UK Bread – Acrylamide Position Paper

Introduction

This document has been written to bring together information and data on the bread supply chain in the UK to help inform the discussion regarding the challenges to reduce acrylamide in bread and to highlight the progress that has already been achieved.

It is hoped that it will also help inform the current discussions taking place within Europe. The document was produced following a meeting at which the following organisations were represented:

- **ABIM - Association of British Ingredients Manufacturers**
- **ACFM - Association of Cereal Food Manufacturers**
- **BSPB - British Society of Plant Breeders**
- **Campden BRI**
- **FDF - Food and Drink Federation**
- **FOB - The Federation of Bakers**
- **AHDB C&O - Agriculture and Horticulture Development Board Cereals and Oilseeds**
- **nabim - National Association of British and Irish Millers**
- **Rothamsted Research**

The bakery supply chain covered in this document is:

- **Plant breeding**
- **Farmers and wheat production**
- **Flour milling**
- **Baking ingredients**
- **Bakers**

There is a clear need for further research to be done on the genetic improvement of milling wheat to reduce the formation of asparagine during processing.

Summary

Following previous initiatives by the baking sector, baked goods sold in the UK, such as bread, are currently low in acrylamide compared with the indicative levels set by the EU in Commission Recommendation (2013/647/EU).

Indicative ACRYLAMIDE Levels	Micrograms/Kilogram
Soft Wheat Based Bread	80
Soft Bread other than Wheat Based Bread	150

While this is encouraging the challenge is that the relatively high volume of bread consumed makes bread a significant contributor to the daily intake of acrylamide. This challenge has been addressed by most bakeries in the UK through the adoption of practices from the FoodDrinkEurope Toolbox. However, pressures from the European Commission are increasing and other food sectors have made progress. The bread sector is now under pressure to demonstrate what further action can be achieved.

It is difficult for those processors at the end of the wheat supply chain, such as flour millers and bakers to adopt significant actions. This is because the levels of acrylamide in the finished products are already pre-determined by the characteristics of the wheat being milled or flour being used in the bakery.

Currently, bakers are able to mitigate the levels in their finished products by using the practices contained within the FoodDrinkEurope Toolbox. If significant reductions in acrylamide levels are to be achieved in the bread sector the main opportunity is through the development of new wheat varieties that produce less acrylamide during processing combined with good agricultural practices that have the same effect during the growth of the crop. This combined with the work to reduce levels with ingredient suppliers and during the baking or processing stages would then be more likely to result in significant acrylamide reduction.

Further reductions in permitted acrylamide levels should be based on clear evidence and a sound scientific justification. Before any such reductions in permitted levels of acrylamide are considered, it will be essential for funding to be made available for further research into both the development of genetic markers and a better understanding of improved agronomy to reduce this problem. Without this investment a situation could be created where, in the absence of new varieties, only a very limited proportion of the EU milling wheat crop would be used to produce bread which meets the limits for subsequent development of acrylamide levels. A section of this document describes the key areas for further research, including the need for rapid analysis techniques, at farm level, to determine levels of sulphur and asparagines in grain.

Plant Breeding

UK plant breeders fully appreciate the importance of food safety and that the issue of acrylamide levels in cereal products requires further attention. However, the nature of plant breeding means changes are unlikely to happen without significant and costly effort.

Manipulating the levels of asparagine or reducing sugars in wheat is a challenging breeding target and there is no quick way to achieve this. The development of a new wheat variety takes 10 to 12 years from the start of the wheat crossing programme to reaching the market place.

UK plant breeders agree that there may be some base level variation between wheat varieties and will examine whether these levels are purely genetic or are a result of certain varieties being more prone/less prone to stresses such as disease infections, climatic variations or adverse growing conditions.

The stimulus for breeders to act would require a strong steer from the processing sector and good evidence that a genetic solution can be achieved.

