Acrylamide in the home:

Home-cooking practices and acrylamide formation

A report for the Food Standards Agency

BROOKLYNDHURST

Contents

Appendices (in separate document)

Project summary

Acrylamide is a chemical compound formed in certain types of food that is thought to be potentially harmful to human health. The precursors to acrylamide formation in foods are thought to be the free amino acid asparagine and reducing (or 'free') sugars, predominantly glucose and fructose. Acrylamide typically forms when foods containing these precursors are heated to temperatures above 120°C.

The UK Food Standards Agency (FSA) recommends that the level of acrylamide in the human diet should be "as low as reasonably practicable" (ALARP) as a precaution to reduce its potential to be harmful to human health. The types of foods consumers choose to purchase, and the methods they use to prepare and cook them, can influence acrylamide intake. Estimated levels of acrylamide intake from food often fail to fully take account of consumer behaviour, however; instead being derived from dietary survey data and laboratory-cooked samples.

This project, led by Brook Lyndhurst, aimed to provide information on actual domestic cooking and preparation practices in the UK to inform this issue, through: identifying the practices in which consumers are engaging that might influence acrylamide formation; and providing *an indication* as to how much acrylamide consumers are exposed to from food prepared at home.

The research was primarily based on in-home observational research with 50 households, so as to represent cooking situations that were as 'normal' as possible. Samples were collected from each participant for laboratory testing. A literature review was conducted at the start of the project, and follow-up telephone interviews with 15 of the participants were conducted after the in-home observation.

The project, which focused primarily on potatoes (though toast was also covered), provided rich evidence of the range of domestic practices that consumers adopt with respect to the preparation and cooking of these items. It was not able to usefully examine links between practices and acrylamide exposure in the home due to natural variability in the presence of acrylamide precursors. There appears to be a link between consumer preferences and acrylamide exposure, however, with notable correlation between desired food colour and acrylamide levels in samples.

Key findings related to domestic practices include:

- **Consumer awareness of acrylamide exposure appears to be low**. No-one in the study reported an aim to reduce acrylamide, but nor did anyone coincidentally follow best practice throughout the entire cooking process.
- **Use of manufacturers' instructions as a proxy will misrepresent the realities of domestic cooking practices**. Manufacturers' instructions were rarely read by participants, particularly if items are cooked regularly. Instead, people have their own systems to find the combination of temperature and time that will work for them.
- **Lack of attention to preheating may result in lower cooking temperatures**, as might regular checking of food (by opening the oven door).
- **Initial cooking times are primarily used as estimates or guidelines**. Visual assessment (i.e. of colour and texture) was usually more influential for participants than abiding strictly to intended (or expected) timings. Food was often cooked for longer than initially planned in order for it to reach the desired state.
- **Domestic storage practices do not appear to significantly increase risk of acrylamide exposure**.
- **Homemade potato items tend not to be finely chopped, avoiding the risk of additional acrylamide exposure through greater surface area to volume ratios.**

Executive summary

Background

Acrylamide is a chemical compound formed in certain types of food - such as potato products, coffee, and baked goods - that is thought to be potentially harmful to human health. The precursors to acrylamide formation in foods are thought to be the free amino acid asparagine and reducing (or 'free') sugars, predominantly glucose and fructose. Acrylamide typically forms when foods containing these precursors are heated to temperatures above 120°C.

Given concerns about its potential to be both carcinogenic and genotoxic, the UK Food Standards Agency (FSA) recommends that the level of acrylamide in the human diet should be "as low as reasonably practicable" (ALARP) as a precaution.

Consumers have the potential to significantly influence the levels of acrylamide to which they are exposed in their diet. The types of foods consumers choose to purchase, and the methods they use to prepare and cook them, can influence acrylamide levels. While significant efforts have been made, both in the UK and elsewhere, to estimate levels of acrylamide intake from food, these fail to fully take account of consumer behaviour. Instead, research has tended to use data from dietary surveys to model typical consumer diets, with manufacturer cooking instructions then used as a proxy for cooking practices on the foods sampled.

This research project

This project aimed to provide information on actual consumer cooking and preparation practices in the UK to inform this issue. The explicit aims of the project were as follows:

- to identify the domestic cooking and preparation practices in which consumers are engaging, which might influence acrylamide formation;
- to provide *an indication* as to how much acrylamide consumers are exposed to from food prepared at home, and to assess – as far as possible – the extent to which this differs from the levels expected in food prepared in accordance with manufacturer instructions.

Research was led by a team from Brook Lyndhurst and involved: a literature review; in-home observational research with 50 households; sampling and scientific testing of cooked food from each participant; and follow-up telephone interviews with 15 of the participants. The project focused primarily on potatoes, though toast was also included. These items were selected the extent of acrylamide formation in these foods is dependent on domestic practices, and they are also significant contributors to diets.

The use of in-home observational research was a relatively novel approach. It was felt that preparing unfamiliar meals, operating in unfamiliar settings, or preparing a meal purely for sampling purposes, would not provide an accurate picture of normal cooking practices. Participants were therefore observed cooking meals that they regularly consume, "as normal" in their own kitchens. Samples of potato products and toast were taken, but the rest of the meal was eaten by participants and others in their households.

The project provided rich evidence of the range of domestic practices that consumers adopt with respect to the preparation and cooking of potatoes and toast. It was not able to examine links between practices and acrylamide exposure in the home. It is well established that practices such as storage; soaking; cooking temperature; and cooking times can influence acrylamide formation. Investigations into existing acrylamide data found that natural variability in the presence of acrylamide precursors appears to be significant. As a result, it was not possible to determine whether the differences in acrylamide levels achieved by participants in this study reflected the impact of observed practices or the 'natural' levels of acrylamide precursors present in the items cooked. Comparisons between the results of this study (where food was prepared at home) and existing data (where food was prepared in a laboratory according to cooking instructions) were also inconclusive for this reason.

Despite this, **colouration appears to show correlation with acrylamide levels: more so than increased cooking time and temperature.** Most people stated a desire for 'crispy' and 'golden' potato products. Despite these same characteristics being almost universally desirable, these descriptors seem to cover a range of looks and textures based on personal preference. Any attempt to reduce acrylamide levels through provision of information would need to bear this in mind. Those who stated a preference for products towards the browner and/or crispier end of the spectrum do also – in general – appeared to generate more acrylamide when preparing these products. Similar findings applied to the cooking of toast.

Clearly, *appearing* more cooked is likely to be a product of being cooked for longer and/or at a higher temperature. Yet observations in this project did not reflect this in either *intended* cooking temperature or *observed* cooking temperature. Achieved oven temperature (and the stability of oven temperatures) during real-life cooking situations is therefore an area that requires further research.

Key findings: cooking potato products

Awareness of acrylamide exposure appears to be low

No one in the study reported an aim to reduce acrylamide, but nor did anyone coincidentally follow best practice throughout the entire process. All participants could therefore have reduced the amount of acrylamide they are exposed to in potato products by altering their practices. Nearly everyone in the study was happy with their end product, however, so their systems and processes produce a result that they enjoy eating. Few practices that would reduce acrylamide exposure are compatible[1] with maintaining the colour, texture, and taste of the final product.

Using manufacturers' instructions as a proxy will misrepresent the realities of domestic cooking practices

This study clearly indicates that domestic cooking of potatoes (and potato products) bears very little resemblance to preparing food in a laboratory in accordance with manufacturers' cooking instructions. Manufacturers' instructions were rarely read, particularly if items are cooked regularly. Instead, people have their own systems to find the combination of temperature and time that will work for them. Some of these systems seemed to be automatic and unexamined: the result of adaptation to kitchen equipment, and/or the influence of the cooking practices of family members. Other systems were built around the preparation of a meal. For example, times and temperatures may be based on the roasting of a chicken, as opposed to the cooking of the roast potatoes.

Lack of attention to preheating may mean lower cooking temperatures

With much pre-heating happening haphazardly, it appears likely that foods were often exposed to lower cooking temperatures than intended for a portion of the cooking process. Temperature drops were also noted on some occasions as a result of opening the oven to check the food. Lower temperatures may lessen the formation of acrylamide in potatoes, but this effect was often offset by the fact that items are cooked for longer than expected[2], with minutes added to the original estimated cooking time (possibly to compensate for these lower temperatures).

[1] Storage behaviours and washing might be exceptions.

[2] Or, potentially, that higher temperatures are used or that the oven over shoots when 'reheating' after opening event. Both of these are aspects that could be investigated further in future research (Section 6.2).

Times are used as guidelines
Few participants referred to cooking instructions or recipes, but all had a sense of how long items should be in the oven. These estimates tended not to be particularly accurate or important, however. Indeed, time – on its own – was not regarded as a suitable indicator that a product was ready to be consumed. Instead participants would use the time they had first intended as a guideline, and as the ‘final’ time approached this served as an indication that a more intense period of checking and assessment was required. Similarly, items were not necessarily turned halfway through the cooking process, but instead at a time when the cook deems it necessary.

Visual assessment is an important part of cooking
Even when timing devices were used, checking the oven was the primary means of judging how far through the cooking process the potatoes were. People appear to have a strong sense of what the end product should look like, in accordance with their tastes (and those of other diners). Towards the end of the ‘expected’ cooking time participants felt confident that they were able to judge how much more time was required, based on a (largely) visual assessment of the state of the food. The decision to end the cooking process was almost universally taken because the product had reached a desired level of colour and/or texture, as opposed to any other reason.

Key findings: storage and preparation of fresh potatoes

Domestic storage behaviours do not appear to significantly increase risk of acrylamide exposure
Few participants in this study kept potatoes in the fridge. Those who did store their potatoes in the fridge had not done so for any great length of time (one to three days). On this (albeit limited) evidence, it appears unlikely that domestic storage is a major factor in acrylamide exposure. Storing potatoes in the fridge was considered an acceptable solution by many, however, with limited fridge space and ‘habit’ the main reasons given as to why this did not happen. As refrigerated storage space increases (e.g. the trend for ‘American style’ fridge-freezers), the risk of acrylamide exposure may therefore increase.

Roast potatoes are parboiled, decreasing acrylamide exposure
Roast potatoes – made from fresh - were all parboiled by participants. This process removes free sugars from the potato and therefore reduces acrylamide generation when potatoes are cooked. The parboiling process was not usually formalised, however, with few people aiming for a particular time.

Homemade potato items tend not to be finely chopped, avoiding the risk of additional acrylamide exposure through greater surface area to volume ratios
Homemade roast potatoes and chips tend to be larger than their equivalent pre-prepared products, with few making extra effort for them to be thinly cut or small. This is particularly true of chips, which tended to be relatively ‘chunky’. Lower surface area to volume ratios decrease the likelihood of acrylamide formation (which primarily takes place at the surface).

Further work

This study recommends further research to improve the salience of acrylamide exposure in the public realm; and to research and test ‘behaviour change’ interventions regarding particular domestic cooking and preparation practices. It is also recommended that further exploratory work is done to investigate oven cooking temperatures, as this study appears to have found considerable inconsistencies in oven use and performance. The apparent paradox - that darker food colouration is not necessarily achieved as a result of longer cooking times and/or higher temperature cooking – also requires further interrogation.

1 Background and aims

1.1 Background

1.1.1. Policy context

Acrylamide is a chemical compound found in certain types of food that is thought to be potentially harmful to human health. It typically forms in starchy foods during high temperature cooking, and is known to be particularly prevalent in foods such as potato products, coffee, biscuits, crisps and baked goods. Current advice[3] is that, given concerns about its potential to be both carcinogenic and genotoxic, efforts should be made to minimise exposure. In light of the UK Food Standards Agency's (FSA) strategic objective to ensure that "food produced or sold in the UK is safe to eat", it currently recommends that the level of acrylamide in the human diet should be "as low as reasonably practicable" (ALARP).

Further to this, the European Food Safety Authority (EFSA) is expected to report on the risks for human health of acrylamide in food in 2015. The EFSA's draft scientific opinion on acrylamide in food, produced for public consultation[4], highlights in-home exposure as an evidence gap.

In order to support this aim of minimising exposure[5], and to contribute to the risk management discussion at an EU level, it is vital for the FSA to understand both:

- the extent to which consumers in the UK are exposed to acrylamide, and;
- the in-home behaviours which influence levels of exposure.

The FSA has therefore commissioned this research project to investigate acrylamide generation in the home. The FSA wished to better understand the cooking and preparation practices in which consumers engage that can impact on levels of exposure to acrylamide. As such, the project combined observational research of practices and laboratory testing of samples cooked by consumers.

1.1.2. Research context

The precursors to acrylamide formation in foods are thought to be the free amino acid asparagine and reducing (or 'free') sugars, predominantly glucose and fructose. Factors such as the amino acid profile of food (level of asparagine compared to other amino acids), and levels of free sugars have a substantial impact on potential acrylamide formation. These precursors are naturally occurring, or industrially determined.

Consumers, however, also have the potential to significantly influence the levels of acrylamide to which they are exposed in their diet. The type of foods consumers choose to purchase, and the methods they use to prepare and cook them, can influence acrylamide levels. Acrylamide formation is closely linked to the Maillard reaction[6] and only occurs when foods are subjected to cooking or other thermal processing at temperatures of above

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[3] From the Joint FAO/WHO Expert Committee on Food Additives, and endorsed by The European Food Safety Authority (EFSA). See: http://www.efsa.europa.eu/en/topics/topic/acrylamide.htm [Accessed 23 February 2015]

[4] http://www.efsa.europa.eu/en/consultationsclosed/call/140701.pdf [Accessed 23 February 2015]

[5] The FSA is also working with the food industry to increase knowledge and understanding of how to reduce acrylamide in food.

[6] The Maillard reaction is a non-enzymatic reaction between certain sugars and amino acids that typically requires temperatures above 120°C. It is this reaction that produces the familiar browning of some foods. This reaction and the implications for acrylamide formation are discussed in Appendix B.

~120°C. Longer cooking times and/or higher temperatures have both been shown to correlate to higher levels of acrylamide[7].

Significant efforts have been made, both in the UK and elsewhere, to estimate levels of acrylamide intake from food[8]. These estimates have, however, yet to fully take account of consumer behaviour. Instead, research has tended to use data from dietary surveys to model typical consumer diets, with manufacturer cooking instructions then used as a proxy for cooking practices on the foods sampled. It is though, widely acknowledged that consumers do not always follow manufacturer cooking instructions. A review by Greenstreet Berman of existing evidence on food safety practices[9], for example, found that use of food labels, including cooking instructions, was limited. Brook Lyndhurst's work with WRAP on the use of date labels and storage guidance[10] supports this, finding that on-pack guidelines are often ignored. Instructions are ignored or overridden for a variety of reasons – from personal, social or cultural motivations, to specific barriers such as knowledge, skills and equipment.

Consumer-facing research to date on acrylamide has focused largely on scientific experiments to assess the effects of different types of cooking methods on acrylamide levels (e.g. Romani et al, 2009[11]; Palazoğlu et al, 2010[12]). There appears to be little or no research published[13] that assesses the actual processes and methods that people use, and how these impact on acrylamide formation.

1.2 This research project

1.2.1. Aims

This research project bridges some of this identified knowledge gap and provides information on actual consumer cooking and preparation practices in the UK. The explicit aims of the project were as follows:

- to identify the domestic cooking and preparation practices in which consumers are engaging, which might influence acrylamide formation ;

- to provide *an indication* as to how much acrylamide consumers are exposed to from food prepared at home, and to assess – as far as possible – the extent to which this differs from the levels expected in food prepared in accordance with manufacturer instructions.

This project was also used as an opportunity to explore - in greater detail - the drivers of consumer cooking practices that lead to higher levels of acrylamide formation. While, for example, there might be anecdotal recognition that consumers often prefer potato products to be 'crispy', little previous research had been undertaken to investigate the underlying drivers of this (e.g. a lack of awareness of the potential for harm, cultural and social norms etc.[14]). A better understanding of these kinds of drivers is clearly very important when considering the development of any future strategies to try and influence consumer behaviour in this area.

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[7] In addition to the review in Appendix C, see, for example: Jackson, S. and Al-Taher, F. (2005). Effects of Consumer Food Preparation on Acrylamide Formation. Advances in Experimental Medicine and Biology. Volume 561, pp 447-465.

[8] See, for example: http://www.ifst.org/knowledge-centre/information-statements/acrylamide-foods [Accessed 23 February 2015]

[9] Greenstreet Berman (2011). Food safety behaviours in the home. A report for the Food Standards Agency. http://www.food.gov.uk/science/research/ssres/foodsafetyss/x04009/ [Accessed 23 February 2015]

[10] Brook Lyndhurst (2011). Consumer insight: date labels and storage guidance. For WRAP: http://www.brooklyndhurst.co.uk/- 155 [Accessed 23 February 2015]

[11] Romani, S., Bacchiocca, M., Rocculi, P. (2009). Influence of frying conditions on acrylamide content and other quality characteristics of French fries. Journal of Food Composition and Analysis. Volume 22, Issue 6. 582-588

[12] Palazoğlu, T., Savran, D., Gökmen V (2010). Effect of cooking method (baking compared with frying) on acrylamide level of potato chips Journal of Food Science. 75(1):E25-9

[13] This assumption was tested in the literature review phase – see Section 2.1

[14] This particular question is addressed in Section 4.4.

1.2.2. Team

The project was delivered by a team from behavioural research consultancy Brook Lyndhurst[15]. The team were supported by academic advisors Professor Monique Raats and Dr Bernadette Egan from the University of Surrey[16], as well as the project team at the FSA. The analysis of collected samples was carried out at the Premier Analytical Services laboratory (PAS lab) in High Wycombe, and was led by Dr Colin G. Hamlet and Dr Lisa Asuncion.

