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CHEMICAL FOOD SAFETY
Acrylamide in New Zealand Food

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Summary

The objective of this project in the 2004/05 year was to identify the foods most likely to contribute significant amounts of acrylamide to typical New Zealand diets using the simulated diets from the 2003/04 Total Diet Survey and use this as the basis of selecting New Zealand foods for further testing. Where no New Zealand data existed, the proposal at this first assessment was to use overseas data for equivalent foods.

The initial assessment identified a number of foods that are significant components of the New Zealand diet that could potentially contain acrylamide but for which the overseas data was non-existent or ambiguous as to likely acrylamide content. These were foods such as beer that is prepared from dried and roasted malt or tea where the available information was for Japanese tea rather than black tea.

Other foods identified included roast kumara, a food containing sugars that is at least in part heated during cooking to significantly over 100°C.

Samples from the earlier analytical report with a significant content of acrylamide were retested, with results showing acrylamide levels that were approximately halved. The lower levels were due to the discovery that the selected analytical method, under some conditions, converted acrylamide precursors in samples to acrylamide at the GLC injection step.

Insertion of the new analytical data into the simulated diets showed that potato crisps and potato chips contribute approximately 40% of the acrylamide in these diets and total dietary intakes of acrylamide are between 0.9 to 2.4 µg/kg bw per day. These intakes are comparable with average estimated intakes internationally, which ranged from 0.3 to 2.0 µg/kg bw per day for the average member of the general population.

It should be noted that in the New Zealand diets, adults had acrylamide intakes of approximately 1 µg/kg bw per day but intakes were higher for younger children reflecting both the relatively larger amount of food per unit body weight consumed by this age group and their dietary preferences.

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1. BACKGROUND

It is now widely known that acrylamide may be present in many processed and cooked starchy foods. As a result WHO and the EU both recommended (WHO 2002, EC 2002) that levels of acrylamide in foods should be as low as reasonably achievable as acrylamide is a known neurotoxin and a potential carcinogen. In February 2005 the Joint FAO/WHO Expert Committee on Food Additives (JECFA) considered amongst other things, the risk posed by acrylamide and while they also came to no clear conclusion on the risk arising from acrylamide in foods, they did recommend that efforts to reduce acrylamide levels in foods should continue (JECFA 2005).

A number of countries continue to accumulate data on the acrylamide content of their foods although JECFA (2005) has noted that it would be useful to have more data from developing countries, as this would be useful in conducting intake assessments and in the consideration of approaches for mitigation. In terms of mitigation, there has been a significant amount of research on developing approaches that could be used to reduce acrylamide levels in particular foods. The most recent studies from overseas that are of significance to the potential problem of acrylamide in foods are therefore looked at below in terms of:

- Current WHO/FAO recommendations (JECFA 2005).
- Assessments of food consumption and dietary exposure to acrylamide.
- Reduction of acrylamide levels in foods.

AOAC International has published a special guest editor section on a survey of research activities related to acrylamide in foods (Anklam and Wenzl 2005).

1.1 Significance of Acrylamide to Public Health

The possible health risks from acrylamide have been considered by JECFA in their February 2005 meeting and they stated that effort to reduce acrylamide in foods should be continued (JECFA 2005, FAO 2005, WHO 2005), the approach that was recommended first by WHO (WHO 2002) following the discovery that food was a vehicle for acrylamide exposure. Acrylamide is still regarded as a known neurotoxin and a potential carcinogen and therefore is undesirable in the diet.

Other recommendations of JECFA (2005) included:

1. Acrylamide be re-evaluated when results of ongoing carcinogenicity and long-term neurotoxicity studies become available.
2. Work should be continued on using PBPK [physiologically-based pharmacokinetic] modelling to better link human biomarker data with exposure assessments and toxicological effects in experimental animals.
3. In addition, the Committee noted that it would be useful to have occurrence data on acrylamide in foods as consumed in developing countries. This information

will be useful in conducting intake assessments as well as considering mitigation approaches to reduce human exposure.

The picture as to the significance of dietary sources of acrylamide and its potential impact on human health remains incomplete. It is now known that acrylamide is rapidly and extensively absorbed from the gastrointestinal tract following oral administration (JECFA 2005) and once absorbed, it becomes widely distributed in the body. It is transferred to the foetus and is metabolised in the body to a chemically reactive epoxide, glycidamide, although both acrylamide and its metabolite are also rapidly eliminated in urine. Glycidamide is more reactive than acrylamide but the kinetics of its formation probably differ between species with the relative rate of formation being greatest in the mouse, less in the rat and less again in the human. However, the significance of these differences is not clear, as the half-life in each species is also different (JECFA 2005).