UK plant breeding companies are looking to further explore the possibilities of forming a consortium to collaborate on a phase 2 project with Rothamsted Research to investigate if there is any breeding target/work that can be done to improve the asparagine levels in wheat. One UK plant breeding company is screening pre-application plant material to identify low asparagine lines and re-introducing them into their crossing programme. However, large scale screening is not practical or economic at this time. If the studies at Rothamsted Research reveal that there is sufficient natural variation in wheat asparagine levels this may lead to work that will be used to identify genetic markers within breeding programmes. However, due to the large influence of, not only environment, but agronomy on the genetics, this project would have to be conducted over several growing seasons with different agronomic input conditions. Once these markers have been identified and validated, they would have to enter several years of back-crossing within a pre-breeding programme before breeding and selection could begin. It may be twenty years before any new wheat varieties are produced from this work.

Whatever new varieties are produced the importance of good agronomy cannot be overlooked if there is to be an overall reduction in acrylamide levels. Further research should also be conducted on optimising nitrogen and sulphur ratios and any other nutrients that may affect asparagine levels.

UK plant breeders remain concerned that if maximum levels for acrylamide are to be set in the finished product, then it will become a difficult hurdle for milling wheat farmers to achieve. The largest wheat market in the UK is for animal feed – perhaps due to farmers unable to achieve the necessary grain protein levels or unwilling to take the risk. The demand to deliver low asparagine levels as well as high protein levels may encourage more of them to grow feed varieties which would have serious impacts on the entire wheat sector of the food industry. If the milling market is reduced plant breeders may concentrate their efforts on developing feed varieties.

Farmers and Crop Agronomy

Currently, much of the initial research on acrylamide has been agronomy-based. Free asparagine levels have been shown to accumulate when wheat is grown in sulphur deficient environments. Evidence suggests that not all milling wheat crops are grown with sufficient sulphur applied to correct sulphur-deficient soils. The significance of sulphur applications needs to be appropriately reinforced by further work on the targeting of these applications. There may be scope to specify minimum sulphur applications when milling wheat contracts permit. Plant breeders accept that sulphur application in isolation is not adequate to guarantee sufficient reduction of asparagine and therefore acrylamide levels in the final product. However, in the short-term this appears to be the most effective control measure to reduce them.

Currently, farmers are the key to further reducing the levels of asparagine in the UK wheat crop. This will be achieved mainly through them being aware of the issue and with the development of better analytical and agronomic practices to aid decisions during the life of the wheat crop. Most growers of milling wheat fully appreciate the importance of sulphur to the nutrition of the crop and make combined applications of nitrogen and sulphur at the appropriate times. The issue is whether sampling and measurement of soil and leaf tissue to determine sulphur levels are sufficiently reliable to accurately adjust sulphur applications.

AHDB Cereals & Oilseeds provide farmers with information on a wide range of topics through its knowledge transfer activities. These include those relating to the agronomy of the wheat crop and most of the information is based on detailed research.

Information sheet 28 (published in 2014) 'Sulphur for Cereals and Oilseed Rape' provides farmers with guidance regarding the optimum application of sulphur. It emphasises that sulphur is an essential nutrient required to build yields and achieve grain and oilseed quality. Appropriate applications of sulphur are cost-effective and are not associated with any major environmental problems. Sulphur is important because yield can be reduced when sulphur is deficient and nitrogen fertiliser may not be fully utilised if sulphur is deficient. Appropriate levels of both nitrogen and sulphur are required to produce 'strong' protein in the wheat grains required to make bread with the required functionality. There is a need to develop rapid analytical techniques to identify stored grain that has good baking functionality, including a low propensity to produce acrylamide.

Soil types such as those of sand and silty origins especially in years of high winter rainfall can increase the risk of sulphur deficiency during the growing season. Research funded by the AHDB levy has shown that asparagine levels and hence acrylamide formation can increase if wheat is grown under conditions of sulphur deficiency. Farmers can minimise the formation of asparagine by applying up to 50kg SO3/ha in early March to early May. The Fertiliser Manual (formerly RB209) provides farmers with more information about nitrogen, sulphur and micro-nutrient applications. This will undergo revision in the coming years.

Flour Milling

UK flour millers are technically focussed on this issue and have been active participants in the FoodDrinkEurope Toolbox discussions and their implementation.

A research study was commissioned by **nabim** and the Federation of Bakers in 2007 at Campden BRI (then CCFRA). In this study nine wheat varieties were selected for investigation on the basis that they were used routinely by cereal processors. The report (published in 2008) revealed that the level of asparagines showed moderate variation within and between wheat varieties. There was some evidence of a link to variation in protein content between harvest years and between bread and biscuit-type wheats. The study also found that a commercially available asparaginase enzyme reduced asparagine in a range of products but its effects were time dependent so not applicable to all product types.

