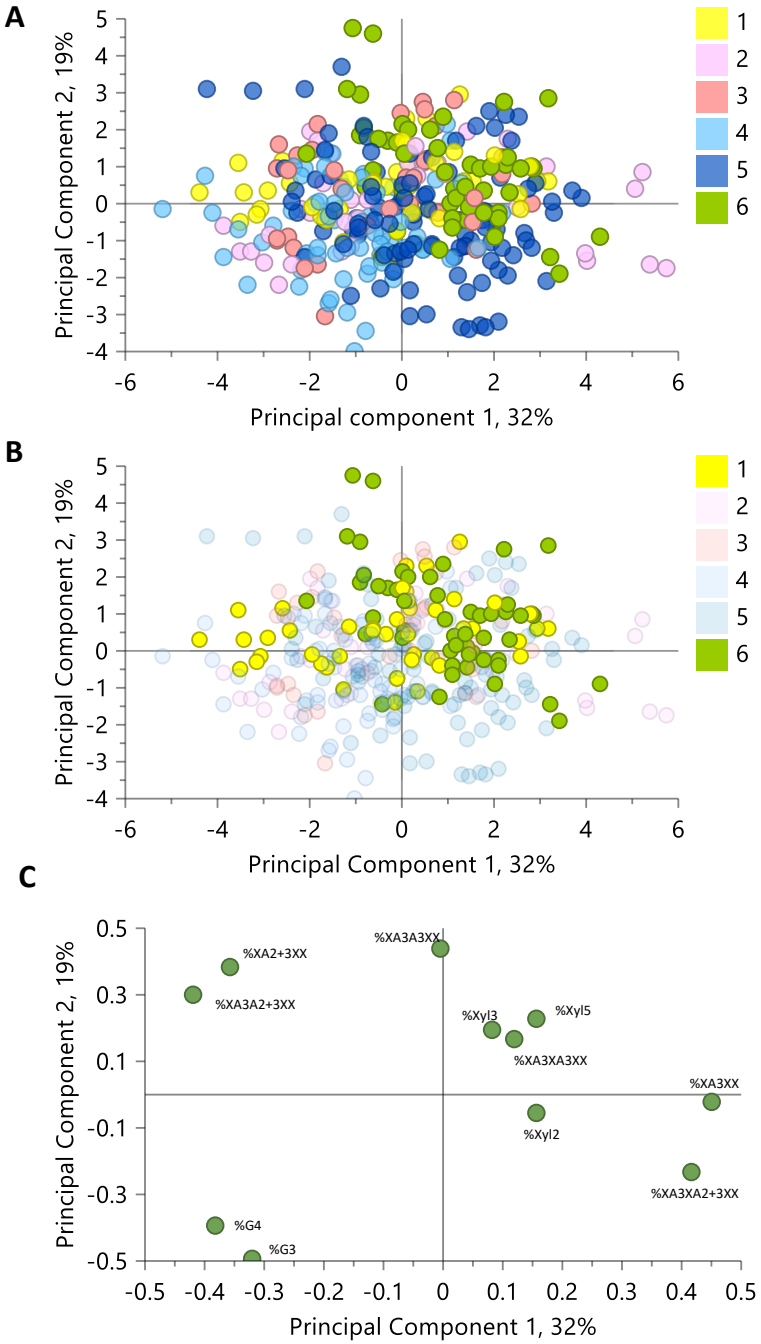
ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

PCA of fibre structure in white flour

- % AXOS from AX
- % G3 and G4 from β-glucan



ROTHAMSTED RESEARCH

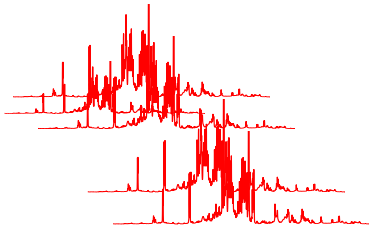
DFW

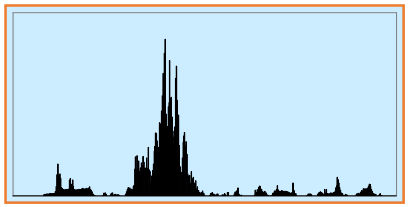
BBSRC bioscience for the future

Metabolomic analysis of wheat flour by ^{1}H NMR spectroscopy

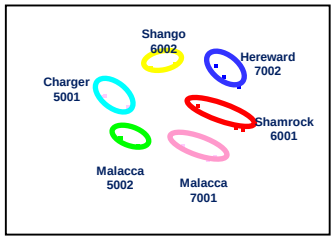
extract 30 mg flour with 20% CD_3OD in D_2O