Epidemiological studies of human industrial and accidental exposures to acrylamide do exist and suggest that the nervous system is the principal site for toxicity in humans (JECFA 2005) but these studies have not shown any association of acrylamide with overall cancer mortality or with any statistically significant dose-related increase in cancer at any organ site except for a doubling of the risk of pancreatic cancer for workers with the highest cumulative exposure. However JECFA (2005) notes that these studies are based on low numbers of cases, they include no measurements of dietary exposure to acrylamide and potential confounders such as smoking were not considered.

1.2 Dietary Exposure to Acrylamide

A number of countries are starting to assess food consumption and dietary intakes of acrylamide. JECFA (2005) has estimated that a daily intake of 1 μg/kg bw[1] represents the average for the general population and 4 μg/kg bw represents the dietary intake of high level consumers; an assessment based on national intakes calculated mainly using deterministic modelling linking national individual consumption and body weight data with national mean occurrence data obtained from national surveys. Intake estimates at national level ranged from 0.3 to 2.0 μg/kg bw per day for the average member of the general population with higher percentile consumers (90th to 97.5th) having acrylamide intake estimates that ranged from 0.6 to 3.5 μg/kg bw per day, with intakes of up to 5.1 μg/kg bw per day for the 99th percentile consumer.

The acrylamide modelling studies (JECFA 2005) also showed that the major contributing foods to total exposure for most countries were potato chips (US=French fries) (16-30%), potato crisps (US=Chips) (6-46%), coffee (13-39%), pastry and sweet biscuits (US=Cookies) (10-20%) and bread and rolls/toasts (10-30%). Other food items contributed less than 10% of the total exposure.

[1] μg/kg bw = μg of acrylamide per kg of body weight. 1 μg/kg bw would be equivalent to 60 μg for a 60 kg person.

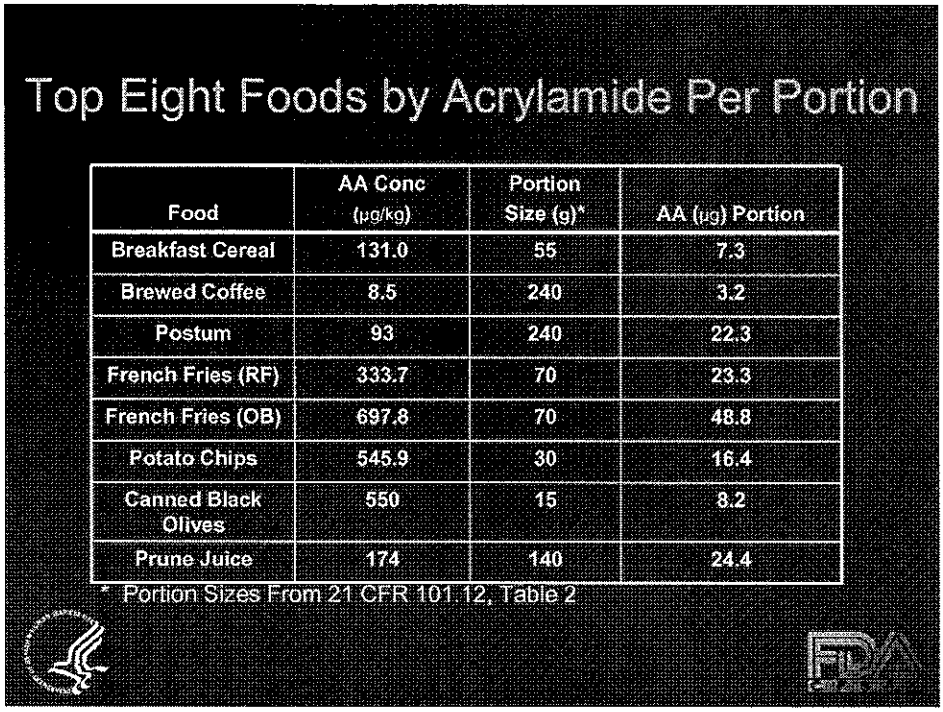
Based on the available data, children have intakes of acrylamide that were around two to three times those of adult consumers when expressed on a body weight basis. It is important to note that children have a high level of food consumption relative to body weight and that their eating patterns that include many of the foods with higher levels of acrylamide.

Mattys et al. (2005) have published a study on the dietary acrylamide intake of Flemish adolescents. This was based on a 7-day diet recall from 341 adolescents and analytical data on the range of acrylamide levels in food. These were then combined using probalistic modelling on varying diets and contamination levels so as to provide a probability representation for all possible individual diets and acrylamide intakes. This study showed a median dietary acrylamide intake of 0.51 μg/kg bw per day with a 95th percentile intake of 1.09 μg/kg bw per day with both the median and 95th percentile intakes being higher for boys as they have a higher food intake. Acrylamide intake from other studies noted in this paper (Mattys et al. 2005) range from a mean of 0.28 μg/kg bw per day for Switzerland to 0.8 μg/kg bw per day estimated for the United States. However, it is also noted (Mattys et al. 2005) that the differences in the absolute value of acrylamide consumption between these studies is probably due to differences between the sub-populations studied, differences in the food consumption questionnaires used, differences in the models used, differences in the number of food items tested and the resultant effects of extrapolation of analytical data to related foods.

