The thirty-nine wheat varieties being grown in demonstration plots at Cereals 2018 (Duxford, Cambridgeshire). Note the decreased height from the early varieties (closest to camera) to the modern varieties

Modern wheat

Modern wheats are high in dietary fibre, but there is still room for improvement!

by Peter R Shewry and Alison Lovegrove, Rothamsted Research, UK

The yields of wheat in the UK and across much of the world have increased massively over the past century, from a few tonnes per hectare at the start of the twentieth century to current UK average yields of between eight and nine tonnes per hectare. Many factors have contributed to these increases, with genetic improvement by plant breeding being particularly important in the second half of the 20th century.

For example, Ian Mackay and colleagues at NIAB estimated that almost 90 percent of the yield increases in the UK over the period 1981-2007, from about six-to-eight tonnes per hectare, were due to varietal improvement. However, it has been suggested that the emphasis of modern breeding on increasing yield and processing quality has resulted in detrimental effects on the contents of other grain components, including those that are important for human health. This is important because wheat is the staple food in many countries and an important source of a number of essential and beneficial components, including protein, dietary fibre, minerals and vitamins.

Cereals, and wheat in particular, are important sources of dietary fibre. For example, in the UK about 40 percent of the fibre in the diet comes from cereals, about 20 percent from all breads and about 10 percent from white bread. Dietary fibre is essential for human health, having a range of established benefits including reducing the rate of glucose release during the digestion of starchy foods (and hence reducing the risk of type 2 diabetes), lowering blood pressure and the level of cholesterol in the serum, and reducing the risk of certain types of cancer (notably colorectal cancer). Fibre is also deficient in almost all diets: the average UK adult consumes about 18g per day, compared with the recommendation of 30g.

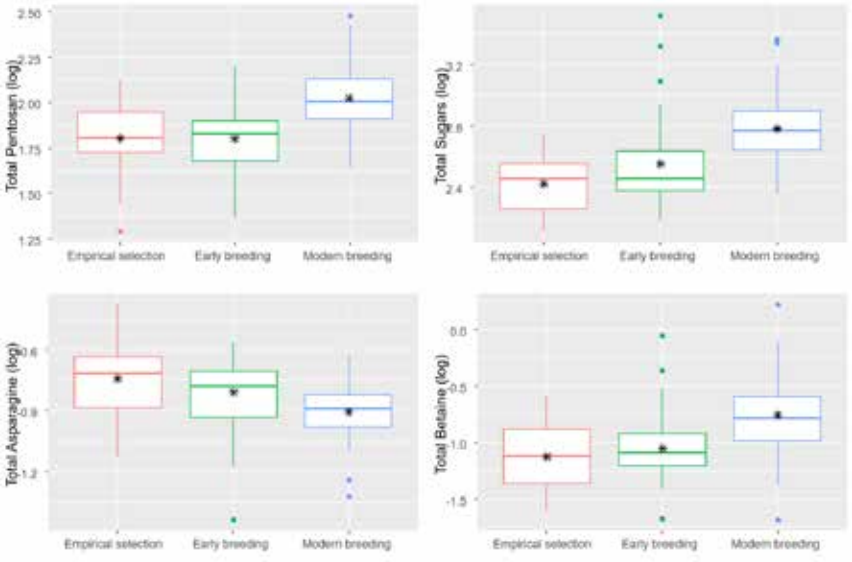
In order to determine whether modern wheat breeding has resulted in decreases in the content of dietary fibre we have compared the composition of a collection of wheat varieties which have been grown and consumed in the UK over the past 250 years. Thirty-nine varieties (See image 1) were selected to include the most successful varieties grown in the UK over this period and also represented different stages of wheat breeding.

Nine of the varieties were released between 1790 and 1916, when varietal improvement was carried out by selecting the best lines from populations and from crosses. However, this was not underpinned by genetic understanding and we therefore refer to this stage as “Empirical Selection”. The second group of thirteen varieties were released between 1935 and 1972 and represented “Early Scientific Breeding”. Finally, seventeen varieties released between 1980 and 2012 represent “Modern Breeding”, including the introduction of short types in the 1970s and the increasing application of modern breeding technologies. In order to minimise the confounding effects of environment, the varieties were grown for three years with three replicate plots per year. The years and replicates were then analysed separately, allowing the use of statistics to identify significant differences (see Figure 1).