^{1}H NMR spectrum recorded





- data processing in AMIX
- scaling & "bucketing"
- removal of unwanted
- areas (ie H0D, CD_2HOD)



Multivariate analysis

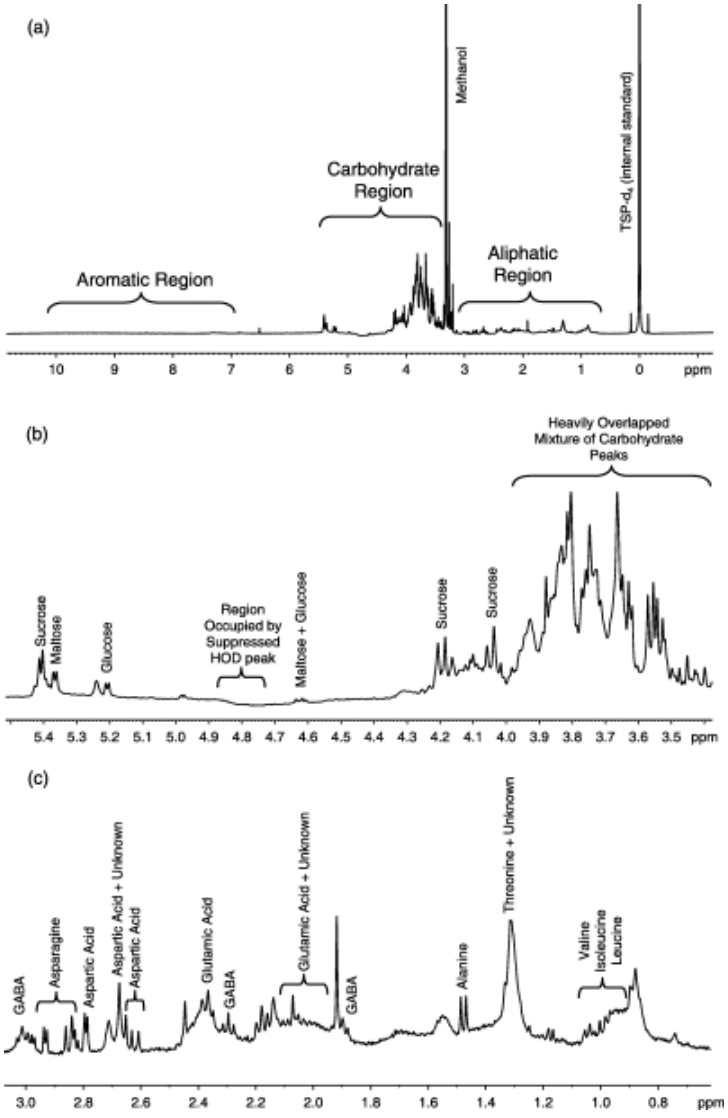
ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