1.3 Report structure

The remainder of the report is structured as follows:

- Chapter 2 gives an overview of the approaches used to gather data, and the limitations of these methods;
- Chapter 3 demonstrates the kinds of data that were generated in this research project through case studies and contextual information;
- Chapter 4 presents patterns and trends from observational and qualitative data;
- Chapter 5 presents an analysis of the results from the acrylamide testing; and
- Chapter 6 provides a summary, conclusions and recommendations for future work

As above, the project is primarily focused on cooking potatoes and potato products, and the conclusions in Chapter 6 are exclusively about these foods. Specific findings related to toast can found in Sections 4.5 and 5.5.

In addition, there are a number of appendices to the report contained in a separate document.

[15] See: http://brooklyndhurst.co.uk/ [Accessed 23 February 2015]
[16] Profiles available at: http://www.surrey.ac.uk/psychology/people/dr_monique_raats/ and http://www.surrey.ac.uk/psychology/people/dr_bernadette_egan/ [both accessed 23 February 2015]

2 Research approach

In order to meet the aims set out in Section 1.2, the project team sought to collect data using a number of different methods. Each of these different methods is set out in the sections below, as follows:

- Literature review (Section 2.1)
- In-home observational research with 50 households (Section 2.2)
- Sampling and scientific testing of cooked food from each participant (Section 2.3)
- Follow-up telephone interviews (Section 2.4)

Section 2.5 details the analytical process that was gone through in order to bring these data together and provide the insights set out in Chapters 3 to 6.

Within these subsections there is information on the research design (determining a suitable approach) as well as the research approach (the specifics of how the data was collected). Given the relative novelty of the approaches selected, Sections 2.2 and 2.3 also include details of the potential limitations of these approaches.

2.1 Literature review

2.1.1. Aims

The research began with a desk-based literature review to identify and review relevant existing research. There were three areas that this review aimed to cover:

1. Existing evidence on acrylamide formation, and whether any similar consumer-focused studies exist;
2. Research that would inform the design of the fieldwork in terms of which foods, cooking and preparation methods should be the focus of the observational research;
3. Previous studies of in-home behaviours that could influence the methods selected to conduct this observational in-home research.

With regards to informing the fieldwork design (the second of these areas), the review sought to:

- Uncover literature which provided evidence on which cooking practices and preparation methods potentially influence consumer acrylamide exposure.
- Inform the selection of food products for the observation phase of the fieldwork. Of particular consideration was the frequency at which these foods are consumed, the acrylamide content of the food, and the influence of cooking on acrylamide levels.
- Note whether any particular groups or demographics were more likely to engage in particular cooking practices (related to potential acrylamide exposure), in order to inform the selection of fieldwork participants.
- Expose any other factors that influence acrylamide levels produced in home cooking that may impact on the subsequent design of the fieldwork.

2.1.2. Literature review approach

A shortlist of 99 documents was created using selected documents from online searches using relevant key words; documents provided by expert academic advisors from the University of Surrey; documents identified during the bidding process for the project; and those signposted by the FSA. Information about these documents was recorded, and a score (using weighted criteria e.g. methodological robustness, relevance to specific research questions) assigned to each one. These scores were used as a basis for selection for a full review. Over 30 documents selected through this process were fully reviewed and relevant information was recorded systematically in a database.

A more detailed description of the literature review approach can be found in Appendix A.

2.1.3. Evidence and gaps

The review generated considerable insight regarding many of the aims and objectives, but only provided limited insight towards achieving others.

Crucially, no evidence was encountered – from the UK or elsewhere - regarding the cooking (or other domestic) practices in which consumers are actually engaging that might have an effect on the concentrations of acrylamide in food. This finding suggests that the observational field research was both necessary and potentially ground-breaking as a means of meeting the aims of the project.

Evidence was, however, successfully drawn out of the literature in relation to:

- Which foods contain acrylamide, and in what concentrations[17];
- Which foods are most purchased, cooked and eaten by consumers, and therefore, which foods are the leading contributors to dietary acrylamide exposure;
- The effect of cooking and other preparation on acrylamide concentrations in foods;
- Which foods have acrylamide concentrations most affected by cooking/other preparation

The summarised findings of the review can be found in Appendices B and C. Key implications for the fieldwork that emerged from the review are set out in Section 2.2 below.

2.2 Observational research

2.2.1. Implications from the review

As set out in Section 2.1, the literature review was designed to inform the selection of:

- Foods
- Cooking practices and preparation methods
- Socio-demographic sample
- Methods of data collection

A topline summary of findings from the review, and how these influenced decisions around the observational fieldwork, is set out in Table 1 and the sections on socio-demographics and methods of gathering information below.

[17] See Appendix B for a more comprehensive review of this information

Table 1 – Fieldwork decisions and supporting evidence

Topic	Decision	Evidence
Foods	Potatoes (and potato products) and breads (and bread products) are the foods to be observed in the fieldwork phase.	Acrylamide has been found in a large range of products. Many of these items are consumed without acrylamide levels being influenced by domestic cooking or preparation and therefore fall outside of the scope of the study. Of items that are affected by domestic practices, the levels found in cooked meats and non-root vegetables appear to be considerably lower than those found in potatoes (and potato products). Soft breads also contain low levels, but it is known that acrylamide levels are higher in toasted bread. Breads and potatoes (and related products) are also widely consumed and make up a considerable portion of UK diets and therefore[18] acrylamide exposure.
	Potatoes (and potato products) to be the primary focus of the observation. Toast to be a secondary focus.	There are large potential variations in the way that potato products are prepared and cooked. Toast has a simpler, consistent, preparation and cooking process.
	Quotas set for minimum numbers of chips and roast potatoes to be observed. Minimum quotas also set for 'fresh' products.	Roast potatoes and chips are commonly eaten variants of potato, and have potential variety in preparation and cooking processes when prepared fresh.
Cooking and preparation methods	Fieldwork will gather data on length and method of home storage, and on potato variety.	Longer storage times and low storage temperatures tend to increase reducing sugar levels (a precursor to acrylamide in uncooked foods) in potatoes, though these fluctuations are quite heavily variety dependent[19].
	Data to be collected in the observation phase on which pre-treatments are undertaken, and for how long these are carried out.	Pre-treatments such as washing, soaking in water or parboiling tend to reduce acrylamide concentrations in final, cooked potatoes. This occurs because acrylamide precursors are removed from the surface, where the Maillard reaction and acrylamide formation primarily take place.
	Researchers to estimate surface:volume ratio of foods during observation, and photographs to be taken.	A high surface:volume ratio increases acrylamide concentrations in cooked products.
	Households boiling or steaming potatoes were not to be included in the observation fieldwork[20]	Roasting, baking, deep-frying, frying and grilling all lead to acrylamide formation. Boiling and steaming do not (due to lower temperatures and higher moisture levels
	Fieldwork to gather data on the temperature (intended and actual) and time (intended and actual) of cooking. Researchers to explore how consumers decide when a food is ready to be eaten - according to their preference ('doneness').	Acrylamide concentrations increase exponentially with higher cooking temperatures and also increase with a longer cooking time. As might be expected, therefore, a darker cooked colour tends to indicate higher acrylamide content.

Socio-demographic sample

The review did not explicitly attempt to cover differences between socio-demographic groups in terms of cooking practices. The review did, however, include UK consumption data in order to assess whether consumption patterns may affect the optimal socio-demographic profile of research participants in the study.

[18] Though, of course, this is based on calculations which use proxies for consumer cooking practices, as outlined in Section 1.1.

[19] No evidence was encountered regarding the effects of storage on acrylamide levels in bread, though given that bread is already (partially) cooked, it is unlikely that storage will have as significant an impact.

[20] Evidence around microwaving was less clear, so this was not actively excluded from the study.

While the data showed some variability in the quantity of fresh potatoes purchased[21] (and therefore expected levels of acrylamide exposure) according to age, ethnicity, and household composition, it was concluded that – for the purposes of this study - more insight would be gained by researching a representative spread of the population than prioritising some sections of the population and neglecting others.

Methods of gathering information

From the literature identified, it was clear that direct observation has considerable advantages over self-reporting (e.g. kitchen diaries or questionnaires[22]) and anecdotal methods, in that it captures actual behaviour (subject to the possible observer effects discussed in section 2.2.4), and behaviour is recorded in a suitable context[23].

Many of the studies reviewed used video recording or webcams in order to provide this observation, either in student settings or with volunteers[24]. It was felt, however, that a researcher would be better placed to conduct the observation in this case, given the range of data the research wished to collect (as detailed in the text above). It was also considered that a video camera may not be any less intrusive than a visit from a researcher.

It was not considered appropriate to use a prescribed recipe[25], or to conduct the observation in a controlled kitchen environment[26], given the emphasis on establishing the behaviours that people actually undertake when preparing and cooking particular foods. Furthermore, since the study was about witnessing and understanding behaviours as opposed to observing any deviation from a 'correct' method, observing participants in as natural a situation as possible, was preferred.

As a result, it was determined that in-home observation, in tandem with measuring specific data and conducting follow up interviews, was a suitable approach. This is very much in line with the mixed methods approach detailed by Steenbekkers[27]:

[21] Defra Family Food Datasets (age of household reference person). Available from: https://www.gov.uk/government/statistical-data-sets/family-food-datasets [Accessed 23 February 2015]

[22] See, for example: Short, F. (2003) Domestic cooking skills - what are they? Journal of the HEIA Vol. 10, No. 3.

[23] See, for example: Gittelsohn, J., Shankar, A., West, K., Ram, R. and Gnywali, T. (1997) Estimating reactivity in direct observation studies of health behaviors. Human Organization 56. pp. 182-189.

[24] These studies include:

- Oliveira, L., Mitchell, V. and Badnia, K. (2012) Cooking behaviours: a user observation study to understand energy use and motivate savings. Work 41. pp. 2122-2128
- Clear, A., Hazas, M., Morley, J., Friday, A. and Bates, O. Domestic Food and Sustainable Design: A Study of University Student Cooking and its Impacts. Available from: http://www.comp.lancs.ac.uk/~hazas/Clear13_DomesticFoodandSustainableDesign.pdf
- Kennedy, J., Gibney, S., Nolan, A., O'Brien, S., McMahon, A., McDowell, D., Fanning, S. and Wall, P. (2011) Identification of critical points during domestic food preparation: an observational study. British Food Journal Vol. 113 No. 6, pp. 766-783
- Phang, H., and Bruhn, C. (2011) Observations of Consumer Salad Preparation. Food Protection Trends, Vol. 31, No. 5. pp. 274–279.
- van Asselt, E., Fischer, A., de Jong, A., Nauta, M. and de Jonge, R. (2009) Cooking Practices in the Kitchen—Observed Versus Predicted Behavior. *Risk Analysis, Vol. 29, No. 4.*

[25] See, for example: Anderson, J. Shuster, T., Hansen, K., Levy, A. and Volk, A. (2004) A Camera's View of Consumer Food-Handling Behaviors. J Am Diet Assoc 104. pp. 186-191.

[26] See, for example: DeDonder, S. (2012) Assessment and validation of on-package handling and cooking instructions for raw, breaded poultry products to promote consumer practices that reduce the risk of foodborne illness. Available from: https://krex.k-state.edu/dspace/handle/2097/13630 [Accessed 23 February 2015]

[27] Steenbekkers, L. (2001) Methods to Study Everyday Use of Products in Households: The Wageningen Mouthing Study as an Example. *Ann. occup. Hyg.*, Vol. 45, No. 1001, pp. S125–S129, 2001.

> *Generally speaking observation is the best way to gain insight into behaviour when using products. Variables like the amount used and frequency of use can best be assessed by means of physical measurements. Demographic (background) information can be gained by a written questionnaire and the reasons for behaving in the way one does can most accurately be discovered by observation and an interview afterwards, in which the subject is also confronted with the shown behaviour.*
>
> Steenbekkers, 2001

2.2.2. In-home observation approach

The intention, from the start of the project, was that the precise approach for the observational research phase of the work would be determined by the outcomes of the literature review phase. Nevertheless, it was provisionally agreed between the research team and the FSA that the work would involve observing the full preparation and cooking of a meal in 50 UK households. While this approach was under consideration, pending findings from the review, it was felt that 50 households was a generous sample size for qualitative/observational research, in that it would likely be a sufficient number for key trends and patterns within the wider population to be identified, and it would allow coverage of key demographic groups.

Using the conclusions drawn from the literature review, professional fieldwork recruiters Criteria Fieldwork[28] were instructed to recruit 50 people who regularly ate chips, roast potatoes or other (relevant) potato products to participate in household visits. Quotas were set for particular products and for socio-demographic groups. Further information regarding recruitment can be found in Appendix G. Visits to households occurred in May and June, 2014.

At the beginning of each visit, researchers presented an information sheet and consent form to participants[29], which did (as above) did not directly mention acrylamide. The information provided to participants is documented in Appendix G.3, and further detail on ethical considerations can be found in Appendix I.

Participants then prepared meals "as normal" while the researcher observed and recorded any and all elements of interest on an iPad (using a pro forma designed in FileMaker Go[30]).

Where appropriate during the observation, the researchers talked to the participant to clarify what they were doing (e.g. to establish intended temperature, cooking time etc.), and to begin exploring the rationale for certain practices observed. This was not done systematically or in depth at this stage, so as not to distract the participants or cause them to question their behaviours.

In addition to the observations and informal conversations, photographs were taken at the various stages of the preparation and cooking process. For participants using the oven, a temperature monitor[31] was also used. This was placed as close to the centre of the oven as possible, without disrupting the cooking process[32]. The intention

[28] Website: http://www.criteria.co.uk/ [Accessed 23 February 2015]

[29] The information sheet detailed the purpose of the research, the methods that would be used, and how the information gathered would be used. Participants were then invited to ask any questions, and signed the consent form to confirm that they have understood the process, and to give the research team and the FSA permission to use all of the information gathered.

[30] The pro forma had seven screens (e.g. storage, pre-treatment, preparation) and included places to record both 'measured' and observed data (see Appendix E). The design was based around the findings from the literature review, though some additional prompts were included.

[31] Details of the temperature monitor used can be found at: http://thermometer.co.uk/catering-thermometers/427-oven-thermometer-and-timer.html [Accessed 23 February 2015] The thermometer has a certified accuracy of ±1°C (0 to 200°C).

[32] The wire linking the probe to the monitor is designed so as not to disrupt the seal around the oven. The monitor screens displaying the temperature of the probe were not made visible to participants.

was not to use this as a scientific measure of oven or food temperature, but as an indication of the temperature fluctuations to which the surface of the food might be exposed[33].

Following the observation visit, all notes were written up by researchers into a pre-designed recording database, containing headings for each of the elements of interest, as well as descriptive and demographic details.

2.2.3. Limitations

Observational research

One of the crucial challenges of observational research of this kind is the "Hawthorne effect" whereby participants modify their behaviour in response to the fact that they are being observed. Designing a "blind" study – i.e. where research participants are unaware of the purpose of the research – is one way of overcoming this challenge. It is for this reason the study's focus on acrylamide was obscured.

Considerable effort was also made to make the process as normal as possible. For example:

- People were recruited on the basis that they cooked these types of foods regularly
- Research was conducted in evenings and at weekends to reflect normal practice
- While one additional portion of potatoes was required for laboratory testing, the rest of the meal was consumed as per normal

Indeed, participants almost unanimously reported that the process was 'as normal' when asked. It is important to acknowledge, however, that the presence of the researcher will still have impacted on behaviours. For example, participant behaviour may be affected by "demand characteristics" (whereby participants form an interpretation of the purpose of the research and unconsciously change their behaviour to fit that interpretation[34]), or simply by the presence of a non-family member in their household (e.g. taking greater care than normal over the preparation of their meal). To help overcome this, research team aimed to establish a good rapport with research participants (making them comfortable with the researcher's presence), took great care to ensure that the observation is as unobtrusive as possible, and fully explained the need to observe "normal" behaviours.

These measures, however, cannot fully overcome the effects of observation of behaviour. Indeed, a few participants commented during the observation that they would 'usually' be doing other things whilst cooking. While researchers encouraged them to do these things as usual, the hospitality of participants was such that some were instead inclined to spend more time in the kitchen (where the researcher was based), giving rise to the possibility that they were more attentive to cooking than normal. Follow up interviews were used as a further opportunity to probe any anomalies (see Section 2.4 and the topic guide in Appendix E). One interviewee said that they forgot to preheat the oven for as long due to the distraction of being observed, while another admitted checking the oven more often than usual. No other interviewees were conscious of anything that they did being different from their usual practices.

Meal planning

Not all meals are planned in advance. A 2012 survey on behalf of the FSA, for example, showed that 20% of people plan very few or none of their meals in advance[35]. Asking participants to decide upon a meal to cook in advance could therefore alter the context of their cooking, and therefore could have an effect on their behaviour. It was determined that this risk was preferable to the alternative, however, which would be to not

[33] See Sections 3.2 and 3.3 for a demonstration of how this data was used

[34] Nichols, A. and Maner, J. (2008). The Good-Subject Effect: Investigating Participant Demand Characteristics. The Journal of General Psychology 135 (2). pp. 151–165.

[35] Harris Interactive (2012). FSA Food Safety Week research. Available from: http://multimedia.food.gov.uk/multimedia/pdfs/fsw-research-2012.pdf [Accessed 23 February 2015]

pre-determine meals, and therefore run the risk of observing the preparation of food types or the use of cooking methods that are of little relevance to this study.

It was noted that almost half of the sample had purchased potato items on the day of the observation, or the day before. It is not clear however, how this may differ from regular purchasing and consumption behaviours.

Sample size and structure
A sample size of 50 households was sufficient to enable all demographic characteristics of interest to be covered in the research. A qualitative sample of this size and spread is likely to pick up trends in the wider population and enables the generation of rich and insightful data. It does not, however, allow conclusions to be drawn regarding characteristics of different groups – e.g. the study is not able to say, definitively that older people cook potatoes differently from younger people.

There are also many characteristics that were not accounted for in the sampling. For example, while households were located in urban, suburban and village locations, the geographic spread of participants was very limited. There may, therefore, be regional variations in cooking methods that are not accounted for in this work.