Flour millers continue to fully support measures to reduce acrylamide in baked goods and will support further research and agronomic initiatives to ensure progress is made on the issue. However, it appears that there is nothing that can be done within the milling process to alter either levels of asparagine or the potential for acrylamide formation during baking.

Both the **nabim** Technical Committee and the R & D Committee have considered how best to approach the issue and have contacted AHDB to press for research to be undertaken.

nabim has also worked with both AHDB and the Red Tractor Assurance scheme to promote farmers understanding of the importance of sulphur not only to limit the formation of acrylamide but also to achieve good baking quality. **nabim** will continue to assist with this knowledge transfer process.

Currently there are five Group 1 winter wheat varieties and six Group 2 winter wheat varieties on the AHDB C&O Recommended List. As far as is known, there is little difference in the ability of these varieties to produce asparagine where sulphur is not a limiting factor.

Baking Ingredients

The manufacturers of ingredients for the bakery sector have, where applicable, adopted methodologies from the FoodDrinkEurope Toolbox in order to mitigate the formation of acrylamide and the presence of free asparagine.

One of the main challenges and considerations for the ingredient manufacturer is that any measurements of acrylamide and/or precursors detected in raw materials do not provide an accurate prediction of acrylamide levels in the finished product. This can be further compounded and demonstrated by the fact that variations in acrylamide levels as a result of the baking process itself can far outweigh any contribution or mitigation from specific ingredients.

Nevertheless, the development and incorporation of certain ingredients have been shown to reduce the levels of free asparagine prior to baking. And this forms part of the FoodDrinkEurope acrylamide Toolbox. The enzyme asparaginase is effective in reducing the asparagine level in dough and thus the acrylamide levels in baked goods. This works by converting asparagine to aspartic acid which is then unable to form acrylamide.

Specialised yeasts have also been developed with enhanced asparagine degradation properties which have the potential to significantly reduce acrylamide formation.

Ultimately any changes in the selection and processing of ingredients could compromise product quality, organoleptic characteristics and consumer expectation. It could also significantly impact the nutritional quality of the product and therefore must be taken into consideration when implementing measures to reduce acrylamide.

Baking

Within the bakery environment the challenge is that some of the opportunities to reduce acrylamide are pre-determined before flour is received and baked into bread. Nevertheless, most bakeries have already ensured that measures to reduce this processing contaminant are included in HACCP plans, company procedures and/or in pre-requisites.

The FoodDrinkEurope Acrylamide Toolbox has been fully acknowledged, implemented where possible and communicated to bakeries of all sizes.

There is a continual monitoring on a range of products, including bread, where the actual levels of acrylamide in the Food Standards Authority (UK) monitoring of 2013 were much lower than any indicative levels, see results summary below.

Products	Number of Samples	Acrylamide (Range µg/kg)	EU Indicative Levels
White Bread	10	10 - 35	80
Wholemeal Bread	4	25 - 42	80
Rolls	3	9 - 32	80
Other Breads	3	16 - 24	80

One of the challenges is that, across Europe, bread is a very different product. It can be made in different ways and from a wide range of cereals other than wheat. There is a need to differentiate between wheat based soft bread and soft bread made from cereals other than wheat. This arises from the differing levels of asparagine in wheat compared with some other cereals. In the UK there is an awareness of the need to keep the typical lidded premium white loaf crust to a medium colour, being neither too dark nor too light to minimise acrylamide production. Most bakeries have reduced the severity of the final baking minutes so the crust does not brown too much.

Another important aspect is to consider how bakers communicate with consumers regarding how they should toast bread to minimise acrylamide production.

Current and Future Research

Significant levels of research have already been undertaken, mainly at Rothamsted Research by Professor Nigel Halford. This has focussed on the genetic improvement of wheat to reduce the potential for acrylamide formation during processing.