Typical metabolite profile of wheat flour by ^{1}H NMR spectroscopy

^{1}H NMR spectrum of polar extract of white wheat flour



whole spectrum

carbohydrate region

aliphatic region

Baker et al (1986) Plant Biotech Journal, 4:381-392

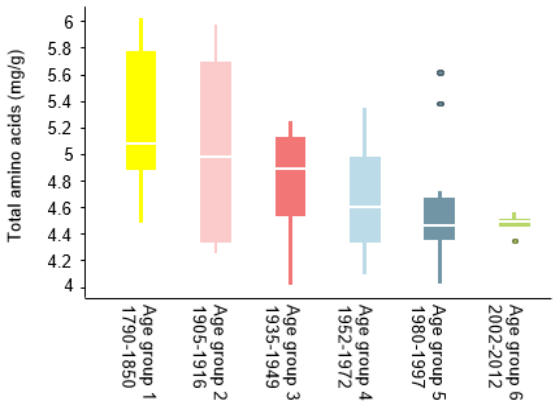
ROTHAMSTED RESEARCH

DFW

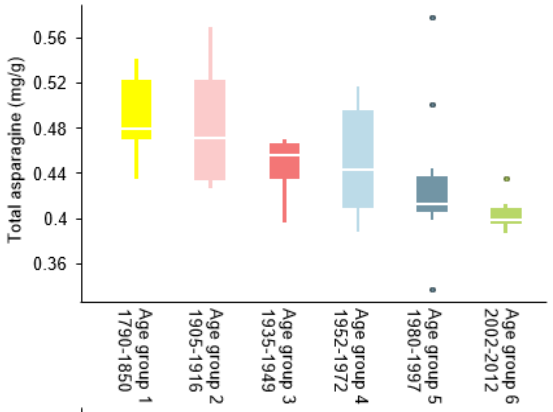
BBSRC bioscience for the future

Variation in polar metabolites in white flour

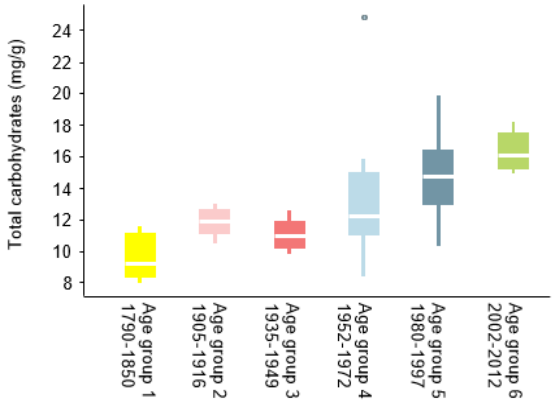
total amino acids



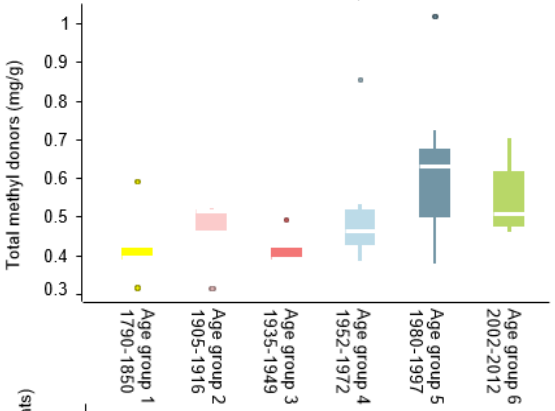
asparagine



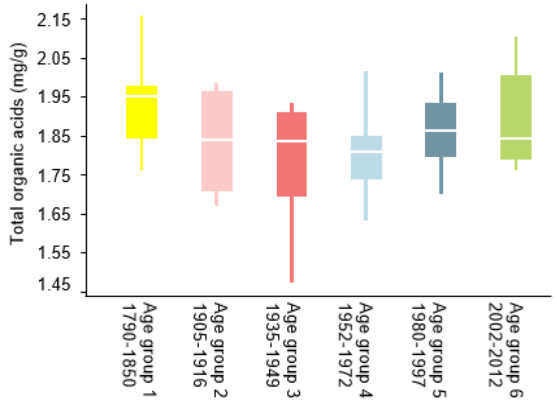
total sugars



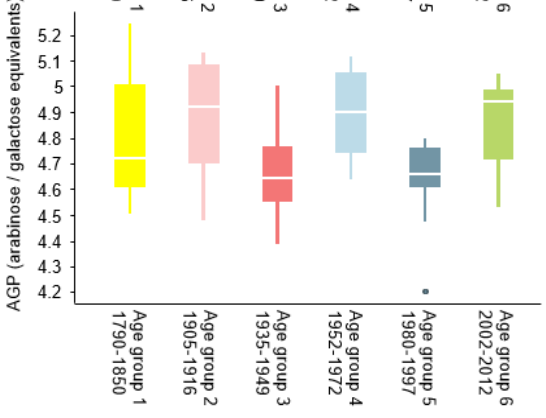
total organic acids



choline and betaine



arabinogalactan peptide (AGP)