2.3 Laboratory testing of samples

2.3.1. Sample collection, storage and delivery

Participants were asked to prepare and cook a 'generous' extra portion of the potato element of the meal, and two slices of toast, to be taken away as samples.

When the cooking of the meal was complete, a random[36] portion of the potato element was put to one side to cool, while the rest of the meal was consumed. Once the potato (or potato product) had cooled (to avoid spoiling the sample with unnecessary moisture), it was put in an airtight freezer bag. That bag was placed inside another freezer bag and labelled with: time and date; location; researcher initial; food type; and participant ID. The samples were then transported in a cool bag, surrounded by ice packs, and refrigerated overnight. Where possible, these samples were couriered the following morning (again surrounded by ice packs), though for visits conducted between Thursday to Saturday, the samples were frozen over the weekend (at temperatures at, or below, -18°C) and delivered to the PAS lab on the following Monday.

Toast was cooked at a convenient point during the visit, and samples were collected, stored and transported in exactly the same manner. Six participants did not provide samples of toast (e.g. due to not having any bread), while a further four only cooked one slice as opposed to two.

2.3.2. Analytical techniques

On arrival at the PAS lab, the samples were documented and stored in freezers. For analysis, the samples were then homogenised, and part of the sample was taken for testing. Acrylamide was then extracted from the sample into water, converted to 2-bromopropenamide by selective bromination, using gas chromatography and tandem mass spectrometry. Quantification was done by a stable isotope internal standard method using carbon-13 labelled acrylamide.

[36] N.B. chips or roast potatoes were not all taken from the same side of the baking tray and nor were only small items selected. Instead the potatoes were mixed up and/or randomly selected.

Articles providing further detail of these methods, authored by the team at the PAS lab, can be found in the footnotes[37][38][39].

2.3.3. Limitations

Sample selection

As explained above, an 'extra' portion of potatoes was taken from each participant to be tested. This sampling method does not necessarily produce an acrylamide result in line with the entirety of the potatoes cooked, however. The levels of acrylamide vary between each chip and each potato considerably, and only by taking the entire tray of chips or potatoes would a reliable result be attainable. This risk was known from the start, and was considered preferable to asking participants to prepare meals that they were not going to eat, which could have potential impacts on behaviours and timings. The research team attempted to mitigate this by selecting the samples from the tray at random (or by mixing the contents up before taking the sample), and by encouraging a 'generous' extra portion to be cooked in addition to the meal. Despite this, a few of the samples collected were quite small – e.g. three or four pieces of roast potato – which increased the chance of the acrylamide content differing from that of the entire batch of cooked potatoes or chips.

There was also a danger of spoiled samples: if one 'rogue' burnt chip (with very high acrylamide content) was in the initial sample and homogenised then the 'overall' acrylamide level may be significantly higher than without that chip. While this result would remain reflective of consumer exposure to acrylamide, it does pose the possibility of misleading results being produced. Photos were taken of all samples (pre-homogenisation) at the PAS lab, in light neutral conditions, and a survey of these photos suggests that this is unlikely to be a major concern for this project. Chips were present in some samples with evidence of burning[40], though this colouration was not out of keeping with the other colours visible in the rest of the sample.

Historic data

A major limitation with the acrylamide results produced is that it is often near impossible to attribute the acrylamide levels to actions the consumer has taken in the home. An analysis of the acrylamide levels in chips and other potato products, as collected by the FSA between 2007 and 2013[41], shows that there are huge variations between different brands and cuts of chips[42]. Importantly though, even a sample of the same product taken in March, for example, can contain five or ten times more acrylamide than the same sample taken the following November, despite being prepared and cooked in an identical fashion. There is natural variability in the amount of free sugars present in different potato varieties, and also within the same varieties by virtue of the different growing conditions. Potatoes may also be stored for different lengths of time even before being processed into chips or reaching the supermarket shelves. As such, attempting to attribute the acrylamide levels found in the samples collected in this research entirely to the practices that were observed would be misleading. Nevertheless, these results are discussed in the context of the historic data in Section 5.

Analytical techniques

The analytical techniques can reliably detect acrylamide at 0.5µg/kg or above, and reliably quantify acrylamide levels at 3µg/kg or above. Very small quantities of acrylamide may not therefore be accurately reported.

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[37] Hamlet, C., Sadd, P., and Liang, L. (2008) Correlations between the amounts of free asparagine and saccharides present in commercial cereal flours in the UK and the generation of acrylamide during cooking. Journal of Agricultural and Food Chemistry, 56, 6145-6153.

[38] Hamlet, C., and Sadd, P. (2004) Rapid, sensitive and selective analysis of acrylamide in cereal products using bromination and GC/MS/MS. Czech Journal of Food Sciences 22. pp. 290-293.

[39] Sadd, P. and Hamlet. C. (2008) Effectiveness of methods for reducing acrylamide in bakery products. Journal of Agricultural and Food Chemistry, 56, 6154-6161.

[40] See, for example the discussion and images in Section 5.2.

[41] For these results, see: http://www.food.gov.uk/science/research/chemical-safety-research/pc-research/ [Accessed 23 February 2015]

[42] These records also exist for (uncooked) soft breads, but not for toast. A discussion of how the toast results from this study can be interpreted can be found in Section 4.5.

There are also some potential margins of error in the analytical techniques used[43]. These margins are small and unavoidable - the methods used by the PAS lab to quantify the acrylamide levels are recognised as being industry-leading. The methods used are also applicable to a wide range of beverages, foods and ingredients, and have been used for mitigation research[44] and to monitor acrylamide in UK retail foods since 2007[45].

All analyses are performed by trained staff in a United Kingdom Accreditation Service (UKAS) accredited laboratory operating an internal audit and review process. The method has been validated in-house and accredited by UKAS (ISO 17025). Method performance is monitored by analysing certified and in-house reference materials with each batch of samples in accordance with the rules governing Shewhart control charts[46]. The laboratory also participates in the FAPAS® performance testing scheme[47] for acrylamide limitations.

2.4 Follow-up interviews

Fifteen follow up interviews were undertaken with a subset of those who participated in the observational research. The primary aim was to probe further into the reasons why the behaviours and practices observed were carried out. The intention was to enable the FSA and others to gain a better understanding of the causes of behaviours that lead to higher levels of acrylamide exposure, and therefore the types of intervention that may influence those behaviours.

Interviews took place over the phone and lasted approximately 30 minutes. Participants were sent an additional cheque for £10 for participating. The topic guide that was used for the interviews can be found in Appendix E. Notes were taken during the interviews, with the conversations also recorded as a backup.

The 15 interviewees were selected because they exhibited behaviours during the observation phase that were of particular interest (e.g. long cooking times, high temperature cooking). A full explanation of this rationale can be found in Appendix F.

2.5 Data analysis

Practices and behaviours

Data from the observational database was cleaned and then interrogated by each member of the research team, before being brought together in an initial brainstorm to establish high level findings. Following on from this was a further wave of individual analysis (e.g. to investigate the strength of patterns across the sample; to build case studies), and a review of the interview transcripts (including examining the recordings for relevant quotes that typified emerging findings and narratives). An analytical workshop was then held involving academic advisors and the project manager from the FSA. This workshop was designed to pull together findings from the

[43] Details:
- Precision (relative standard deviation (RSD)): ≤ 6.3 % (spiked samples; certified reference material (CRM); in-house reference material (IHRM))
- Accuracy / bias: 106±4% at 25 µg/kg and 104±1% at 1000 µg/kg (spiked samples; 95% confidence level)
- Uncertainty: ± 11% at 18 µg kg-1 and ± 2% at 716 µg kg-1 (single analysis; expanded uncertainty with a coverage factor of 2)

[44] Sadd, P. and Hamlet. C. (2008) Effectiveness of methods for reducing acrylamide in bakery products. Journal of Agricultural and Food Chemistry 56. pp. 6154–6161.

[45] Food survey information sheet number 01/13 April 2013. A rolling programme of surveys on process contaminants in UK retail foods. Interim report covering sampling during 2011-2012, Acrylamide and Furan: Survey 5. Available at: http://www.food.gov.uk/multimedia/pdfs/publication/acryfuran1112.pdf [Accessed 23 February 2015]

[46] See: http://en.wikipedia.org/wiki/Control_chart [Accessed 23 February 2015] for more information about control charts

[47] More information on the Food Analysis Performance Assessment Scheme (FAPAS): http://fapas.com/proficiency-testing-schemes/fapas/ [Accessed 23 February 2015]

observation and interview phases and receive guidance as to which the most salient findings were. Initial findings were then presented to the FSA for feedback, before final reporting started.

Acrylamide results

Firstly, the acrylamide results were analysed through comparisons to the 'historic' data. This aimed to assess the extent to which they differed from 'expected' results.

Secondly, research team looked at the practices undertaken by participants whose potato products or toast had produced particularly high or low results. Whilst aware that it is not possible to say definitively that the practices were the reason behind high recorded acrylamide levels (see discussion in Section 2.3.3), it was nonetheless an interesting analytical exercise.

3 Findings: Context and case studies

Chapter 3 provides a brief overview of the findings from the observational research and follow-up interviews. While Chapter 4 presents trends and patterns in the data by disaggregating the behaviours, it is important to recognise that these behaviours and practices do not happen in isolation.

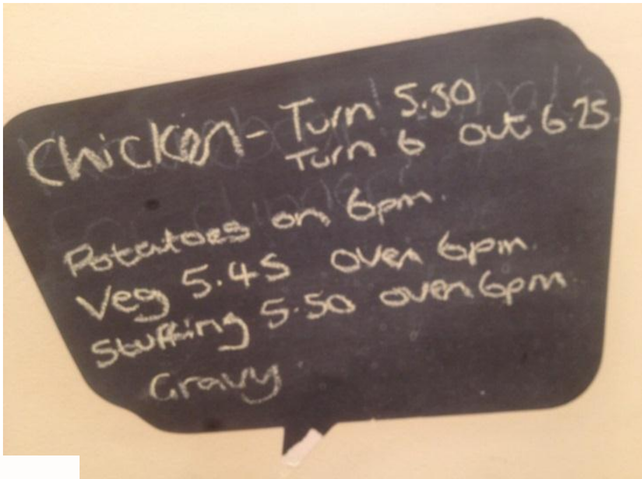
This chapter, therefore, aims to demonstrate the overall picture with regards to the variability in cooking practices and the multitude of influences on observed behaviours. It first sets out some key observations from the fieldwork on potatoes as a whole (Section 3.1); before presenting three case studies that demonstrate the kinds of complexities and interdependencies that were observed (Section 3.2 to 3.4).

3.1 Key observations

Acrylamide was not mentioned by any of the participants, and no actions were actively taken to mitigate its formation.

Potatoes and potato products were not usually the focus of the meal. Instead, they often accompanied a meat dish. As such, timings were often built around other foods, and getting the entire meal ready at the same time (see Figure 1). This puts ‘real life’ practices out of line with studies that have estimated acrylamide exposure by cooking potato products in line with manufacturers’ instructions.

Figure 1 – A photo of a chalk board in one of the participants’ kitchens, outlining ‘roast dinner’ timings



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Personalised approaches to preparation and cooking – in particular with regards to time and temperature – were common throughout the fieldwork. Only a handful of participants glanced at or read any cooking instructions, and none strictly followed a recipe from a book (or digital source). This appeared to be due to the fact that these were items that participants cooked regularly, meaning that they had 'tried and tested' methods. While some appeared to be vaguely aware of manufacturer instructions, people were apparently more comfortable using their own approximations and judgement.

The cooking process was often fluid, and was rarely as simple, or as static as "put X in oven at X degrees, for X minutes".

Preheating, for example, tended not to be a measured process in terms of time or temperature. Often the oven was turned on to heat up while food was being prepared or tasks were taking place. Food was then put in the oven when the preparation or tasks were complete, as opposed to when the oven had hit a particular mark.

In many cases food was then regularly checked throughout the process, with adjustments in intended time and temperature made at certain points (often towards the end of original intended time). This meant that ovens were frequently opened, and potato items turned or tossed where required. The timing of these checks was usually ad hoc, although in a small number of cases timers were set to remind participants to do so at the half way stage.

Definitions of freshly made products were fairly loose and subjective. There is little difference objectively between large homemade chips and potato wedges. One participant who made what he called 'sautéed' potatoes, had deep fried them. Figure 2, below, shows some photographic examples of these items.

Participants appeared not to give much consideration as to why they are doing the practices that they do. When asked in follow-up interviews, participants often traced storage behaviours back to their parents. Family also appears to be a major influence on preparation and cooking practices (see the quotes below), though a couple of participants mentioned the influence of cooking programmes on television.

"Probably when I was growing up, I watched what my mother was doing, because she used to do superb things with potatoes and I always rather enjoyed it... I think other people are exactly the same. These things generally come from home."

Male, West London, Pre-prepared roast potatoes

"My first wife was a trained chef, and she used to do it [make roast potatoes], and she explained the benefits of parboiling them. Then my second wife showed the benefits of putting flour on!"

Male, High Wycombe, Fresh roast potatoes

Figure 2 – Photos of what were described as: Chips (top row), Sautéed potatoes (bottom left), and Potato wedges (bottom right). Photos from Brook Lyndhurst and PAS lab

3.2 Case study 1

Background

- This visit was to the house of a retired gentleman who was cooking some frozen oven chips as part of a meal for himself and his wife.
- The chips had been purchased a couple of days before and stored in the freezer (the temperature of which was -20°C).

Preparation and cooking

- The oven was set to 160°C, and the participant stated that he intends to cook the chips for 15 minutes. No reference was made to the cooking guidelines of the product (see image).
- The chips were removed from freezer and put on foil on top of a tray, while

the oven was left to preheat.
- The chips were put in the oven, and were checked four times, and stirred on two of these occasions. The timings of these checks and the reasons for them are presented in Figure 3.
- Each time the chips were checked the door was opened and the temperature monitor probe recorded a drop in temperature. It also appears that the oven temperature over compensated for these drops by boosting the temperature beyond 160°C (Figure 3).
- The participant tasted a chip after they had been in the oven for 15 minutes. They remained in the oven for a further five minutes after this test.
- The total cooking time was 20 minutes: five minutes longer than had been intended at the start.

Doneness

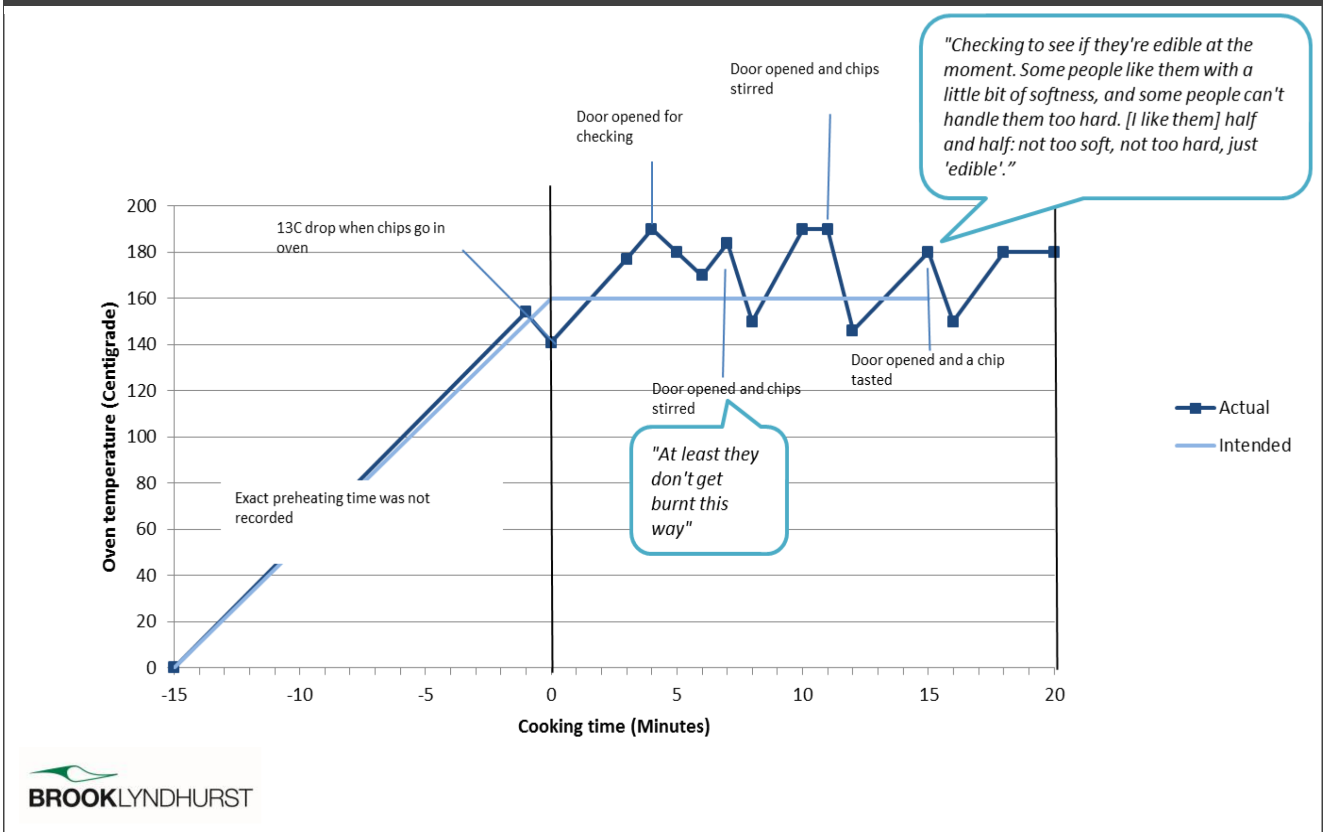
- When asked how he had decided the chips were 'done' and ready to come out of the oven, the participant suggested that they were cooked to his personal taste. Further to this, he added that he and his wife are conscious not to overcook anything. He described chips being 'done' in the following terms:

> *"They've got firmness in them still, but yet all the frost has gone out of it"*

Acrylamide

- The acrylamide level from the collected sample was: 67 µg/kg[48].