The key findings so far are:

- Free asparagine concentration has been identified as the major determinant of acrylamide forming potential in wheat and other cereals.
- Sulphur deprivation has been shown to cause the accumulation of free asparagine in wheat grain to extremely high concentrations, with a concomitant effect on acrylamide formation during processing. The advice on sulphur application to wheat has been revised as a result.
- In the longer term, classification of commercial wheat varieties with respect to free asparagine concentration with a view to enabling AHDB to include this information in its variety descriptions. This is ongoing and will only occur if consistent differences in free asparagine can be established.
- Assessment of variation in asparagine concentration in a wide range of non-commercial genotypes.
- Characterisation of the asparagine synthetase gene family in wheat and generation of valuable tools for the study of asparagine synthetase in wheat, including cloned genes and monoclonal antibodies.
- Fine imaging of the distribution of free asparagine in wheat grain and its implications for acrylamide risk in different milling fractions
- Development of a mathematical model of asparagine metabolism that is far more detailed than anything in the current scientific literature. This has been made possible by the production of huge datasets on gene activity and amino acid concentrations.
- Production of the first soft wheat mapping population.
- Identification of wheat plants carrying mutations in genes involved in asparagine metabolism.
- Indication that the control of fungal pathogens with fungicide may reduce free asparagine

accumulation in wheat.
- Generation of increased knowledge on the effect of reduced concentrations of free asparagine and other amino acids on food processing and product quality. This is ongoing.

Further basic research is still required although this will have a relatively long lead-in time until results can be translated into the production of new wheat varieties with the potential to produce less asparagine or reducing sugars. The Rothamsted group has identified targets for future work as:

- Development of high-throughput amino acid analyses for variety assessment and potentially quality control.
- Further screening of varieties and genotypes and classification of varieties according to free asparagine concentration in the grain.
- Development and refinement of our mathematical model of asparagine metabolism.
- Identification of QTL for low free asparagine concentration and crossing of quality trait loci (QTLs) into modern varieties using marker assisted selection to produce pre-breeding germplasm with reduced acrylamide-forming potential.
- Development of a standard methodology for assessing the effects of grain composition on the kinetics of acrylamide formation.
- Widening the scope of the research to give it a European dimension.

Meeting these objectives would provide plant breeders with the tools and resources to deliver low acrylamide-forming wheat varieties. This would enable processors to comply with any future indicative values and regulatory limits. Such action would limit changes to processes and loss of the flavour, colour and aroma characteristics that define products and brands and are valued by consumers.

Annex 1

Extract From AIBI/Original FoodDrinkEurope Paper

Code of Practice for Managing Acrylamide Formation in Foods

I. INTRODUCTION AND GENERAL REQUIREMENTS

1. Acrylamide is formed in cooked starchy foods mainly by the reaction of the amino acid asparagine with reducing sugars such as glucose and fructose as part of the Maillard reaction.

2. Acrylamide formation primarily takes place under conditions of high temperature (usually in excess of 120°C) and low moisture. It is the combination of temperature and heating time to which the product is subjected that is pivotal to acrylamide formation, not the specific temperature *per se* or the specific cooking process (e.g. roasting, frying, baking).

3. Asparagine and sugars are important and desirable nutrients necessary for plant growth and development and so cannot be considered in isolation. Furthermore, the Maillard reaction depends on these common food components to provide the characteristic flavour, colour and texture of a given product.

4. Following guidance from formal risk assessments, the food industry is requested to reduce acrylamide in food products. Whereas a complete elimination of acrylamide from foods is not possible the principle objective should be to reduce levels in foods to as low as is reasonably achievable (ALARA). [Shouldn't we add a definition?]

5. Food business operators should take every reasonable measure to reduce the presence of acrylamide in final foods to ALARA. It is therefore mandatory to assess those recommendations set out in Parts III-VI for potential application under the specific products and process facility conditions while taking into account legitimate considerations. Considerations may include:

   - potential impact on levels of acrylamide in the final product
   - potential impact on the formation of other process contaminants and/or reduction in control of other hazards e.g. microbiological
   - feasibility of implementing the identified controls, e.g. legal compliance, commercial availability, occupational health hazards, timescales and costs associated with upgrading or replacing plant equipment.
   - impact on organoleptic/product-identity properties and other quality-related aspects of the final product
   - potential impact on product safety
   - nutritional quality of using certain ingredients in preference to others, e.g. use of whole grain cereals instead of refined cereals.

