Can you introduce your key research goals?

I investigate signalling networks that mediate the regulation of plant metabolism. A major application of this research at present is aimed at reducing the acrylamide-forming potential of wheat, rye and potato; improving understanding of the genetic and agronomic factors that affect free asparagine and the accumulation of reducing sugars; and the mathematical modelling of asparagine metabolism.

In addition to this, I am working to understand the interactions between metabolic and stress signalling pathways in plants, the effect of environmental stress and crop management on crop composition, and the implications this has for food quality and safety. I am also investigating the role of abscisic acid (ABA) and sucrose nonfermenting-1 (SNF1)-related protein kinases (SnRKs) in different developmental processes, such as phase changes in cereal seed development and the sensitivity of wheat flowers to extreme temperature. Finally, I am studying the role of general control non-derepressible-2 (GCN2)-type protein kinase in controlling free amino acid levels in cereal grain and stress responses. I also have a general interest in the use of plant biotechnology for crop improvement.

How can crop composition affect the acrylamide-forming potential of cereal and potato plants?

Although acrylamide is not present in the crop when it is harvested, it forms from precursors that are. These precursors are free asparagine (asparagine that is not incorporated into proteins) and reducing sugars such as glucose, fructose and maltose. Their concentrations in the crop raw material determine the potential for acrylamide to form during cooking or processing. How much actually forms is also dependent on the temperature and duration of cooking, as well as a number of other factors.

What are the difficulties associated with retaining the benefits of cereal and potato products while reducing their acrylamide levels?

Potato and cereal foods are essential for our food security, being irreplaceable sources of energy (in the form of complex carbohydrates) and valuable nutrients. Wholegrain wheat products, for example, are a rich source of fibre, protein, B vitamins, iron, calcium, phosphoric acid, zinc, potassium and magnesium; while rye is also rich in fibre, as well as beneficial phytochemicals such as folate, phenolic acids, alkylresorcinols (phenolic lipids) and sterols. Fortunately, reducing the levels of free asparagine in the grain should not interfere with the content of these nutrients.

Conflict does exist, however, in the fact that the bran fraction of the grain usually contains significantly more free asparagine than the white flour fraction, and wholegrain products therefore generally contain more acrylamide than products made with white flour. As such, you have to balance the known, proven health benefits of wholegrain cereal products against the unknown risk represented by tiny concentrations of acrylamide. The consensus at present is that we do not want to put consumers off eating wholegrain cereals; however, history has taught us that debating risk against benefit with consumers is extremely difficult.

The reaction that produces acrylamide from asparagine also gives rise to a plethora of compounds that impart flavour, colour and aroma to foods when other amino acids participate. These give fried, baked and roasted foods the characteristics that define products and brands, and that consumers demand. Food processors are therefore struggling to reduce acrylamide levels and still produce the tasty foods that customers want.
At Rothamsted Research in the UK, investigations are underway towards reducing acrylamide-formation risk in common food products by limiting the levels of its precursors – free asparagine and reducing sugars such as glucose, fructose and maltose – in potato and cereal crops.

We tell breeders that they must engage with the contaminants issue or risk losing market shares to those who do. Switching to a variety with lower concentrations of acrylamide precursors is the easiest and cheapest way for food producers to reduce the levels of acrylamide in their products.

We also urge breeders to consider not just the current regulatory scenario, but what it might be in 10 years’ time, since that is the sort of timescale required to develop and market a new variety.

How does your team contribute to improving food quality and safety?

We give advice on crop management. To date, for example, our advice on sulphur fertilisation of wheat has been adopted by the UK’s Home Grown Cereals Association, and our advice that potatoes should only be used for the manufacture of crisps and French fries within their optimum storage window has also received wide publicity.

Furthermore, we give advice on variety selection, so that food manufacturers can use the best varieties available for the product that they are making. We have published several variety comparisons for potato, rye and wheat, and aim to be able to classify current UK wheat varieties on the basis of acrylamide risk, although we concede that this is a difficult issue for breeders.

In the longer term, we propose to provide plant breeders with the knowledge and tools to breed varieties with lower acrylamide-forming potential.

A CARCINOGENIC CHEMICAL produced during cooking and processing, acrylamide has long been a constituent of the human diet, but it was only recently that it was identified in a range of popular foods. Although research aimed at quantifying the health risks that dietary exposure to acrylamide poses to humans is ongoing, food safety agencies and the food industry are increasingly in support of any advances that can reduce the amount of the compound within food.

Acrylamide forms when foods such as potatoes, coffee and cereals like wheat and rye, are cooked at high temperatures. While a wide variety of food preparation methods aimed at reducing acrylamide formation have been – and continue to be – developed, they are not without their limitations. Often they are costly, cannot be applied universally, and can compromise the resulting product’s colour, flavour or aroma. For this reason, efforts are increasingly focused on reducing the acrylamide-forming potential of the raw crops themselves.