Figure 3 – Annotated graph showing the approximate oven temperature and participant interaction with the oven[49]



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[48] For a discussion of whether this (and the other acrylamide levels reported in the case studies) can be considered 'high' or 'low' please see Section 5.

[49] Please note that the temperatures presented in this graph are indicative. The square markers on the 'actual' temperature line are instances where the temperatures on the probe were recorded, the lines are created through interpolation, not through continuous recording of temperature.

Figure 4 – A photograph of the chip sample collected from the Case Study 1 household

3.3 Case study 2

Background

- This visit was to the home of a male participant who was cooking a meal of chicken, vegetables and roast potatoes for himself and his housemate. This is a meal he makes around once a month, and he says that he has never read a recipe for roast potatoes.

  "I enjoy cooking it [a roast dinner] actually. It's one of my favourite things to cook, I suppose. It's actually relatively easy."

- He was using Saxon potatoes that he had bought from supermarket that day, though he was not aware of the variety he had purchased:

  "I'll be brutally honest, I don't know [what varieties I buy]… I pick up a bag of potatoes… if they're the right sized bag… and if it's a good price then I'll buy them and cook them."

- Potatoes are always stored in a kitchen cupboard. There is less room in his fridge and as they are not stored in the fridge in the supermarket, he does not think it is necessary.

Preparation and cooking

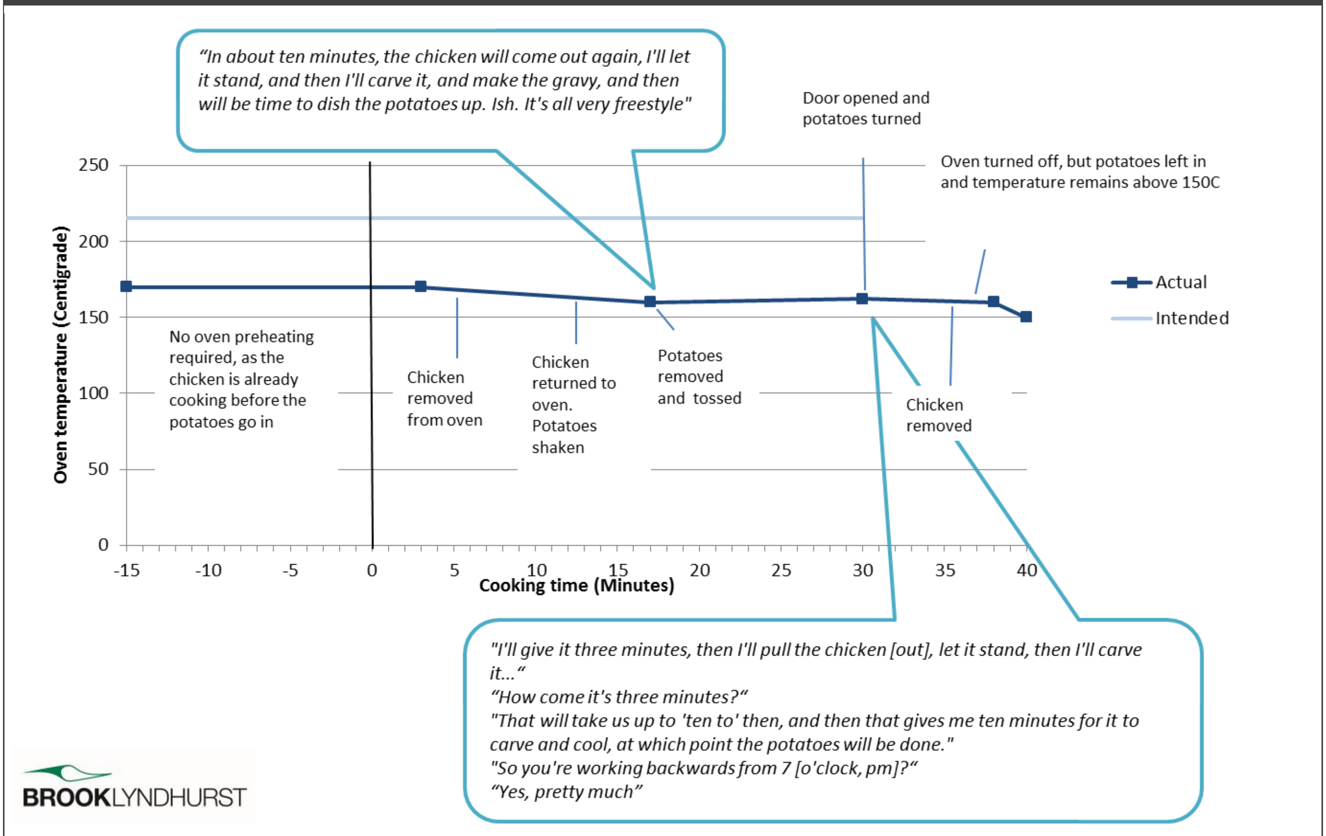
- The potatoes were peeled and roughly chopped. Most potatoes were cut in halves, though bigger halves were cut again (see photograph).
- The chopped potatoes were not washed or soaked. As they are going into boiling water anyway, so he did not see a reason for washing them.
- The potatoes were then parboiled (with the lid on) for eight minutes, though this was not timed.
- After parboiling, potatoes were shaken in a pan with plain flour to fluff them up and to coat them.
- The meat was already cooking at 215°C so the oven had time to preheat.

"That [temperature of 215°C] was on the wrapping for the chicken"

- A tray of sunflower oil was added to the oven for a few minutes to heat up, so that the potatoes were added to hot oil. He suspects he picked up this 'tip' from time spent working in hotels and pubs.
- He stated that he expected to cook the potatoes for 30 minutes, though he acknowledged that timings were quite 'freestyle'. The whole meal was geared up for being ready at about 7pm, at which time he intended to serve up (see quotes in Figure 5).

"I tend to read the packaging on the chicken I was cooking alongside. So I time the potatoes in with it. I know half an hour is around about a good time for a roast potato."

Figure 5 – Annotated graph showing the approximate oven temperature and participant interaction with the oven



- The oven temperature remained relatively stable throughout the cooking process.
- The potatoes were removed from the oven and shaken or turned three times during the process.
- The participant eventually cooked the potatoes for 37 minutes in total before turning the oven off. The potatoes remained in the oven for a further three minutes after the oven was turned off, as he began serving other food.

Doneness

- The timing of the potatoes was an important guide as he tried to bring the components of the meal together at the same time. It was the look and colour of the potatoes that he used to judge if they were done:

> *"If the potato itself is a nice golden brown, but the cut edges are starting to turn almost black, that to me as absolutely perfect on a potato"*
>
> Male, High Wycombe, Fresh roast potatoes

- He claims to 'almost always' get the cooking of roast potatoes 'right' (N.B. in line with his desired outcome).
- He attributes his desire for the potatoes to be golden brown (and definitely not 'undercooked') to the way his mother used to cook them (every week) when he was younger.

Acrylamide

- The acrylamide level from the collected sample was: 176 µg/kg

3.4 Case study 3

Background

- This visit was to the home of a male participant, who was cooking roast potatoes for scratch for himself, his wife, child, and a couple of friends. They were part of a roast dinner of chicken, potatoes and other vegetables.
- He had purchased Charlotte potatoes two days before the visit, and stored them in a basket in the kitchen.

> *"Putting potatoes in the fridge is going to take up a lot of space and we need it for other things. Obviously it will stop them growing or stop developing [sprouting], but no, we've never seen any need to keep them in the fridge"*

Preparation and cooking

- The potatoes were pre-washed, and he did not wash them again, or peel them:

> *"We never peel any veg. You're losing some of the vegetable, there's no real need to. When you roast veg the skin becomes soft enough as it is. There might be more nutrition in the skin. It's also partly laziness: we don't really see a need to."*

- The potatoes were chopped roughly in half.
- He then parboiled the potatoes, for approximately 14 minutes. The water was heated to boiling, and then turned down to a simmer. The participant mentioned this as an important process in achieving soft-centred, crispy roast potatoes. Parboiling was something that he had seen professional chefs do, and something that he had always done when preparing roast potatoes:

"…when I was a lot younger I went to a friend's house and his mum made amazing roast potatoes, and I asked her how you do it - before I was cooking myself. And she said that she parboils them, she bashes them, and they turned out like that. So I always thought that [parboiling] was the best way to do it."

- The participant preheated the oven and the cooking oil while potatoes were parboiling. He noted that on special occasions he would use goose fat and cook the potatoes at a higher temperature, in order to make them really crispy.

"We've just had more success the hotter the oil is. When they've been bashed, if you put them into really hot oil and coat them with the silicon brush, it just seems to make them more crispy"

- After parboiling and draining the potatoes, they were shaken to break up the edges. This was done as a way of getting the potatoes as crisp as possible.
- Following this, the participant took great care to get the potatoes covered in hot oil before they went into the oven for cooking (see photo).

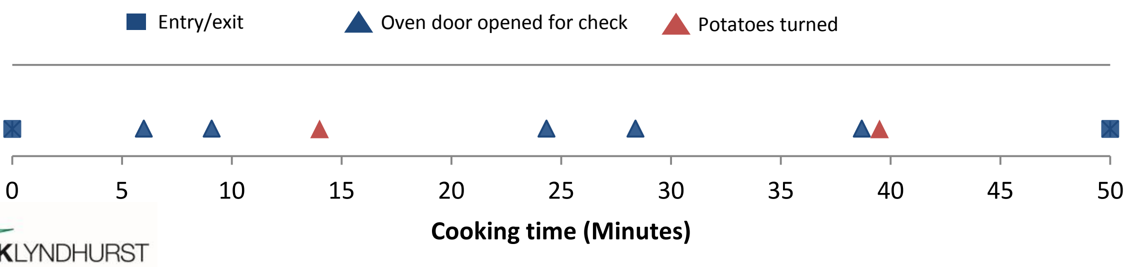
"You hear of people in chip shops who make lots of chips, they parboil it, let it cool down, and then drop it obviously into hot fat so, lots of people who want to have crispy potato do it that way, so I just sort of copy them"

- The oven was set to approximately 190°C, though the numbers were worn off on the dial, so this was not necessarily accurate.
- He expected to cook the potatoes in the oven for about an hour, though this time was very approximate and dependent on checks. The potatoes were actually cooked for 50 minutes as they were deemed to be ready:

"It's all about the outcome. If you stuck to 60 minutes and your potatoes aren't done, what's the point?"

- During cooking the potatoes were checked several times, and turned twice (Figure 6).

Figure 6 – Chart showing times at which the roast potatoes were checked or turned during cooking



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Doneness

- He looked for colour and texture signals to decide when the potatoes were ready. A mid-brown colour and very crispy texture were seen as ideal. The final colour of the potatoes is shown in the photograph on the right.

> *"If it was absolutely perfect, it shouldn't really go dark. It should be very crispy, possibly a mid-brown. If you could possibly have it almost detached, but light and fluffy on the inside, then that would be perfect. Like a chip, like a perfect chip: proper crispy."*

Acrylamide

- The acrylamide level from the collected sample was: 192 µg/kg

3.5 Summary

This chapter provides an overview of the information elicited by the observational research and follow up interviews. Chapter 4 breaks these observations down by practice, but this chapter gives a sense of the overall cooking processes that participants were undertaking and details notable observations.

The research found that the cooking practices of participants in this study were not influenced by any concerns regarding acrylamide formation. Participants, by and large, also did not abide by FSA guidelines to carefully follow manufacturers' instructions for oven-heating or frying foods[50]. The case studies in this chapter serve to highlight the broader finding that approaches to cooking potato products appeared to be personalised and highly variable. Instructions or recipes were rarely looked at, let alone followed, as participants felt sufficiently familiar with the products and how to cook them. Cooking processes, for the products of interest, instead often relied on experience, approximations and subjective judgements.

In particular, the time preheating the oven, and the number of times the oven door was opened to check the food, often appeared arbitrary. These aspects may also have impacted on temperatures at which the food was being cooked, generally resulting in oven temperatures being lower than intended for portions of the cooking process.

[50] https://www.food.gov.uk/science/acrylamide [Accessed 23 February 2015]

4 Findings: Practices

Chapter 3 gave an overview of the kinds of information that was collected. This chapter provides a more detailed look at the different practices that participants did, or did not undertake, that have implications for acrylamide levels. This chapter only presents findings related to practices, however, with conclusions related to domestic acrylamide exposure set out in Chapter 6.

The sections in this chapter follow the different categories of relevant behaviours, as outlined in Chapter 2 (and Appendix C):

- Section 4.1 covers **storage** – acrylamide precursors (such as reducing sugars) are increased when potato items are stored at cool temperatures for long periods of time.
- Section 4.2 looks at aspects of **preparation** – some acrylamide precursors can be removed by washing, soaking and parboiling processes; larger surface areas increase acrylamide generation as the generation process tends to occur on the outer layer of foods.
- Section 4.3 is about **cooking processes** – longer times and higher cooking temperatures are key components of acrylamide generation.
- Section 4.4 covers **'doneness'** – do people like products to be prepared in ways that are likely to increase acrylamide exposure?

Section 4.5 looks at **toast** storage and cooking, and covers many of the same issues as sections 4.1, 4.3 and 4.4.

4.1 Storage

4.1.1. Fresh potatoes

In this study, 21 participants prepared potato items from scratch (i.e. starting with raw potatoes). The majority of these people stored their potatoes outside of the fridge prior to preparing and cooking them, such as in a kitchen cupboard, garage, or utility room.

Four participants did store potatoes in the fridge. One of these participants mentioned that they were aware of potatoes sweetening in the fridge (the only mention of this effect) and so only stored potatoes in the fridge in the summer. Fridge storage was used by participants because it was perceived to keep potatoes fresher for longer (e.g. prevented them from sprouting as early).

Amongst other participants, there was no apparent opposition to fridge storage. For some, it was largely a practical decision: a few interviewees suggested that they would keep potatoes in the fridge if space were not an issue. For others, storing potatoes outside of the fridge was something had been inherited from parents and the practice had stuck.

None of the participants had stored 'fresh' potatoes for more than two weeks.

My father used to garden and we used to keep potatoes in a thing outside. It's inherited really, I'd say.

Male, High Wycombe, Fresh chips

I buy them from the fridge so I store them in the fridge. When I go to the supermarket they're in the cold bit - the fridges. I think when you keep them out in the kitchen they grow roots… I can eat them when I want them, because they last weeks in the fridge.

Female, High Wycombe, Fresh potato wedges

Putting potatoes in the fridge is going to take up a lot of space and we need it for other things.

Male, High Wycombe, Fresh roast potatoes

4.1.2. Pre-prepared products

The majority – 29 participants - cooked 'pre-prepared' items when they were visited. These pre-prepared products were almost universally 'frozen' products and therefore stored in freezer[51].

Freezer temperatures were only visible in a handful of cases, and temperatures were found to be between -18°C and -23°C.

4.2 Preparation (fresh potato products)

4.2.1. Peeling

Peeling practices generally reflected what was being cooked: the three participants preparing fresh chips, and most of the nine cooking roast potatoes, peeled the potatoes before cooking. Jacket potatoes and potato wedges were likely to remain unpeeled.

A couple of participants were quite happy to leave roast potatoes unpeeled, however[52], because they enjoy the taste of the skin, and/or the relative ease of preparation.

I don't do roast potatoes very often, but I like the taste because the skin goes quite crispy. With the organic ones it's probably good to eat the skin: it's got fibre in it. I believe all the vitamins are just underneath the skin, so that's another reason.

Female, High Wycombe, Other (Sweet potato)

4.2.2. Washing and soaking

There appeared to be mixed practices regarding the washing of potatoes. Often participants did not see the need for washing as the potatoes were already peeled and were going to be parboiled. Others washed potatoes even if the potatoes were peeled and to be parboiled, due to habit or for hygiene purposes. A couple of participants did not peel, wash or parboil potatoes before they were cooked. Washing, when it occurred tended to last no more than 5-10 seconds.

[Why does he wash them?]
I don't know really. It costs nothing to wash them. There's no reason I can think of – I just automatically wash them… My parents always washed them beforehand.

Male, West London, Fresh roast potatoes

No participants actively soaked potatoes as part of the preparation process. A few participants 'left the potatoes in water' whilst they prepared other elements of the meal. Indeed, several participants reported that - although they had not done it during the visit - this was an action that they sometimes took so that time was used effectively when there was a lot of preparation to be done (e.g. for a 'full' roast dinner): potatoes were peeled early in the preparation process and left in water to prevent them turning brown, allowing the cook to spend time on other tasks.

4.2.3. Parboiling

All participants that prepared roast potatoes parboiled them before roasting. Participants' reasons for doing this tended to revolve around the

Always done it… I went to a friend's house and his mum made amazing roast potatoes, and I asked her how

[51] One exception was a participant who had bought a pre-prepared jacket potato with cheese, and stored this in the fridge for a few days prior to cooking. Another participant did not have a freezer, so stored 'frozen' roast potatoes in the fridge.
[52] See Case Study 3, in Section 3.4 as an example

desired texture of the final cooked potatoes. Shorter cooking time in the oven was also given as a reason. There did not seem to be a standard procedure for parboiling, however, with parboiling times ranging from 4 minutes up to almost half an hour. Few participants timed this process, instead apparently relying on guesswork and intuition.

you do it… and she said that she parboils them, she bashes them, and they turned out like that

Male, High Wycombe, Fresh roast potatoes

So I think it's just, they just come out nicer. I think it's a Jamie Oliver tip as well, I think I must have watched him years ago do it and then I've started doing it

Female, Slough, Fresh potato wedges

Only one of the participants that prepared fresh chips, wedges and the other (fresh) potato products parboiled the potatoes before cooking them further. With potatoes cut into smaller pieces for chips or wedges than for roasts, participants generally did not want to soften them too much by also parboiling them.