Because white bread continues to be the dominant wheat-based food in the UK and many other countries, we compared white flour prepared using a Chopin CD1 laboratory mill. Dietary fibre is a mixture of several components, but the major one of these (accounting for half or more of the total) is pentosan (arabinoxylan). Statistically significant differences in the contents of pentosans were observed between the varieties within each group, with further significant effects of environment.

Nevertheless, the pentosan content was higher in the modern varieties than in the two earlier groups: this difference was statistically significant and observed over all three years (See Figure 1). Analysis of the same samples showed that the increase

Figure 1: Box and whisker plots of the contents of pentosans, total soluble sugars, asparagine and betaine in white flour of the 39 cultivars measured in three years and averaged over three replicates. Cultivars are grouped to represent stages in wheat breeding: red, empirical selection (190–1916); green, early breeding (1935–1972), blue, modern breeding (1980–2012)



in pentosans was associated with significantly increased contents of soluble carbohydrates, a fraction comprising monosaccharides (glucose, fructose, galactose and arabinose), disaccharides (sucrose, maltose) and the trisaccharide raffinose (called "soluble sugars" in Figure 1).

The increased yields of modern wheats result from higher rates of synthesis and accumulation of starch, which accounts for about 80 percent of the dry weight of white flour. The increased starch accumulation results in dilution of the second most abundant flour component, protein, which decreased from about 15 percent in the early varieties to about 12 percent in the modern group. Proteins are polymers of about 20 amino acids and the total amounts of these, and the amounts of most individual amino acids, were generally lower in the modern wheats. This is of interest because the amino acids which decreased included asparagine (See Figure 1), which is a precursor of acrylamide formed during processing with asparagine concentration being the limiting factor for acrylamide formation in cereal-based foods. Hence, we would anticipate that products made from the modern wheats would have lower contents of acrylamide than products made from older types of wheat.

Finally, the flours from modern wheats also contained significantly higher contents of betaine, a modified amino acid which is beneficial for cardio-vascular health by acting as a "methyl donor" in the homocysteine cycle.

The modern wheat varieties included in this study included some of the most successful breadmaking wheats grown in the UK, such as the nabim Groups 1 varieties Hereward, Xi19, Solstice, Gallant and Crusoe. This shows that it is possible to combine higher levels of fibre (pentosan) with high yield and good breadmaking quality. However, it is necessary to increase the amounts further to

reduce the "fibre deficit" in the diet of most consumers.

Wider comparisons of wheats grown globally have shown that some varieties have higher contents of pentosan in white flour than those grown in the UK. We are, therefore, studying two of these, the Chinese variety Yumai 34 and the French variety Valoris, in order to identify the genes controlling the content of pentosan and to develop markers to enable breeders to screen for high pentosan content. Yumai 34 has good breadmaking quality and we have made crosses with UK varieties to develop pre-breeding lines which are being used in collaboration with partners in UK-based breeding companies to develop elite high fibre cultivars for growth in the UK. Preliminary analyses of lines from these studies confirm that high pentosan content can be combined with good breadmaking quality (see image 2).

The significance of changes in grain composition for human health may be difficult to estimate as wheat is usually consumed as part of a varied diet and is therefore a relatively minor dietary source of many components. However, because bread is a major source of fibre it is possible to make more precise calculations. White bread currently accounts for about 10 percent of the total intake of fibre in the UK and a two-fold increase in fibre content should therefore result in an increase of 1.8g in the average daily intake. This accounts for about 15 percent of the current shortfall in the daily intake of fibre in the UK.

Acknowledgements

Rothamsted Research receives grant-aided support from the Biotechnology and Biological Sciences Research Council (BBSRC) of the UK and the work forms part of the Designing Future Wheat strategic programme (BB/P016855/1). We are grateful to colleagues at Rothamsted, particularly Dr Kirsty Hassall for statistical analyses and preparing Figure 1 and Dr Jane Ward for the analyses of sugars, asparagine and betaine, and to Prof Simon Griffiths and Dr Luzie Wingen at the John Innes Centre.

The loaf in Figure 3 was provided by Mark Waples at Marks and Spencer plc (London UK) as part of Innovate UK project L005654/1 which was led by Dr Jacob Lage (KWS Seeds).

www.rothamsted.ac.uk