6. Food Industry under FoodDrinkEurope has developed and is maintaining a document (FoodDrinkEurope 'Acrylamide Toolbox') which contains descriptions of potential intervention steps, which may prevent and reduce formation of acrylamide in specific manufacturing processes and products. As this Toolbox contains all potential mitigation options including those at Research or Development stage, sector specific extracts of this tools have been established to only include those 'Tools' which have been proven to be effective in commercial applications to provide a more clearly focused orientation. Parts III-V of this Code

of Practice contains these as recommendations for potato-based products, cereal-based products, coffee, roasted grains and substitutes, and baby foods.

7. Owing to the diversity of individual products and manufacturing processes, not all recommendations will be effective and reasonable in every situation. Part VI contains a pro-forma or similar that may be used by food business operators to assess recommendations, identify those that are applicable and establish which recommendations are ineffective or unreasonable for their particular product and process.

8. Food business operators should establish controls to minimise the potential for acrylamide formation within the context of existing food safety and quality management systems.

9. Food business operators should establish monitoring programmes to confirm mitigation steps are effective.

10. Sampling and methods.

11. Sectors are encouraged to develop additional detailed guidance on best practices for specific raw materials or final product categories where appropriate.

II. RECOMMENDED PRACTICES FOR CEREAL-BASED PRODUCTS

Raw materials

Asparagine is the key determinant of acrylamide formation in cereal products. Free asparagine can vary widely within and between individual varieties and is also dependent on specific growing conditions. At present it is not possible to source specific cereals or grains with controlled low levels of asparagine.

12. Avoid growing crops on sulphur deficient soil as low levels of sulphur result in higher levels of asparagine in the crop.

Product design, processing and heating

13. Consider using less wholemeal flour and/or bran in recipes as these typically contain higher concentrations of asparagine. Lowering the wholemeal and/or bran content will have a negative impact on the nutritional quality of products so should be considered carefully.

14. In biscuits, consider reducing or replacing ammonium bicarbonate with alternative raising agents.

15. In biscuits where the product design allows, replace fructose with glucose particularly in recipes containing ammonium bicarbonate.

16. Where a recipe allows, consider partial or full replacement of wheat flour with rice flour.

17. Limit the use of co-ingredients that have the potential to raise acrylamide levels in the final product (e.g. use almonds roasted at lower rather than higher temperatures)

18. In bread products extend yeast fermentation time where this is an option. This can contribute to acrylamide reduction as yeast metabolises asparagine.

19. In dough-based products such as biscuits, cereals and crisp breads, consider using asparaginase to reduce asparagine and mitigate the potential for acrylamide formation. The efficacy of asparaginase is dependent on recipe, ingredients, moisture content and process.

20. Control thermal input by optimising cooking temperature and time. Thermal input rather than temperature alone is critical to controlling product characteristics and acrylamide formation. Solutions may vary depending on the particular product and processing equipment.

21. Cook products to the maximum end moisture content that is feasible for the particular product and process in line with expected quality and food safety standards.

22. For hard sweet biscuits, crisp bread and bread, cook to a lighter colour endpoint.

23. For bread that is to be finished in the home or in catering establishments, include on-pack cooking instructions.

Annex A: ASSESSMENT FORM

Product Description and Relevant Recommendations

Product/ Product Group Description:	**Date:**

No.	**Relevant Measures**

Measures Selected to Reduce Acrylamide Formation

Details of application and reductions achieved

Measures that are not applicable in the context of the ALARA Concept

Recommendations that have been shown to be inefficient or ineffective in reducing acrylamide levels in this product

Evaluation and justification

Recommendations that change key product acceptance parameters to the extent that the product is not commercially viable (e.g. cost, quality)

Evaluation and justification

Recommendations that have a negative impact on other food safety aspects (e.g. increased formation of another process contaminant or reduction in control of a microbiological hazard)

Evaluation and justification

Recommendations that would have an undesirable impact on the nutritional attributes of the product

Evaluation/Justification

Recommendations for which implementation is not feasible for other legitimate reasons (e.g. in consideration of legal compliance, commercial availability, occupational health hazards, timescales (?) and costs)

Evaluation and justification