4.2.4. Chopping and size

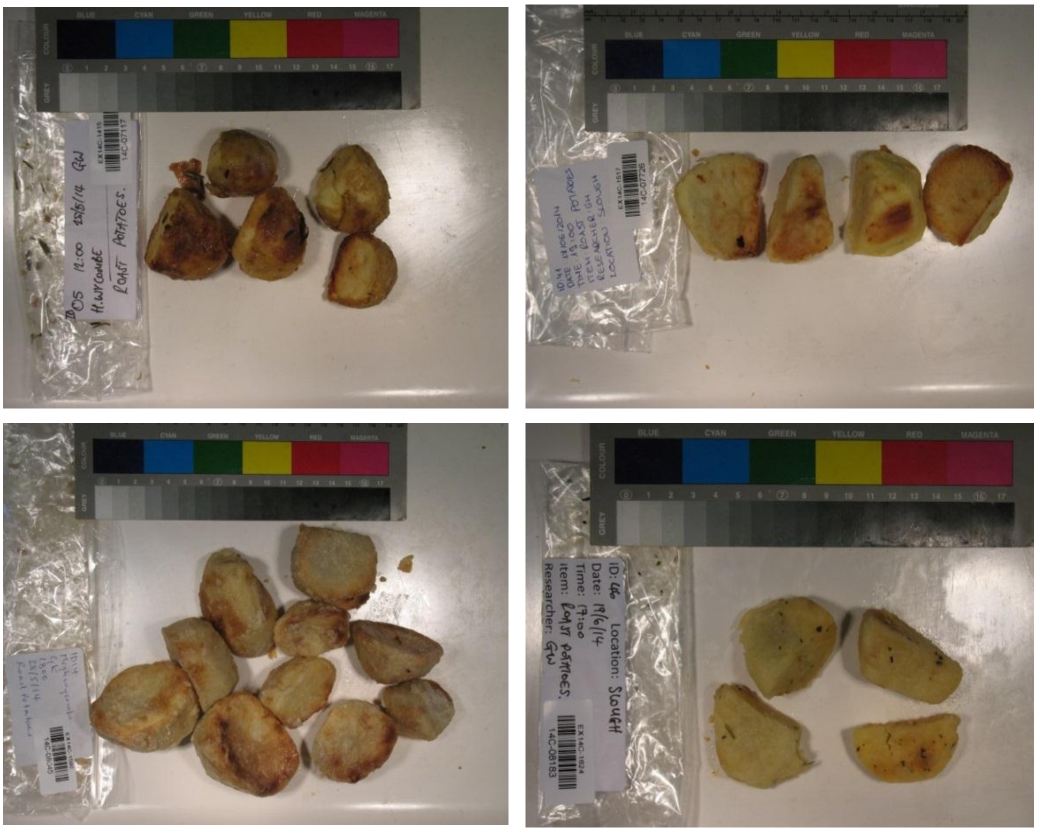
When chopping potatoes, participants aimed to make the pieces – whether roast potatoes, chips or wedges – roughly of equal size (Figure 8). This was to enable relatively even cooking. Not a great deal of care or effort was done to ensure this, however, as some participants were happy to have some variety in potato size. With roast potatoes, for example, all participants chopped potatoes into half, but only in some cases were the larger halves were halved again.

I try to make them not too big, but not too small. I like a few small ones because everybody likes a crispy roast potato.

Male, High Wycombe, Fresh roast potatoes

As discussed in Section 3.1, there were not necessarily clear size differences between homemade chips and wedges.

Figure 7 – Four photos of participants' freshly prepared roast potatoes. Photos courtesy of PAS lab



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4.3 Cooking

4.3.1. Method

As one might expect, all freshly prepared (from raw) roast potatoes were roasted[53]. Eight of these were roasted in conventional ovens, with one participant using a countertop halogen oven. Treatment of the oil varied, with some preheating the oil, and others adding it 'cold' to the potatoes before roasting. A couple of participants also added flour to the potatoes after parboiling, while the majority did not.

> [Describing the advantages of a halogen oven]
> *Unlike a conventional oven where you have to open and shut to see how the potatoes are progressing, you can actually see through the glass.*
>
> Male, West London, Fresh roast potatoes

Most pre-prepared 'frozen' roast potatoes were baked, though a couple of participants did add oil to the tray to roast the potatoes.

Thirteen of fourteen participants cooking pre-prepared 'frozen' chips oven baked them straight from frozen, although a few participants also added a dash of oil. This oil was added either to stop the chips sticking, or to aid even cooking. One participant used a microwave to cook chips from frozen.

[53] For the purposes of this research roasting is defined as: oven cooking in a tray of oil or fat; and baking as: 'dry' oven cooking without significant added oil or fat.

Of the three participants who prepared fresh chips, two used deep-fryers: one a deep fat fryer using rapeseed oil; the other a 'health' fryer that requires one tablespoon of oil per portion of chips. The other participant preparing fresh chips roasted them in a tray of olive oil.

Other products were cooked in a variety of ways. Items such as pre-prepared waffles, croquettes and hash browns tended to be baked[54], while wedges (or sweet potato chunks) tended to be roasted.

4.3.2. Preheating

The oven, when used, was preheated by all participants to some extent. With a few exceptions, there appeared to be no apparent aim for particular preheating times or temperatures to be achieved before cooking. More common was that people would turn the oven on whilst preparing the food, and put the food in the oven when the preparation was complete. A certain amount of time preheating, or some tangible heat from the oven, usually sufficed.

That's what they say isn't it? When you want to cook something the oven should be preheated... this is, I think, a common conception.

Male, West London, Pre-prepared chips

... if I'm in a rush, I might wait for the oven for five minutes, and then I might test it by turning the temperature down to see when the light goes off. And if it's close to the desired temperature then I'll just put them in. I don't think it matters that much with potatoes.

Female, High Wycombe, Other (Sweet potato)

Most ovens were equipped with a light to indicate whether the particular temperature that was set has been reached, but while participants tended to be aware of it, it was not used as a definitive guide. Preheating lights were used more definitively in the couple of instances where deep fat fryers were used. Countertop devices (e.g. halogen oven, 'actifry', microwave) did not require preheating.

Yeah I do [use the oven light as a guide], but I tend to test it myself as well... I just leave it [the oven] on for 5 or 10 minutes then sort of open up and feel the heat hit your face, and think 'oh that's done'.

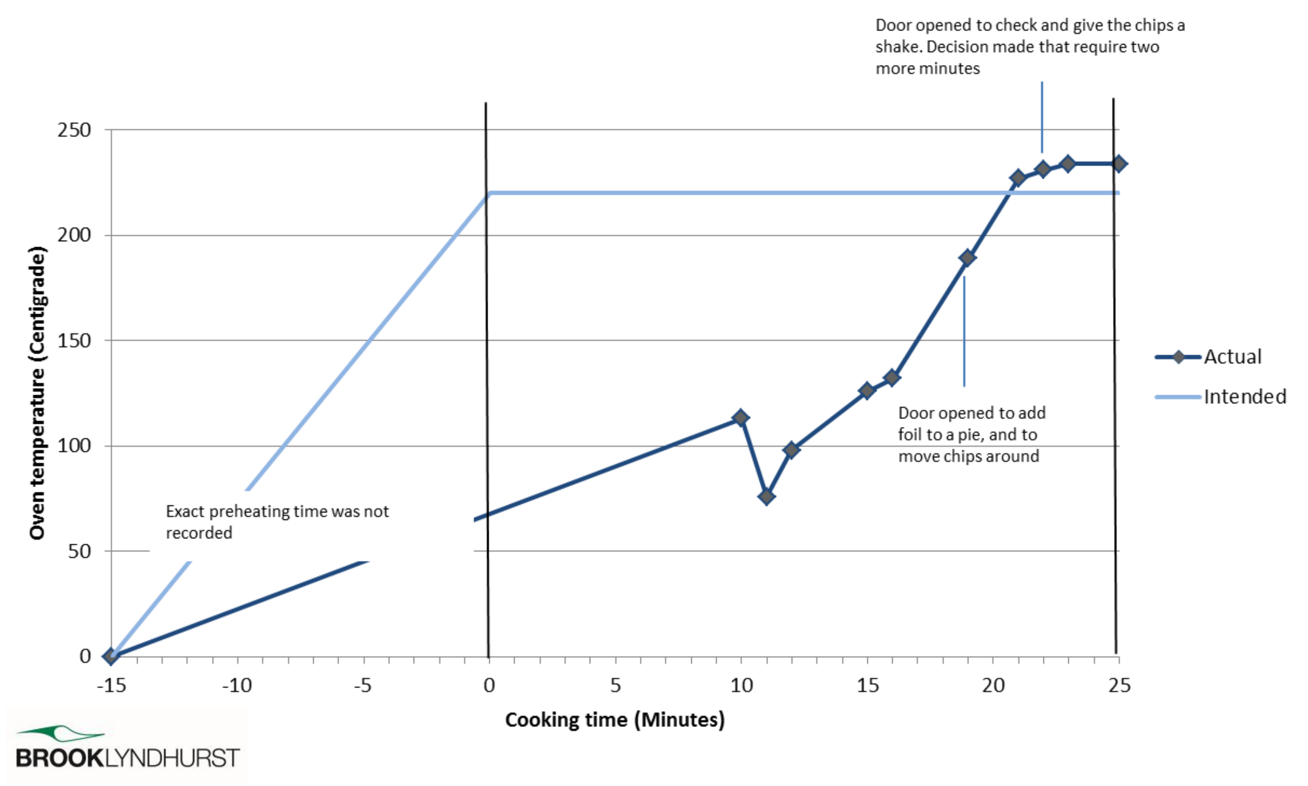
Female, West London, Other (Pre-prepared potato waffles)

In addition to this there was considerable variability in oven equipment. Ovens were used that were gas and electric; old and new; digital and analogue. As such, even similar preheating behaviours could produce different results in terms of oven temperatures.

Figure 9 below shows the temperatures recorded by the temperature monitor probe during one visit. While (as discussed in Section 2.2.3) this does not provide a scientific measure of either oven or food temperature (and indeed, in this case, no temperature was recorded until 10 minutes into the cooking process), it suggests that the oven did not reach the set oven temperature until the chips had been in the oven for 20 minutes.

[54] Though one participant did cook hash browns using a countertop "Tefal Actifry".

Figure 8 – Annotated time-temperature graph of a participant cooking pre-prepared chips



4.3.3. Temperature

Participants rarely referred to the on-pack instructions, and oven temperatures tended to be set to the participants' own 'go to' temperature. This tended to be a personalised temperature somewhere in the range of 180°C to 220°C at which all foods - not just potatoes - were cooked. A couple of participants simply turned the oven up to maximum though, in order to shorten cooking times.

Participants generally gave the impression that they understood the nuances of how their ovens worked, and had developed a system that made the oven temperature work for them. Once set, temperatures tended to remain untouched throughout the cooking process, though a few participants did tweak temperatures in order to alter the speed of cooking processes.

There was some evidence that temperatures were affected by what else was cooking in the oven. Concerns about the cooking temperature of meat, for instance, could override the importance of the temperature of the potatoes or chips.

Oven temperatures were not necessarily stable[55]. Researchers noticed fluctuations in the temperatures recorded by the temperature monitor

I cook everything at 200°C... It doesn't really matter: for cooking potatoes it's not that important.

Female, High Wycombe, Other (Sweet Potato)

They cook better if you put them in a hotter oven... It's simply a matter of convenience... If I want to cook something, I cook it, and I want it done quickly. And cooking at a high temperature tends to do it... I don't know whether you are supposed to or not. I just find it easier – it's quicker, easier and it doesn't seem to do any harm to the potato, or me.

Male, West London, Pre-prepared roast potatoes

Depending on what meat or something we're cooking, you find a happy medium with everything else that's going in the oven, don't you? I'd say for me it'd generally be 180°C to maybe 200°C, but generally about 180°C.

[55] See, for reference, Figure 3 in Section 3.2, Figure 9 in Section 4.3.2, and the data in Appendix J.

probes, even when the oven door remained shut. Temperatures were also seen to overshoot the intended temperature of the oven on occasion.

Male, High Wycombe, Fresh roast potatoes

4.3.4. Time and timing

Though very few participants referred to cooking instructions or recipes - as noted in Section 3.1 - all were able to cite an estimate for how long they expected the potato products to cook. For many, this was explicitly an estimate and they had little intention of using exact timings. For pre-prepared products, which tend to require shorter cooking times, this was generally a more precise 'expected' timing.

Often, these estimates (or 'expected' times) and recorded cooking times were markedly different, however. Despite cooking these items regularly, it appeared that people were generally not good at estimating cooking times. More often than not, cooking times were underestimated, with participants adding minutes to the cooking time[56]. Of course, attempts to estimate cooking times will not be helped if there are temperature fluctuations or if the oven is not fully pre-heated prior to cooking (Sections 4.3.2 and 4.3.3).

Use of timing devices was mixed: some participants used oven alarms, while others would glance at clocks or phones to see how much time had elapsed. Some participants even claimed to 'just know' when food was ready and did not use timing devices at all. As pre-prepared potato products were often seen as a convenience food, timers were sometimes used to allow participants to do something else while the food was cooking. This could involve the preparation of other food, or other tasks such as ironing, supervising homework or playing on an Xbox. Timers were also used by some to tell them when to turn items, though it was more common for people to check the oven and turn (or shake) items on an ad hoc basis.

There were only a couple of participants who relied entirely on timing to let them know that the food was cooked. For the vast majority, the time was just a guideline. Once the 'time' approached, participants often checked the food, and gave a renewed estimate of how much more cooking was required. Participants were often able to give quite precise estimates as to how many more minutes of cooking would be needed before the food was ready to eat. This process could be repeated however, with additional minutes or two tacked onto the end of the cooking procedure. So, while temperature is generally fixed and stable, it seems participants more naturally varied the time required for cooking to achieve the desired result.

I use [the time on the instructions] as a guideline. I'm not so obsessed to follow it to the letter. I just look at it for guidance.

Male, West London, Pre-prepared roast potatoes

[My son] has them so often that I just know [when they're done]… If that makes sense? I just throw them in, go and do what I'm doing, and I just know to come back and open it [the fryer]. It's so easy

Female, West London, Other (Pre-prepared hash browns)

I probably look at the time when I put them in. Then I'll probably go back to them after 10 or 15 minutes to check. And then after that I'll probably go back every 5 minutes to check again… It's very approximate. It all depends what else I'm doing in the kitchen. It's all very haphazard really.

Female, High Wycombe, Other (Fresh sweet potato).

I always check things. I like to check things visually, I don't like being ruled by a timer… I've always done that, I never worked with a timer. I'd rather just go and look.

Male, West London, Pre-prepared roast potatoes

Generally when you cook things by the instructions they're a bit undercooked, so I tend to just watch them

Female, West London, Other (Pre-prepared potato waffles)

[56] This observation corresponds with the findings in: Oliveira, L., Mitchell, V. and Badnia, K. (2012) Cooking behaviours: a user observation study to understand energy use and motivate savings. Work 41. pp2122-2128

4.4 ‘Doneness’

While – as detailed in Section 4.3 – time alone is rarely the deciding factor when judging if the potato product is ready, it remained an important guide for most participants.

Once enough time had passed for the item to be edible, participants began checking the colour and appearance. This visual checking was the dominant way of deciding whether a product was ‘ready’ as desired.

> *Half an hour is a good starting point, and if I look in the oven and they’ve gone nice and crispy then that’s time to take them out. I don’t want to overcook them.*
>
> Male, High Wycombe, Fresh roast potatoes

Some participants were unable to elaborate on what it was that they were looking for in particular, claiming that they ‘can just see’ when the items were ready. More commonly, participants were looking for potato products to turn ‘crispy’, or something similar to ‘light’ or ‘golden’ brown.

> *If they look done, they're done… I consider myself quite an experienced chip chef!*
>
> Male, West London, Pre-prepared chips

While a golden brown colour was almost universally desired, there were variations as to what other colours were acceptable. A couple of participants, for example, suggested that elements of the chips or potatoes should be turning even darker, as an indication that the batch overall was the ‘right’ colour and texture. On the other hand, a couple of households reported being conscious not to overcook things, and would not have been happy to see dark brown and black colours appearing[57].

> *They just look appealing, don’t they? And if they do, you think, ‘that’ll do’.*
>
> Female, Slough, Other (Fresh potato wedges)

Desiring a ‘golden’ colour is not a particularly useful guide as to how people cook, however. The photographs below were taken in light-neutral conditions and are all from participants who used the word ‘golden’ to describe the desired colour. The participants who prepared the middle items in each row described them as undercooked, the other four told researchers that the items ended up roughly as intended.

> *The idea is that they have a golden crispy look to them. And that most of them will look like that.*
>
> Female, High Wycombe, Fresh chips


Pre-prepared chips, baked


Fresh chips, fried


Fresh chips, roasted

> *A light brown to golden brown. The moment you go too dark that’s it: the kids tell you you’ve burned them.*
>
> Male, Slough, Other (Fresh sautéed potatoes)


Fresh wedges, roasted


Fresh wedges, roasted


Fresh roast potatoes, roasted

> *The outside’s got to be a golden colour at least, and - as I say - if it’s got little tinges of slightly darker colour on the corners where it’s thinner, that to me would be an ideal chip.*
>
> Male, High Wycombe, Fresh chips

Similarly, the research was not able to paint a clear picture of what a ‘crispy’ potato looked like. The photographs below show three samples of roast potatoes, and in each case, the participant described them as being ‘crispy’.

[57] See Case Study 2, Section 3.3, for an example.


Fresh


Fresh


Pre-prepared

Visible colour and crispiness were the primary indicators of 'doneness', but not necessarily the only ones. Some participants prodded potatoes with a knife or fork to check that the insides were cooked. On a few occasions chips and jacket potatoes were also touched by hand to assess texture. Several of those cooking chips tasted a chip to make sure that they were cooked (as desired) all the way through – though this was often done as a double check: after the decision to remove chips from the oven had already been made.

