Reducing the acrylamide-forming potential of wheat, rye and potato: Variety selection, genetic improvement and crop management

ROTHAMSTED RESEARCH

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INTRODUCTION

Acrylamide (C_3H_5NO), a Group 2A carcinogen, is a processing contaminant produced during frying, baking, roasting, toasting or high-temperature (> 120 °C) food processing. Potato, coffee and cereal products are the major contributors to dietary acrylamide intake. The European Commission has just introduced (April 2018) strengthened risk management measures for acrylamide in food, including compulsory Codes of Practice and Benchmark Levels.

Acrylamide forms from free asparagine and reducing sugars in the Maillard reaction. The effectiveness of measures developed to reduce its formation in potato crisps is shown in Fig. 1. However, since 2011 there has been a levelling off, suggesting that the easy gains have already been made.

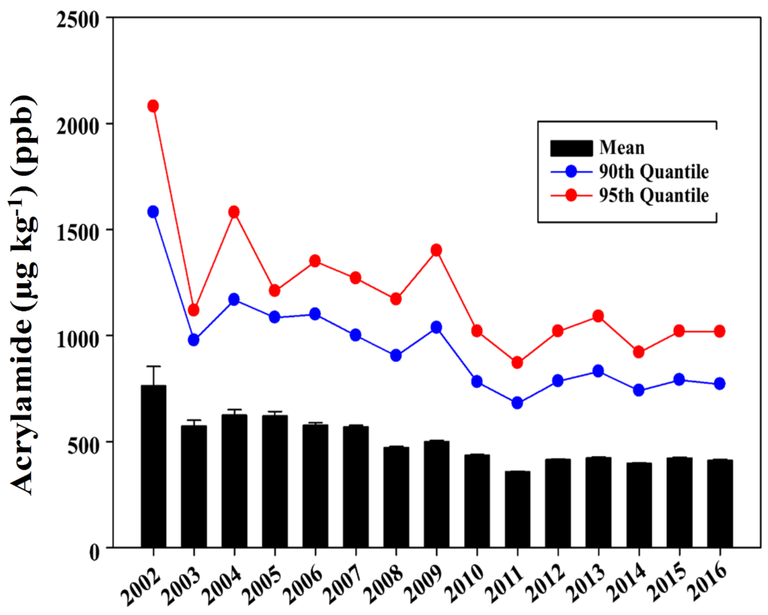

FIGURE 1. Acrylamide concentrations (µg kg^{-1}) (parts per billion (ppb)) in potato crisps in Europe from 2002 to 2016 (*Food Addit. Contam. Part A* 34, 2085-2100).

POTATO

The concentration of reducing sugars is the major determinant of acrylamide-forming potential in potato. Storage is very important, due to cold and senescent sweetening, and there are big differences between varieties. Acrylamide levels in crisps show a distinct seasonality due to the effects of long-term storage (Fig. 2A) and there is also a geographical effect (Fig. 2B).

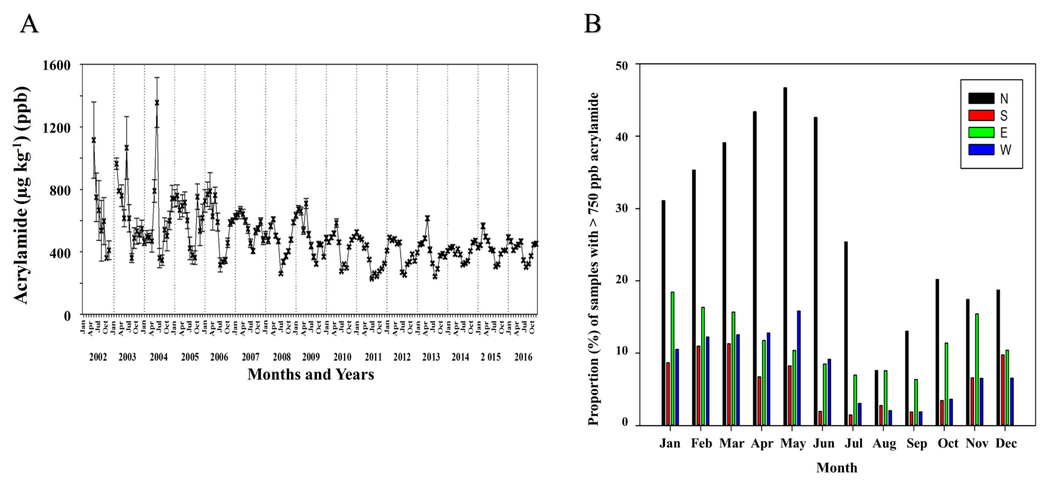

FIGURE 2. A. Seasonality of potato crisp acrylamide content. B. Proportion (%) of potato crisp samples with more than the Benchmark Level of 750 ppb acrylamide for each month for geographic regions of Europe (*Food Addit. Contam. Part A* 34, 2085-2100).

WHEAT AND RYE

Acrylamide formation in cereals is determined by free asparagine concentration, and this parameter varies greatly between different varieties (Fig. 3). Crop management, including good disease control and sulphur sufficiency (in wheat), is also extremely important (Fig. 4).