CRP SCIENCE SOLUTIONS

Rothamsted Research is the oldest agricultural research station in the world, having run continuously since its foundation in 1843. Based in the UK, this independent scientific research institute is dedicated to building an integrated, multidisciplinary environment for the study of plant and soil science.

Based at Rothamsted Research and leading its plant biology and crop science research programme, Professor Nigel Halford’s investigations are largely aimed at elucidating how various factors, such as environmental stressors and different crop management strategies, impact crop composition and subsequent food quality and safety. Clearly, this approach could have significant applications in the context of reducing acrylamide formation in potato and cereal crops.

AGRONOMIC APPROACHES

While there has already been a considerable amount of research dedicated to understanding the impact of biotic and abiotic stresses and crop management strategies on crop composition, including concentrations of sugars and free asparagine, it has predominantly focused on the vegetative parts of plants rather than potato tubers and cereal grains. This is something that Halford and his team hope to remedy: “We feel that the profound effects of stress on the composition of crop plants that we eat have received too little attention, and that this must be rectified,” he explains.
REDUCING THE POTENTIAL FOR PROCESSING CONTAMINANT FORMATION IN POTATO AND CEREAL PRODUCTS

OBJECTIVES

• To investigate and understand how signalling networks regulate plant metabolism
• To elucidate the influence of environmental stress and crop management on crop composition, which in turn has influence on food quality and safety

KEY COLLABORATORS

Dr Tanya Curtis, Rothamsted Research, UK
Dr Simon Griffiths, John Innes Centre, UK
Dr Stephen Elmore, University of Reading, UK
Professor David Gilbert, Brunel University, UK
Dr Mauro Cesar Celaro Teixeira, Embrapa Wheat, Brazil

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CONTACT

Professor Nigel Halford
Principal Investigator and Research Leader
Rothamsted Research
West Common
Hertfordshire
AL5 2JQ
UK
T +44 1582 763 133 x 2203
E nigel.halford@rothamsted.ac.uk
www.rothamsted.ac.uk/people/halford

Over recent years, Halford’s group has been instrumental in assessing the role of crop management strategies in reducing the acrylamide-forming potential of crops. For example, on the issue of fertilisation, the researchers discovered that failing to provide wheat with sufficient sulphur causes a massive accumulation of free asparagine.

Regarding irrigation, the team produced findings indicating that it may increase the acrylamide-forming potential of potatoes, leading the scientists to advise potato farmers to irrigate only if necessary to maintain the health and yield of the crop. Finally, Halford and his colleagues have also highlighted the need to ensure that post-harvest potato storage temperature is both optimum and stable: too cold and the potatoes accumulate sugars, too warm and they may sprout. This has been a problem for the potato industry for many years, greatly exacerbated by the acrylamide issue.

The Rothamsted researchers are determined to translate their findings into practical impact. To this end, they work closely with growers, breeders and food manufacturers to advise on crop management strategies and varieties that will minimise acrylamide risk without compromising product quality.

GENOMIC POSSIBILITIES

However, the Halford team’s research is not limited to traditional agronomic approaches; they are also exploring the potential of novel, plant breeding and biotechnological methods, particularly genomic approaches, in reducing acrylamide-formation risk in crops. In the US, progress has been made through genetic modification (GM) – indeed, a low-acrylamide GM potato variety is already on the market, produced by US company Simplot. According to Halford, this is a fascinating development: “No market has yet been established for GM potatoes, even in the US. Moreover, I am not aware of anything similar being attempted in any cereal.”

The GM approach is not currently an option in Europe, but novel biotechnological techniques such as genome editing hold significant promise, particularly as an alternative to GM in regions like Europe, where the controversial process is either heavily regulated or not widely accepted. Genome editing enables the introduction of a mutation at a specific location in the genome in order to knock out a target gene. US and Canadian food safety authorities have already stated that they do not consider plants carrying genome edits to be GM. It is unknown at present whether the European Food Safety Authority (EFSA) will follow suit, however, it will be publishing its opinion on this issue later in the year.

AN UNCERTAIN FUTURE

The issue of compliance with food safety regulations is particularly fraught, as the regulatory situation surrounding acrylamide levels in food is rapidly evolving. EFSA is currently leading the way in this area, having established ‘indicative’ levels aimed at reducing consumers’ dietary intake of acrylamide. While these are not regulatory limits, the situation may well change: “There is a chance that these indicative levels will become regulatory limits, possibly in the near future,” Halford comments.

However the regulatory scenario develops over the upcoming years, the Halford group will continue to work closely with food manufacturers and plant breeders to identify management strategies and develop varieties that result in crops of the highest possible safety and quality. In terms of reducing acrylamide-formation potential, Halford is optimistic that the food manufacturers are on the right track: “The food industry is already working hard to reduce the levels of acrylamide in its products to as low as reasonably achievable, and in my view, it could do little more.” he states. If correct, it seems likely that dietary exposure to acrylamide will be reduced in the future – a change that could bring about significant public health benefits.