[I knew they were ready] because I squeezed them and they felt cooked. I don't try them until I eat them.

Male, West London, Pre-prepared chips

The desire for crispy, golden brown potatoes and chips genuinely seems to come from the personal taste preferences of household members. Participants were able to describe how their partners or children liked potato products to be cooked. Some interviewees suggested that their desired colour and texture was something they could trace back to their childhoods, while a couple of interviewees mentioned the appearance of roast potatoes cooked by TV chefs as an inspiration.

4.5 Toast

4.5.1. Bread storage

Bread does not undergo the same 'low temperature sweetening'[58] as potatoes. Bread storage practices were still recorded, even though the influence on acrylamide formation is likely to be negligible.

Bread is stored in kitchen by the majority of participants: either in a bread bin, a cupboard or on the kitchen worktop. A significant minority stored bread in the fridge, with a handful of participants primarily storing bread in the freezer.

I suppose [a breadbin] is just something that we've always had, and I've always grown up with.

Male, Slough

The location of bread seems to largely be based on calculations of how much bread will be required. Households that are aware that they consume bread quickly are happy to store the bread in the kitchen, while those eating bread less frequently store the bread in the fridge or freezer to keep it for longer. One participant, for example, would keep sliced bread in the freezer and defrost only the number of slices each morning that were going to be eaten (see Figure 7).

Some people put it in the fridge but I don't like it like that. It goes sort of hard-ish, and I just don't like it like that

Female, West London

There were, however, some objections to storing bread in the fridge, with concerns about it hardening or 'drying out'.

[58] See Appendix C.1.1.

Figure 9 – A photo of some bread stored in a zip-lock bag by a participant – the rest of the loaf was stored in the freezer

4.5.2. Making toast

There was little or no preparation required for toast. A handful of participants cooked toast directly from frozen bread, and only a couple of people had to physically cut the bread to provide slices.

Nearly all of those who provided toast samples used a toaster to cook the bread. There were four participants who grilled toast in the oven, and one who used a George Foreman grill to make toast. These grills were used as these participants did not have toasters, and this was the standard toasting procedure for them.

There was a variety of different kinds of toasters used. The settings were also variable – while it was reasonably common for the maximum setting to be '6', other toasters observed had maximum settings of '3', '5', '7', '8', '9' and 'High'. Others had a timer in the place of numbers.

Participants appeared to be a divided into two camps:

- Some participants had set the toaster to their desired setting and were happy that when the toast popped up, it was cooked as desired.
- Others did not pay a great deal of attention to the toaster setting, instead waiting for the toast to pop up (or popping it up manually) to check its progress, and putting it back down again if required.

Six of the 44 participants who made toast during the visit regarded the

After [my daughter has] used [the toaster] I need to put it back up to normal. She'll put it right down to zero, and I have it normal.

Female, High Wycombe

I often do it [add more time], definitely. The thought process behind it is that I put them in the first time and then that is done, fine. But then they come out and you think, oh no, it needs a bit longer… I like toast to be a light golden brown. Even if you've been doing it for long time, it's difficult to get the timing right

Male, West London

I always check [the toaster] because the kids like theirs different (sic.), so they change the setting.

Female, West London

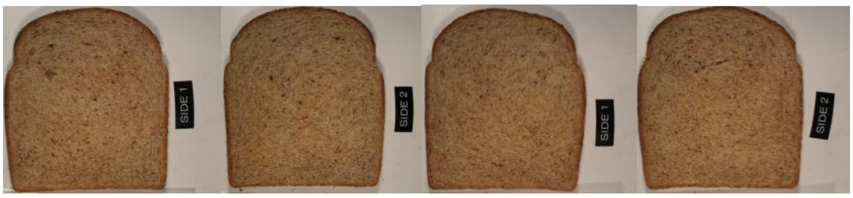
toast they had prepared as over- or under-cooked. There were several more, however, that appeared not to have cooked it exactly as planned, but still regarded it as 'acceptable'. Despite toast making being an apparently simple process, it appears that cooking toast 'exactly' as desired is inconsistently achieved.

Perhaps even more so than there was with potatoes, there seemed to be a very strong awareness of personal preferences. The majority of participants described desiring toast to be cooked 'somewhere in the middle'. When probed further on what this means, participants referred to the bread turning a light brown or golden colour. There were, however, a significant minority that explicitly stated that they preferred toast 'lightly' done, or 'well' done. This was reflected in the toaster settings observed, with many toasters set towards the lower and higher ends of the range provided (though, as noted above, these settings were redundant for many participants). A few male participants also declared that they were happy with toast that was almost to the point of 'being burnt', even if it meant scraping bits off.

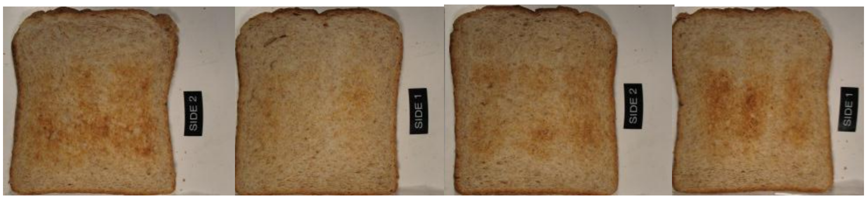
I actually don't mind burnt toast. I like burnt toast rather than it being slightly anaemic.

Male, High Wycombe

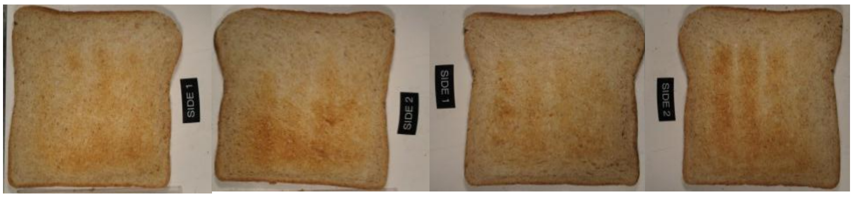
The following images give examples where people have cooked the toast as they intended, along with quotes taken from the observational visits that describe how they like their toast cooked. Each set of four images comprises both sides of two slices of brown/wholemeal toast. Both slices were cooked simultaneously.



"I like the toast very lightly toasted: hardly brown at all." (Female)



"I prefer to have it very light" (Female)



"I don't like warm bread and I don't like the burnt toast either. So that 'somewhere in between' tastes nice." (Female)

"Sometimes if there's any burn you might scrape it off, but I like it quite well done." (Male)

"I like it well toasted" (Male)

4.6 Summary

This chapter set out the findings from the research, broken down by practice (e.g. storage, preparation, cooking of potato products), with a separate section on toast. Key findings related to particular practices are set out below.

- **Storage**: Few participants in this study kept fresh potatoes in the fridge. Those who did store their potatoes in the fridge had not done so for any great length of time (one to three days). Storing potatoes in the fridge was considered an acceptable solution by many, and only limited fridge space and 'habit' prevented more participants doing this.
- **Soaking**: Soaking was not part of the preparation process for any participants in this study preparing potato products from scratch. Many were peeled and washed, and parboiling was common (particularly for roast potatoes) in order to achieve a particular texture.
- **Chopping**: Few participants made any particular effort for homemade potato products (e.g. chips, wedges, roast potatoes) to be thinly cut or small. This is particularly true of chips, which tended to be relatively 'chunky'.

- **Preheating**: The oven, when used, was preheated by all participants to some extent. With a few exceptions, there appeared to be no apparent aim for particular preheating times or temperatures to be achieved before cooking.
- **Oven temperature**: Participants often used a ‘go to’ temperature that they used for all oven-cooked foods, as opposed to following instructions or recipes. Oven temperatures were found to sometimes fluctuate, rather than remain stable, whilst food was in the oven.
- **Timing**: All participants had a sense of how long potato items should be in the oven, but timings were generally not strictly adhered to and were instead used as guidelines (particularly for items requiring longer in the oven).
- **‘Doneness’**: Visual appearance, more so than ‘time in the oven’, was used to determine whether potato products were ‘done’. People appeared to have a strong sense of what the end product should look like, in accordance with their tastes (and those of other diners). Most people stated a desire for ‘crispy’ and ‘golden’ potato products.
- **Toasting bread:** Personal tastes were even more evident in toast than in potatoes, with a significant minority aiming for ‘lightly’ or ‘well’ done toast. For several participants, toast is inconsistently produced *exactly* as they desire, despite the availability of settings on toasters.

5 Findings: Acrylamide levels

5.1 Introduction

As set out in Section 1.2, this research project aimed to provide an indication as to how much acrylamide consumers are exposed to from food prepared at home. It also sought to assess – as far as possible – the extent to which this exposure differs from the levels found in previous studies that have not taken domestic preparation and cooking practices into account. To achieve this, each of the samples collected from the homes of participants was taken to the PAS lab and tested to find the levels of acrylamide present (Section 2.3).

Potatoes

To put the lab results in context, the 'potato' results are compared against findings from the FSA's ongoing survey of acrylamide in UK retail products[59]. The same laboratory techniques were used in both studies.

The survey of acrylamide in UK retail products has involved the collection and testing of hundreds of samples from a wide range of retail outlets, twice a year, since 2007[60]. These samples are from 10 food groups, all of which have been identified as containing acrylamide to some degree. Three of these food groups are of interest here:

- Group 1 - French fries sold as ready to eat
- Group 3 - Pre-cooked French fries for home-cooking
- Group 10 – Others (which in some years includes 'Prefabricated potato products for home-cooking'[61])

This work therefore provides ideal comparators for the chip samples collected in this study. Chips in Group 1 were collected from cafés, quick service restaurants and pubs. Chips in Group 3 were purchased from retailers and then cooked according to manufacturers' instructions as a proxy for domestic cooking. The results from this study will be placed in the context of these results in Section 5.2.

Group 3 also contains a limited number of pre-prepared roast potato products which can be compared against the potato samples collected in this study. Similarly, Group 10 includes samples of waffles and hash browns that can be used as comparators. Comparisons are presented in Sections 5.3 and 5.4 respectively.

As will become clear across the following sections, these results do not lend themselves to neat comparisons and analysis. Analysis of the 'historic' acrylamide levels shows that even the same product, cooked in the same way, can have acrylamide levels that vary dramatically from sample to sample. Potato growing conditions and storage procedures[62] are just two of a multitude of reasons why this variability might exist. In addition, some food industries (including UK manufacturers of chips/french fries) have been working with the FSA to reduce acrylamide levels in products since the FSA study began.

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[59] See: http://www.food.gov.uk/science/research/chemical-safety-research/fs142001 [Accessed 23 February 2015]
[60] These include major and smaller supermarkets, as well as independent retailers in the UK.
[61] In more recent years, the 'prefabricated potato products' category was included in Group 3.
[62] For example, it is generally anticipated that potatoes processed soon after harvest will contain fewer free sugars that act as precursors to acrylamide than potatoes that are stored and then processed.

Toast

The survey of acrylamide in UK retail products also collects samples of soft breads, but does not include toast. As such, the toast results from samples in this study are compared against the results from a separate recent study of acrylamide in Section 5.5.

5.2 Chips

The recorded acrylamide levels from the chips sampled in this study can be found in Appendix J.1. In summary:

- The three samples of fresh chips prepared from raw potato had acrylamide levels of:
  - 86µg/kg;
  - 249µg/kg; and
  - 621µg/kg.
- The 14 samples of pre-prepared chips had acrylamide levels ranging from 26µg/kg to 1062µg/kg.

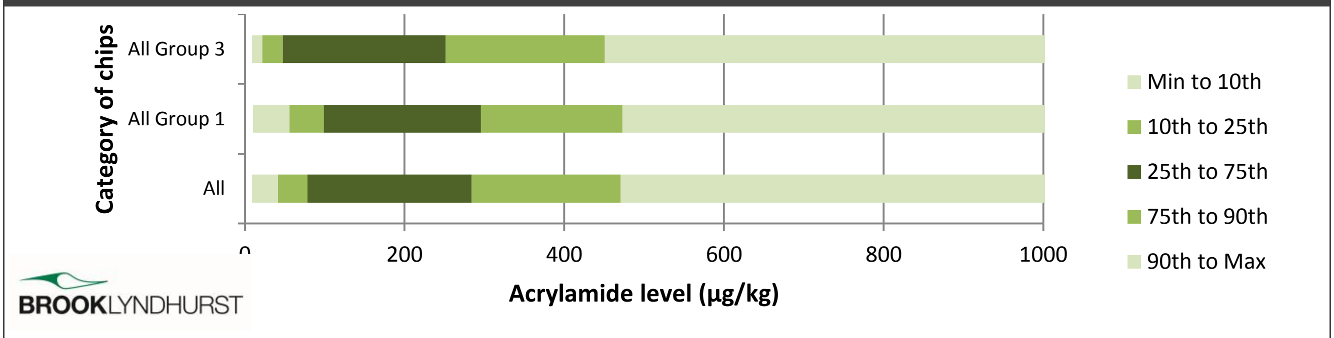
'Historic' data collected by the FSA's survey of acrylamide in UK retail products gives data as below[63]:

Table 2 – Acrylamide levels found in chip samples collected for the FSA survey

	Number of samples	Median (µg/kg)	Min (µg/kg)	Max (µg/kg)	Mean (µg/kg)
Group 1	351	**168**	10	1556	230
Group 3	156	**117**	9	2908	219
All	507	**149**	9	2908	226

The chart below gives a further idea of the deviation of these results. The darkest green areas show the range of the 'middle 50%' of samples, and the second darkest green demarcates the levels where the 'middle 80%' of samples reside (Figure 10).

Figure 10 – Chart showing the variation in acrylamide levels of chip samples between different quartile and decile ranges[64].



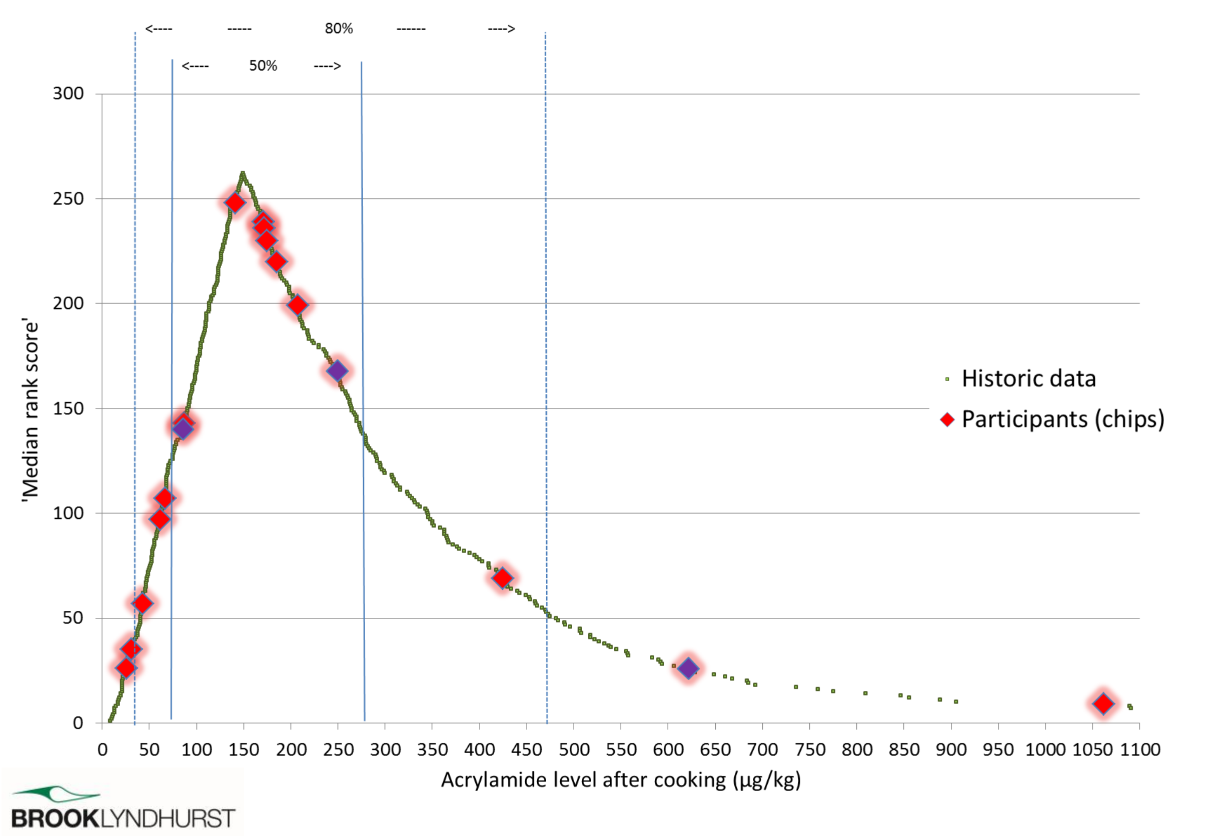
Acrylamide results in the FSA study have been found to vary considerably even though products are cooked in laboratory conditions and to manufacturers' instructions. Indeed, even when the same product

[63] For a more detailed table and an explanation of which chip products were included in Group 3, please see Appendix K.1.
[64] Please note that for ease of reading the chart stops at 1000µg/kg, though the maximum numbers considerably exceed this figure.

is cooked in the same way, results from one batch to the next have demonstrated that acrylamide levels can be several times higher or lower than previous batches. It is incredibly difficult, therefore, to draw meaningful conclusions or comparisons between the data collected for this study, and any historic acrylamide data. As a result, the data is presented side by side as an exploration of how it fits together, but there is no attempt to claim that comparisons provide robust evidence one way or the other.

The graph in Figure 11 below shows how the acrylamide levels in the 17 chip samples compared with the historic data. Acrylamide levels from participants are shown as larger red markers (purple for those preparing homemade chips from fresh), while historic data is shown with smaller green markers. The y-axis is a 'median rank score' simply meaning that the median result of the two datasets combined is awarded the highest score (262) and the two results furthest from the median were given a score of 1.