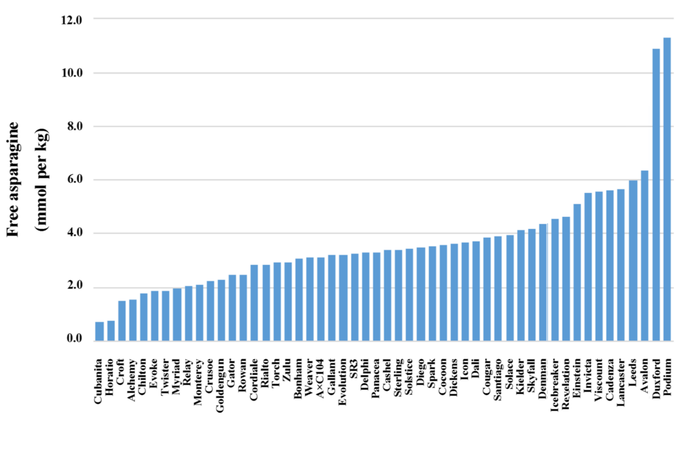

FIGURE 3. Free asparagine concentration in grain of winter wheat varieties grown in a field trial at Woburn, Bedfordshire, UK, 2012-2013 (*Food Chem.* 239, 304-313).

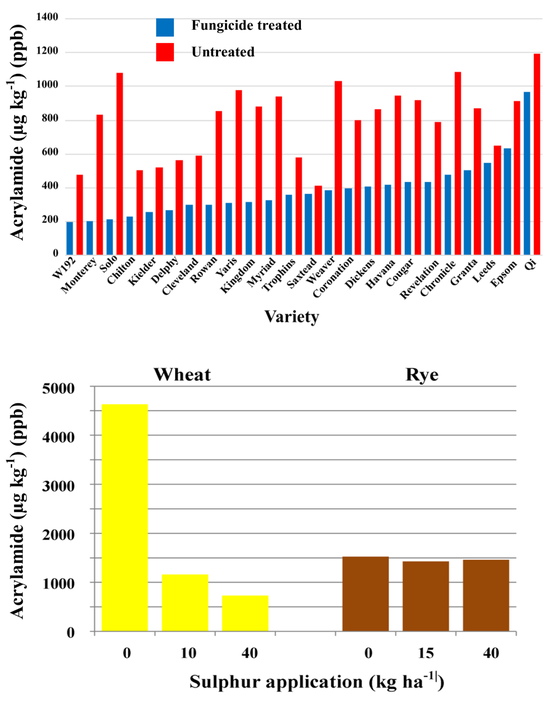

FIGURE 4. Top. Acrylamide formation in flour from wheat grown with or without fungicide treatment (*J. Agric. Food Chem.* 64, 9689-9696). Bottom. Effects of sulphur availability on acrylamide-forming potential in wheat and rye (*J. Cereal Sci.* 59, 382-392).

WHEAT ASPARAGINE SYNTHETASES

Wheat has four asparagine synthetase genes (*TaASN1-4*) (Fig. 5A). The expression of *TaASN2* in the embryo and endosperm during mid to late grain development is the highest of any of the genes in any tissue (Fig. 5B).

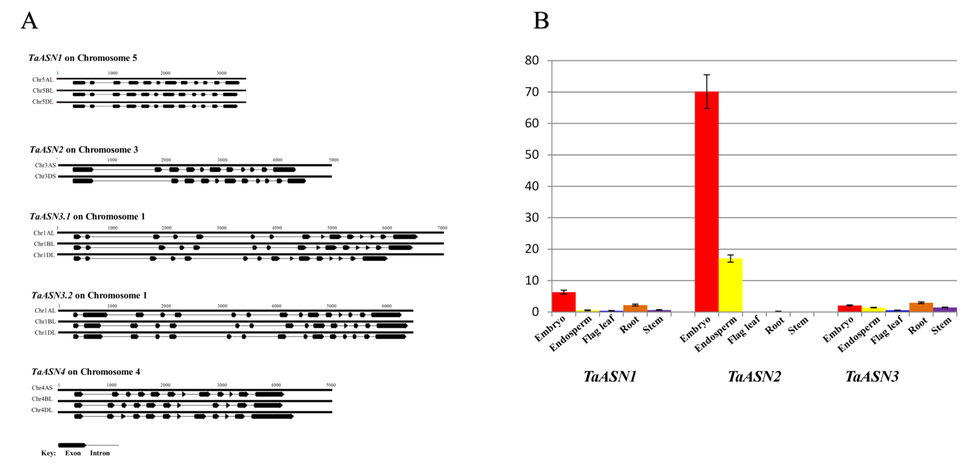

FIGURE 5. A. Asparagine synthetase genes from wheat (*Frontiers Plant Sci* 8, 2237). B. Differential expression (NRQ means and standard errors) of asparagine synthetase genes in different tissues of wheat at 21 days post-anthesis (*J. Cereal Sci.* 68, 122-131).

We have identified separate mutant lines produced by 'classical' chemical mutagenesis carrying mutations in each of the *TaASN2* homeologues. These lines are being crossed to generate a null line. We are also using CRISPR-Cas to knock out *TaASN2*. This work will be presented by Sarah Raffan in the Plant Genome Engineering: Strategies & Development session on the afternoon of Day 1 (14th May).

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