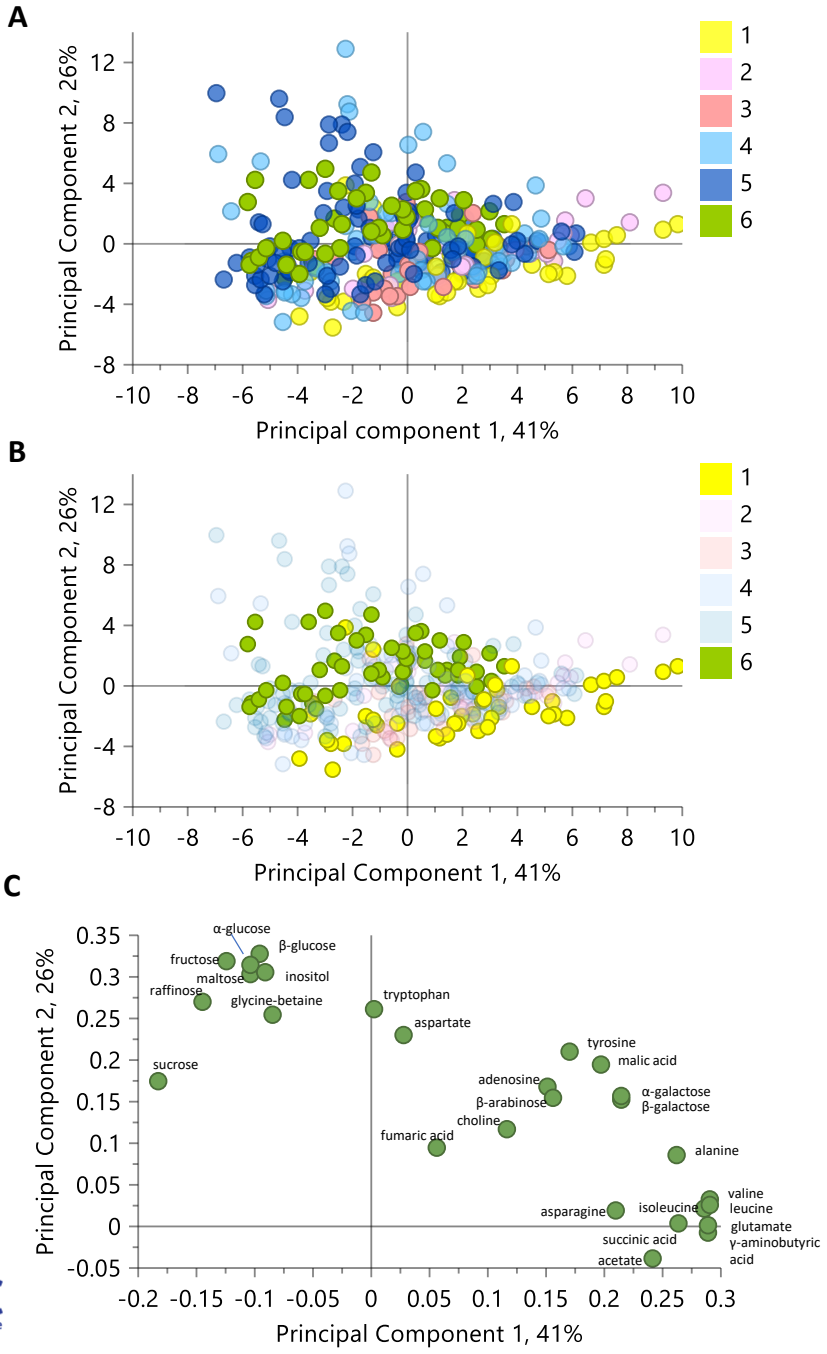


ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

PCA of polar metabolites in white flour



ROTHAMSTED RESEARCH

DFW

BBSRC bioscience for the future

Conclusions

1. Wide genetic variation
2. Strong effect of environment
3. Nevertheless some trends are observed
    - increase in arabinoxylan fibre
    - decreases in some individual and total amino acids
    - increases in sugars (mono-, di- and oligosaccharides), including FODMAPs.
    - Increase in betaine
4. Biological significance not clear
5. Limited significance for health!

ROTHAMSTED RESEARCH DFW BBSRC bioscience for the future