Figure 11 – Chart showing the acrylamide levels of the collected chip samples in relation to historic acrylamide data[65].



With the heavy caveats regarding natural acrylamide variability and difficulties interpreting the data still remaining, it would appear that consumers in general are not exposed to any more acrylamide than might be suggested by the FSA survey results. Nine of the 17 samples collected fall within the 'middle 50%' of historic results. Four of the samples fall outside of the 'middle 80%'.

High and low acrylamide levels

Given what is known about acrylamide formation[66], it would generally be anticipated that where participants cooked products for a longer time at a higher temperature and to a darker preference, the

[65] Please note that for ease of reading six 'historic' data points have been removed from the right hand side of the chart (with values between 1155 and 2908µg/kg).

[66] See appendices B and C.

sample would tend to have higher acrylamide levels than other samples. While it remains reasonable to assume that if this is a life-long habit (and the meal is consumed regularly) then these practices will increase exposure to acrylamide, there is not a clear pattern emerging from the data collected in this study. Cooking times and observed oven temperatures fail to provide a consistent association with final acrylamide level (Appendix J). This is perhaps related to the inconsistencies in pre-heating and oven temperature discussed in Section 4.3, while it must also be borne in mind that temperature recording was not conducted in a scientifically robust manner. Furthermore, there may have been aspects of the cooking process which contributed to the results that were not noted in the observation, such as position of food in the oven and the type of baking/roasting tray used.

There appears to be ‘natural’ variability in the amount of acrylamide produced in chips (as seen in Table 3, and Figures 10 and 11), and this variability initially appears to preclude most analysis of the impacts of observed behaviours.

An analysis of pre-prepared chip colouration provides some insight, however. While there is not a consistent pattern between observed darkening and higher acrylamide levels, the sample of pre-prepared chips with the darkest colouration did have the highest acrylamide levels (Figure 12). Indeed, the two samples with the highest levels of acrylamide also displayed more evidence of burned edges than other samples (Figure 12).

Most participants claimed to be guided by a combination of a ‘golden’ colouration and timing, and there were few explicit remarks recorded that suggested any conscious differentiation from ‘average’ chips (cf Section 4.4). This evidence suggests, however, that there are perhaps a minority of people whose interpretation of this is different from (darker than) that of others and may therefore be exposed by higher levels of acrylamide.

Figure 12 – The samples containing the highest and lowest acrylamide levels of the 14 pre-prepared chip samples collected. Photographs from the PAS lab.

Highest levels: 1062 µg/kg

Second highest levels: 425 µg/kg

Lowest levels: 26 µg/kg

Second lowest levels: 31 µg/kg

BROOKLYNDHURST

5.3 Roast potatoes

The recorded acrylamide levels from the roast potatoes sampled in this study can be found in Appendix J.2. In summary:

- The nine samples of fresh roast potatoes had acrylamide levels ranging from 6µg/kg to 490µg/kg.
- The six samples of pre-prepared roast potatoes had acrylamide levels ranging from 14µg/kg to 312µg/kg.

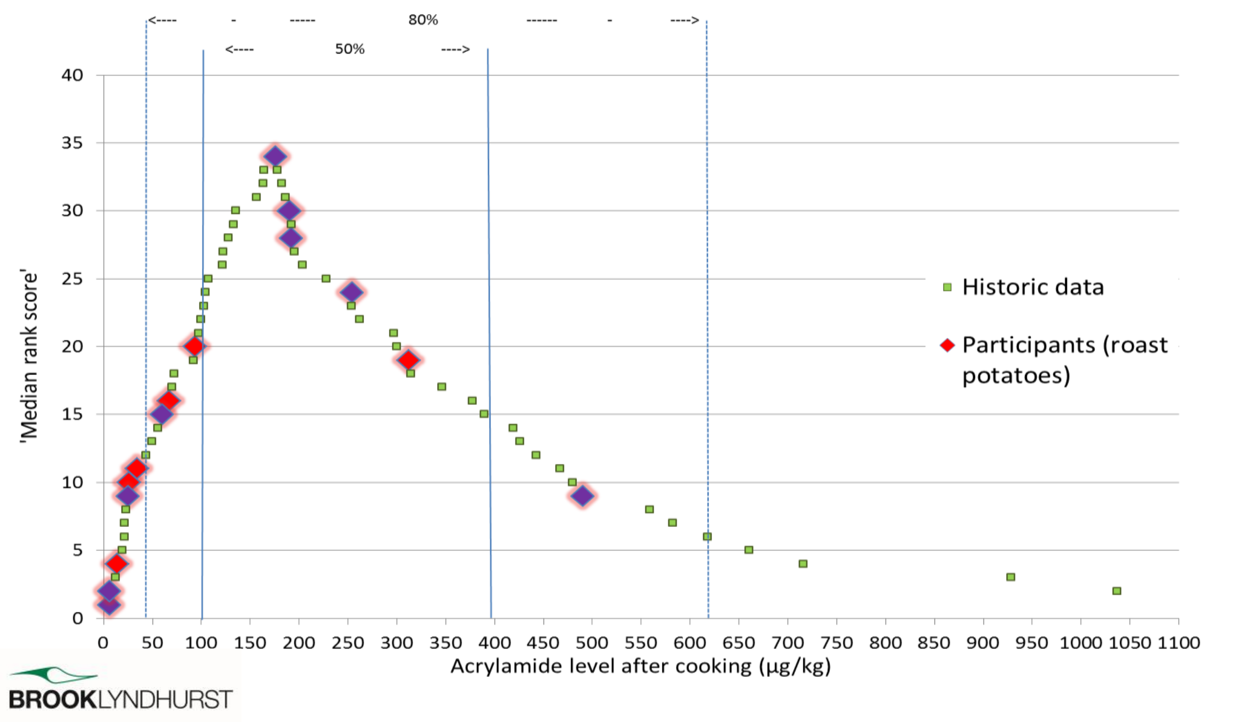
'Historic' data collected by the FSA's survey of acrylamide in UK retail products is not as extensive for roast potatoes as it is for chips. Only pre-prepared roast potatoes were sampled, and these were cooked according to manufacturer instructions. These samples provided the following data:

Table 3 – Acrylamide levels found in roast potato samples collected for the FSA survey

Number of samples	Median (µg/kg)	Min (µg/kg)	Max (µg/kg)	Mean (µg/kg)
52	**184**	13	3067	316

The graph below shows how the acrylamide levels in the 17 roast potato samples compared with the historic data[67].

Figure 13 – Chart showing the acrylamide levels of the collected roast potato samples in relation to historic acrylamide data[68].



There is a suggestion from this research that domestic acrylamide exposure from roast potatoes is generally lower than would be anticipated (based on comparative samples of pre-prepared roast potatoes prepared in line with manufacturer guidelines). Six of the fifteen samples collected had acrylamide levels that correspond with the lowest 10% of historic results (though four of these were from roast potatoes prepared from scratch which are not directly comparable to the pre-prepared potatoes in the historic data). Of course, a larger sample of participants (and indeed of baseline or historic data) would be needed to confirm this in any case.

High and low acrylamide levels

As with chips, historic acrylamide results for roast potatoes indicate a wide range of possible acrylamide levels, even before variable domestic behaviours are introduced. The tables in Appendix J.2 outline some of the key preparation and cooking behaviours undertaken by participants, and the final acrylamide results. Perhaps for the same reasons as outlined above, there appears to be no discernible pattern between particular practices that might be expected to increase acrylamide levels (e.g. cooking time and temperature) and the actual acrylamide level[69][70].

[67] As before, acrylamide levels from participants are shown as larger red markers (purple for those preparing homemade roast potatoes from fresh), while historic data is shown with smaller green markers. The y-axis is a 'median rank score', meaning that the median result is awarded the highest score (34) and the two results furthest from the median were given a score of 1.

[68] Please note that for ease of reading one 'historic' data point (acrylamide level 3067µg/kg) was removed

[69] It is notable, however, that the pre-prepared roast potato sample that was cooked at temperatures consistently above 200C had a markedly higher acrylamide content than other pre-prepared samples.

[70] There is not enough evidence in this study to look at size (or size preference) as a variable, largely because most participants cut potatoes for roasting to roughly the same size.

The expected link between colour and acrylamide level appears to have even more strength in roast potatoes than with chips, though the number of samples (e.g. nine prepared from fresh) is too small to definitively establish this correlation. The potatoes prepared from fresh with the highest acrylamide levels were considerably darker than those with lower levels, with a couple of samples appearing to sit neatly in the middle of this range (Figure 14).

Figure 14 – Samples of ‘from fresh’ roast potatoes demonstrating the link between colouration and acrylamide levels. Photographs from the PAS lab.

Highest levels: 490 µg/kg

Fourth highest levels (out of nine ‘from fresh’ samples): 190 µg/kg

Lowest levels: 6 µg/kg

BROOKLYNDHURST

The achieved colouration was sometimes explicitly sought by participants, with the darkest colours achieved by participants aiming for the potatoes to be ‘crispy’ or ‘brown all over’. Participants cooking to lighter colours still aimed for a particular colour and texture, but clearly did not share the same desire for browning.

The fact that there does appear to be the expected link between colouration and acrylamide levels, but not a clear link between cooking time/temperature and acrylamide levels requires investigation. Section 4.3 discusses potential explanations related to the preheating of the oven, temperature fluctuations, and the sharing of oven space with other foods. This study was also focused on qualitative and observational research, and as such the methods used to record actual oven temperature were limited. This dichotomy is therefore something that may be worth exploring in future research with a larger number of samples (Section 6.2).

5.4 Other potato products

5.4.1. Waffles

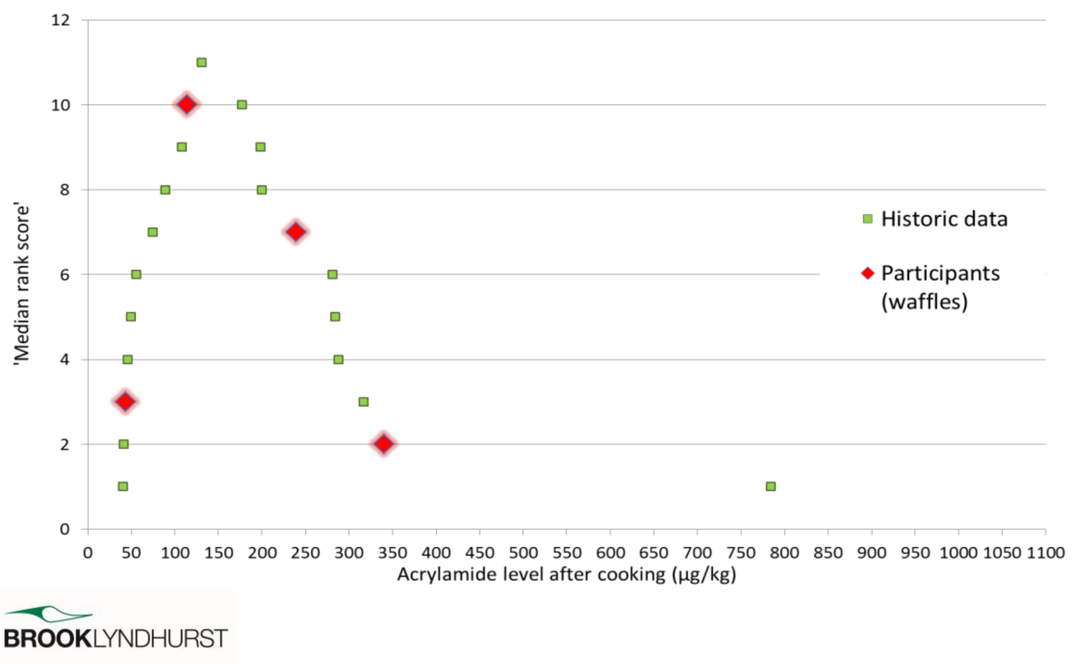
Four participants cooked waffles from frozen, all – coincidentally – by the same brand. The acrylamide levels of the four samples after cooking were:

- 44µg/kg
- 114µg/kg
- 239µg/kg
- 340µg/kg

Though it would appear to indicate that different cooking approaches have had an effect, there was no obvious conclusion to be drawn from the observational data. For example, the sample with the lowest acrylamide levels was actually cooked for the longest time.

Seventeen samples of waffles were collected for the FSA survey between 2007 and 2013, including waffles from four different brands. Acrylamide levels in these cooked samples were mostly spread between 40µg/kg and 314µg/kg, with one outlier at 784µg/kg. Figure 15 plots the distribution of these results.

Figure 15 – Chart showing the acrylamide levels of the collected roast potato samples in relation to historic acrylamide data[71].



5.4.2. Wedges

Four participants cooked wedges. One of these participants cooked pre-prepared wedges from frozen, and the collected sample had acrylamide levels of 37µg/kg. The other three participants cooked homemade wedges from fresh. The acrylamide levels of these three samples after cooking were:

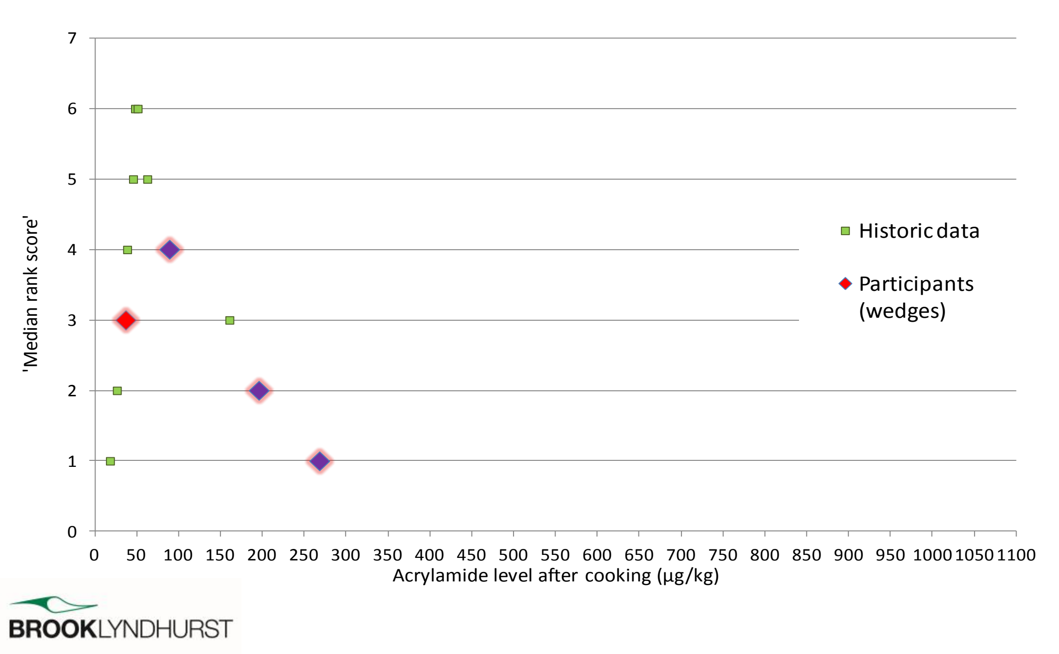
- 89µg/kg
- 196µg/kg
- 268µg/kg

There is nothing in the observational data which satisfactorily explains the different acrylamide levels accrued.

Eight samples of (rustic or lightly spiced) wedges were collected for the FSA survey between 2007 and 2009. Acrylamide levels in these cooked samples were mostly spread between 18µg/kg and 63µg/kg, with one (relative) outlier at 161µg/kg. Figure 16 plots the distribution of these results.

[71] Please note that for ease of reading one 'historic' data point (acrylamide level 3067µg/kg) was removed

Figure 16 – Chart showing the acrylamide levels of the collected samples of wedges in relation to historic acrylamide data.



5.4.3. Hash browns

Two participants cooked hash browns from frozen[72]. The acrylamide levels of the samples after cooking were:

- 119µg/kg
- 146µg/kg

The hash browns with lower levels (119µg/kg) were baked in an oven for 33 minutes, while the hash browns with higher levels were cooking in a Tefal 'Actifry' for 10 mintes.

Three samples of hash browns were collected for the FSA survey between 2007 and 2009. The acrylamide levels were:

- 59µg/kg
- 62µg/kg
- 72µg/kg

5.4.4. Jacket potatoes

Three participants cooked jacket potatoes: two from fresh and one pre-prepared jacket potato with cheese.

One of the 'from fresh' samples contained the lowest acrylamide levels in the study, at around ~1µg/kg. The participant had bought the potato loose (so the variety was unknown) and stored it in a basket in her larder. The potato was not washed, but was 'dry scrubbed' for about thirty seconds, before bits of the potato with any hint of sprouting were removed. The potato was then prodded with a knife to aid the

[72] Note that one of them cooked hash browns and hash brown waffles. These items were combined in the sample

heating of the centre of the potato, before being microwaved for six minutes (in two minute cycles). The potato was prodded with a knife after each two minutes, and after six minutes was declared soft enough to eat.

The pre-prepared potato was also microwaved, this time for six-and-a-half minutes (though it had already been partially cooked). This was a minute longer than the on-pack guidelines suggested. The acrylamide levels in the sample were 227µg/kg. A similar ‘ready baked’ jacket potato sample was collected for the FSA survey in both 2012 and 2013. These samples had acrylamide levels (after microwaving) of 159µg/kg and 185µg/kg.

The other freshly prepared jacket potato was microwaved for eight minutes and baked for a further 25 minutes. The sample from this potato contained acrylamide levels of 57µg/kg.

5.4.5. Other potato products

Further items such as ‘tray baked’ new potatoes, sautéed potatoes, potato croquettes, and fried potato (as part of a curry) were only cooked once each. The acrylamide levels from these samples can be found in Appendix J.3.

Of these samples, the most notable were some potatoes described as ‘sautéed potatoes’ by the participant. The potato was not washed, peeled or soaked and cut into chunks. The participant usually sautés them, but on this occasion they were deep fried for 11 minutes (Figure 17).

Figure 17 – The ‘sautéed’ potatoes. Photo from PAS lab.

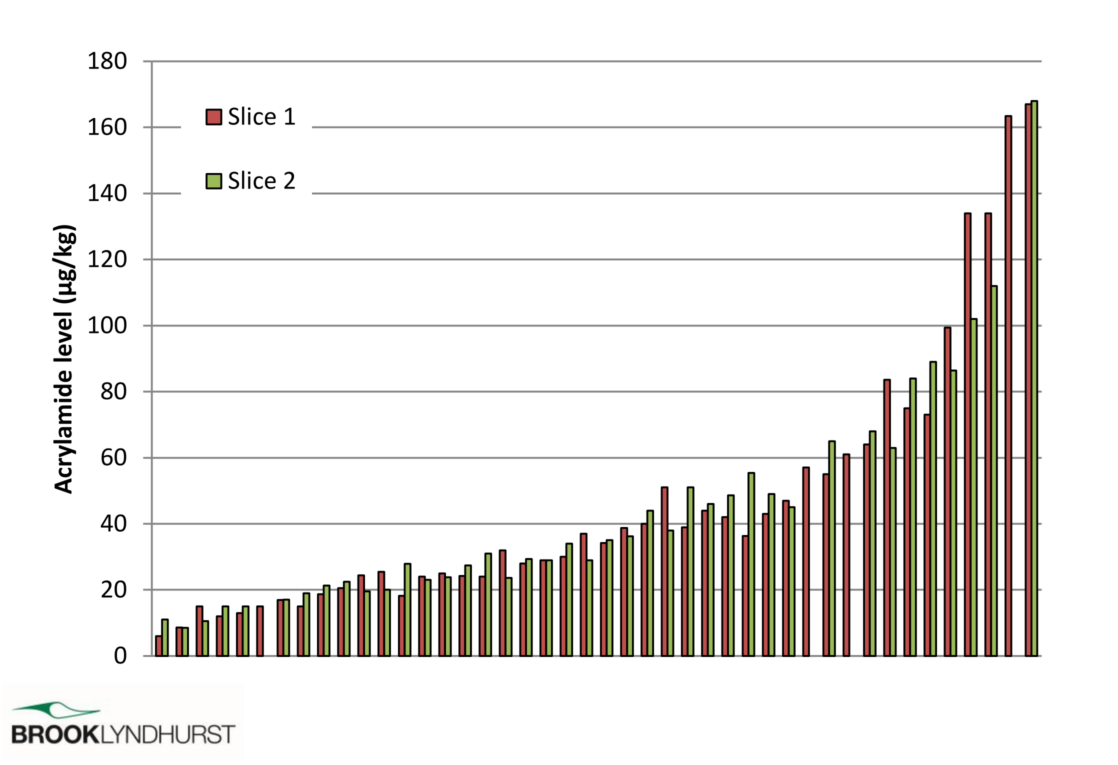
5.5 Toast

The FSA survey contains information on acrylamide levels of soft bread but not toast. Other sources were therefore required to provide guidance as to whether the results from this study are comparable to other ‘baseline’ results.

The EFSA draft consultation on acrylamide[73], for example, includes toast data from the HEATOX[74] study. Acrylamide levels before toasting in the HEATOX work were found to be 3µg/kg to 8µg/kg (fresh weight) in white breads and 29µg/kg to 42µg/kg in rye containing breads. The levels for toast after "medium" toasting were 16µg/kg to 61µg/kg, while 'heavier' toasting levels gave results ranged between 31µg/kg and 118µg/kg.

Forty-four participants submitted samples of toast. The samples ranged in acrylamide content from 6µg/kg to 168µg/kg. The median level was 34µg/kg, and the distribution of these results is plotted on the graph below (Figure 18).

Figure 18 – Chart showing the acrylamide levels of the collected samples of toast. The results from the two toast slices from each participant are presented together, where available.

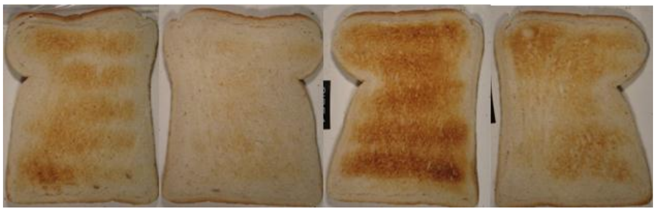


High and low acrylamide levels
The toast with the highest and lowest acrylamide levels are shown below.

[73] Available at: http://www.efsa.europa.eu/en/consultations/call/140701.pdf [Accessed 23 February 2015]
[74] HEATOX – Heat-generated food toxicants, identification, characterisation and risk minimisation. Project No. 506820. Deliverable reference number: 59. Guidelines to authorities and consumer organisations on home cooking and consumption. Available at: http://www.slv.se/upload/heatox/documents/d59_guidelines_to_authorities_and_consumer_organisations _on_home_cooking_and_consumption.pdf [Accessed 23 February 2015]

Lowest:

[9µg/kg and 9µg/kg]

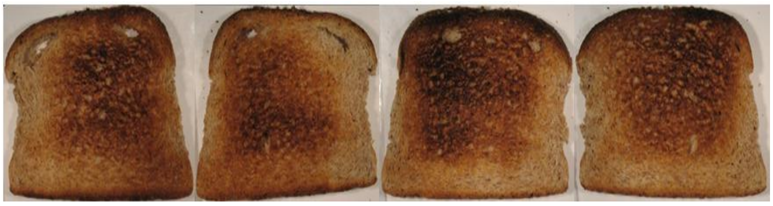


[6µg/kg and 11µg/kg]

Highest:

[167µg/kg and 168µg/kg]

[163µg/kg – only one slice provided]



[112µg/kg and 134µg/kg]

A few things are apparent from these images. Firstly, it is not a coincidence that the lowest levels of acrylamide were found in toasted white bread, and the toast with the highest levels of acrylamide is toasted brown bread. Brown bread contains naturally higher quantities of the precursors to acrylamide. Indeed, the five samples with the highest acrylamide were all brown or wholemeal toast, while the five samples with the lowest acrylamide were all toasted white bread.

Secondly, is that it is evident that toasters do not produce consistently cooked toast: coloration varies between slices cooked simultaneously in the same toaster, and from one side of the toast to the other.

Finally, the toast with the highest levels of acrylamide exhibits evidence of burning (dark brown and black colouration), while the toast with the lowest levels does not. As acrylamide is formed when foods are cooked at higher temperatures and/or for longer times, this finding is expected. This pattern also broadly confirms the findings from the study by Jackson and Al Tahler[75] which suggested that darker cooked toast

[75] Jackson, S. and Al-Taher, F. (2005). Effects of Consumer Food Preparation on Acrylamide Formation. Advances in Experimental Medicine and Biology. Volume 561, pp 447-465.

contains more acrylamide. While the general pattern is clear in this study, it is not entirely clear cut: some samples contained less acrylamide than others despite being cooked to a darker colour (and vice-versa[76]).

As discussed in Section 4.5, the colouration was usually a deliberate result of participants' preference. Preference for wholemeal toast, and/or for toast to be cooked to a darker colour, is therefore linked with higher acrylamide exposure. The study did not, however, explicitly investigate the frequency at which toast was eaten by participants.

5.6 Summary

Samples collected in this study were tested in the PAS laboratory and acrylamide levels were determined. The intention was to compare these results with FSA data from a large UK acrylamide survey dating back to 2007. This FSA data was to act as a 'control' group as the products in this survey were cooked in accordance with manufacturers' instructions.

The data from the FSA survey showed that acrylamide levels can vary dramatically from sample to sample, and even between samples of exactly the same product. As levels of 'reducing sugars' are influenced by aspects such as growing conditions and storage temperatures, it appears that these precursors to acrylamide formation (e.g. free sugars) vary significantly before cooking takes place.

The results collected and analysed in this study also varied significantly within the product types, with some samples displaying acrylamide levels multiple times higher than other, similar, samples. It was not possible to draw clear links between practices and acrylamide level data collected. Major contributors to acrylamide formation – cooking temperature and cooking time – were not neatly correlated with the acrylamide data returned from the PAS lab. Again, this may be due to natural variation in acrylamide precursors.

Nevertheless, chips and toast with the highest levels of acrylamide did look noticeably darker (more brown) than the corresponding samples with the lowest levels. Given that participants often only classed food as being 'done' after visual inspection for colour, this suggests that consumer preference does play a role in potential acrylamide exposure.

[76] NB this is true even if both samples were the same type of bread (i.e. brown or white)

6 Conclusions and future prospects

6.1 Conclusions

6.1.1. Consumer awareness

Awareness of acrylamide exposure appears to be low

No one in the study reported an aim to reduce acrylamide, but nor did anyone coincidentally follow best practice throughout the entire process. All participants could therefore have reduced the amount of acrylamide they are exposed to in potato products by altering their practices. Nearly everyone in the study was happy with their end product, however, so their systems and processes produced a result that they enjoy eating. Few practices that would reduce acrylamide exposure are compatible[77] with maintaining the colour, texture, and taste of the final product.

6.1.2. Storage

Domestic storage behaviours do not appear to significantly increase risk of acrylamide exposure

Few participants in this study kept potatoes in the fridge. Storing potatoes at low temperatures, such as those found in refrigerators, can lead to 'low temperature sweetening' – an increase in free sugars in potatoes that causes higher levels of acrylamide to be generated when cooked[78]. Those who did store their potatoes in the fridge had not done so for any great length of time (one to three days). On this (albeit limited) evidence, it appears unlikely that domestic storage is a major factor in acrylamide exposure.

Awareness of acrylamide appears to be low, and was apparently non-existent amongst the participants in this research. As such, storing potatoes in the fridge was considered an acceptable solution by many, with limited fridge space and 'habit' the main reasons given as to why this did not happen. As refrigerated storage space increases (e.g. the trend for 'American style' fridge-freezers), the risk of acrylamide exposure may therefore increase.

6.1.3. Preparation

Roast potatoes are parboiled, decreasing acrylamide exposure

Roast potatoes – made from fresh - were all parboiled by participants. This process removes free sugars from the potato and therefore reduces acrylamide generation when potatoes are cooked. The parboiling process was not usually formalised, however, with few people aiming for a particular time.

Parboiling was less common for people preparing products such as chips or wedges. This was because participants did not see the need for this process, and were concerned that the end product would be too soft if parboiling was done before oven cooking.

[77] Storage behaviours and washing might be exceptions.
[78] See Appendix C.1.1

Homemade potato items tend not to be finely chopped, avoiding the risk of additional acrylamide exposure through greater surface area to volume ratios
Homemade roasts and chips tended to be larger than their equivalent pre-prepared products, with few making extra effort for them to be thinly cut or small. This is particularly true of chips, which tended to be relatively ‘chunky’.

For roast potatoes, the deliberate fluffing up (shaking parboiled potatoes in a pan) that was witnessed on a few occasions is a deliberate attempt to increase surface area. Participants’ aim for this process is for cooked potatoes to be crispier (i.e. through more oil or fat being absorbed). The increased surface area may lead to greater acrylamide generation[79].

6.1.4. Cooking

Using manufacturers’ instructions as a proxy will misrepresent the realities of domestic cooking practices
This study clearly indicates that domestic cooking of potatoes (and potato products) bears very little resemblance to preparing food in a laboratory in accordance with manufacturers’ cooking instructions.

Manufacturers’ instructions are rarely read, particularly if items are cooked regularly. For products cooked from scratch these instructions are often not available, and nor are they sought. Instead, people have their own systems to find the combination of temperature and time that will work for them. Some of these systems seemed to be automatic and unexamined: the result of adaptation to kitchen equipment, and/or the influence of the cooking practices of family members.

Other systems were built around the preparation of a meal. For example, times and temperatures may be based on the roasting of a chicken, as opposed to the cooking of the roast potatoes.

Lack of attention to preheating may mean lower cooking temperatures
With much pre-heating happening haphazardly, it appears likely that foods were often exposed to lower cooking temperatures than intended for a portion of the cooking process. Temperature drops were also noted on some occasions as a result of opening the oven to check the food. Lower temperatures may lessen the formation of acrylamide in potatoes, but this effect was often offset by the fact that items are cooked for longer than expected[80], with minutes added to the original estimated cooking time[81] (possibly to compensate for these lower temperatures).

Times are used as guidelines
Few participants referred to cooking instructions or recipes, but all had a sense of how long items should be in the oven. These estimates tended not to be particularly accurate or important, however. Indeed, time – on its own – was not regarded as a suitable indicator that a product was ready to be consumed. Instead participants used the time as a guideline, and as the ‘final’ time approached this served as an indication that a more intense period of checking and assessment was required.

[79] Definitive evidence was not provided in this study, however. There were three samples that had been ‘fluffed up’ (of the nine roast potato samples prepared from fresh) and the acrylamide levels from these three all sat neatly in the middle of the range (see Appendix J2)
[80] Or, potentially, that higher temperatures are used or that the oven over shoots when ‘reheating’ after opening event. Both of these are aspects that could be investigated further in future research (Section 6.2).
[81] This observation corresponds with the findings in: Oliveira, L., Mitchell, V. and Badnia, K. (2012) Cooking behaviours: a user observation study to understand energy use and motivate savings. Work 41. pp2122-2128

Similarly, items were not necessarily turned halfway through the cooking process, but instead at a time when the cook deems it necessary.

Visual assessment is an important part of cooking
Even when timing devices were used, checking the oven was the primary means of judging how far through the cooking process the potatoes were. People appeared to have a strong sense of what the end product should look like, in accordance with their tastes (and those of other diners). Towards the end of the 'expected' cooking time participants felt confident that they were able to judge how much more time was required, based on a (largely) visual assessment of the state of the food.

The decision to end the cooking process was almost universally taken because the product had reached a desired level of colour and/or texture, as opposed to any other reason.

6.1.5. 'Doneness'

Colouration appears to show correlation with acrylamide levels: more so than increased cooking time and temperature
Most people stated a desire for 'crispy' and 'golden' potato products. Despite these same characteristics being almost universally desirable, these descriptors seem to cover a range of looks and textures based on personal preference. Any attempt to reduce acrylamide levels through provision of information would need to bear this in mind[82]. Those who preferred products towards the browner and/or crispier end of the spectrum do also – in general – appeared to generate more acrylamide when preparing these products.

Clearly, *appearing* more cooked is a product of being cooked for longer and/or at a higher temperature. Yet observations in this project do not reflect this in either *intended* cooking temperature or *observed* cooking temperature. Achieved oven temperature (and the stability of oven temperatures) during real-life cooking situations is therefore an area that requires further research.

6.2 Further work

Consumer awareness
Acrylamide appears to have low salience with the public. Evidence from this study indicates that consumer practices are driven by wanting to achieve a product of a desired colour and appearance, with little (if any) consideration for any potential safety issues. Any engagement which increases consumer knowledge of the potential risks may therefore have some impact on exposure.

Other food items
This study focused on a fairly narrow group of foods. Though it was felt that potatoes (and, to a lesser extent, toast) were the most appropriate items for study, there are many more food items in which the acrylamide levels could be influenced by domestic practices. These may involve different sets of processes, and research could help to better understand in-home practices (and the extent to which these differ from FSA guidelines and/or manufacturers' instructions).

[82] Personal preferences are less subtle and easier to articulate when it comes to toast, and clear visual differences can be seen between toast described as 'lightly done' and 'well done'.

Consumer behaviour

This work suggests that providing time or temperature guidelines that aim to lower acrylamide exposure may be a largely fruitless exercise. On-pack instructions are rarely read, while the unique understanding that participants had built up over how their ovens would work suggests that instructions would, in any case, be overruled.

This study highlights a number of key points in the preparation and cooking process at which consumer behaviour could be modified. If people became more aware that, for example, low temperature storage or not soaking/parboiling potatoes could increase the risk of being exposed to a potential carcinogen, this may alter practices. Similarly, it is apparently little-known that the darkened (burned) tips of chips contain far more acrylamide (per kg) than non-burned chips. If this information entered into the public consciousness and burned elements were not eaten (or were more actively avoided during cooking) then acrylamide exposure may be reduced. Further work is needed to determine the content of these kinds of messages and the best format in which to convey them to consumers. Appropriate messages could be delivered via a number of channels (including social media as well as more traditional media) and may need to be targeted at different groups of consumers.

It would be important for messages to be based on evidence of the consequences of long-term exposure to acrylamide, and the contribution of domestic cooking practices to acrylamide formation therefore requires further exploratory research and quantification. It is also essential that these messages do not cause unnecessary concern, so waves of iterative consumer testing would be recommended.

Provision of information and advice is often an unsuccessful approach, unless coupled with other 'behaviour change' strategies. If there is a desire to alter a particular behaviour, researching the potential of a range of Individual, Social and Material interventions may be necessary[83].

Understanding oven temperatures in context

This study has highlighted how many ovens appear not to provide a stable temperature during cooking. Some of this is due to user practices, such as opening the oven to perform a visual check, or turn potatoes, or to add another food item. Some of this appears not to be, with oven temperatures fluctuating (or - at least - failing to stabilise) whilst the oven door remains shut. There is even a suggestion that ovens can overshoot intended temperatures at times, perhaps over-compensating for heat lost through door opening. As such, further research into the temperatures to which food is actually exposed needs to be undertaken. This will help to explore further the relationship between oven cooking and acrylamide exposure.

Understanding more about pre-heating practices and the resulting deficiencies in temperature that this appears to cause would be another avenue for exploration.

Furthermore, there is an apparent paradox in this project: that darker food colouration is not necessarily achieved as a result of longer cooking times and/or higher temperature cooking. This apparent finding, therefore, also requires further interrogation.

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83 See Darnton and Evans' 'Influencing Behaviours' for a review of key theories: http://www.scotland.gov.uk/Resource/0042/00423531.pdf [Accessed 23 February 2015]