The United Kingdom Food Standards Agency (2005) tested its 2003 Total Diet Survey samples for acrylamide and published an Information Sheet on the results obtained. This study showed estimated acrylamide intakes of between 0.3 μg/kg bw/day for adult females to 1.0 μg/kg bw/day for younger children and toddlers. However in the study the authors note that the potato sample included no crisps or fried potato products and most of the potatoes were prepared for consumption by boiling or steaming, or had been prepared from instant mashed potato. As the types of potato products not included are major contributors to the dietary intake of acrylamide, it is not entirely clear as to how well this study represents the United Kingdom diet. It emphasises the difficulty of adding a new study to an existing programme.

The FDA in the United States also has an on-going action plan to gather information relevant to developing an appropriate risk management response for dietary acrylamide (FDA 2004a). This action plan includes testing of foods, exposure assessment using both probalistic modelling of food intake distributions and exposure assessments from food consumption total diet studies, toxicological investigations and epidemiological studies. Levels of acrylamide in individual foods have been reported for their 2003 and 2004 market basket surveys for the approximately 280 core foods tested (FDA 2005). The eight top foods in respect to their contribution of acrylamide per portion were as shown in the table from a FDA presentation (FDA 2004b).

Table 1- Acrylamide contributions by US foods



Source of data: FDA (2004b)

(NB Postum is a coffee substitute made with chicory and roasted grains)

1.3 Approaches to Reduce Dietary Exposures to Acrylamide

The countries of Europe, those of the European Community and countries such as Switzerland, have probably been the most active in developing and testing approaches that could be used to reduce dietary sources of acrylamide. Appendix 1 provides a summary of European reports on these approaches.

2. MODIFICATION OF THE METHOD OF ANALYSIS

The method of analysis used was that reported by Grob (Biedermann et al. 2002). It is reported (Walz and Trinh 2005) that this method has become the basis of a common gas chromatographic mass spectral (GC-MS) approach for acrylamide analysis; it is relatively simple to carry out as it does not involve the complexity of derivative formation and the associated clean-up procedures. However, Zhang et al. (2005) have also noted that there is more potential for interference from similar molecular weight co-extractives when acrylamide is analysed by GC-MS without use of a derivative. However, they also point out that use of a derivative forming step may not be without problems and that the commonly prepared 2,3-dibromopropionamide derivative may be converted to 2-bromopropanenamide on the inlet during injection, an effect that will also result in poor repeatability and accuracy.

In taking part in the FAPAS Proficiency Programme run by the Central Science Laboratory in York, UK, we have found that the Grob method within ESR tended to give high results and investigations have shown that this relates to the temperature of the injection inlet. The original method reported use of a temperature of 210°C[2] but we have found that this can result in a significantly increased result for acrylamide. However, the results from the FAPAS supplied reference materials are close to the certified value if the injection temperature is lowered to 100°C and samples tested in the current year, plus repeated testing of selected samples from the previous year, have been carried out with this modification.

Our belief is that precursors of acrylamide formation, also inevitably present in the extract, are converted to acrylamide at injection with use of a high injection temperature with a resultant increase in the apparent acrylamide content. If this is in fact occurring, differences in design between injection ports and prior use of the instrument are likely to explain differences in the level of interference between laboratories.

Because of this problem, a selection of the foods tested in the 2003-04 year that contribute the greater proportion of acrylamide to the diet have been re-tested during the current year, together with new foods that appear likely to be significant contributors to the New Zealand diet and for which there is no local information on acrylamide content available.

[2] Analysts normally choose to run the injector at quite a high temperature as this gives flash evaporation of the solvent and volatile sample components thus giving a sharp peak for samples after the chromatographic separation. In the case of acrylamide, running the injector at 100°C was still sufficiently high to flash evaporate this more volatile analyte while eliminating the possibility of acrylamide formation during the injection step.

3. RESULTS FROM ACRYLAMIDE TESTING 2005

Testing in the 2004/05 year was targeted on:

- Check re-testing of earlier foods reported from the 2003-04 year using the modified method (lowered GLC injector temperature).
- Foods that appeared to have a potential to contribute to the dietary exposure of New Zealanders to acrylamide but for which there was limited overseas information.
- Local foods, unlikely to be represented in overseas testing programmes.

The second group included products like beer as this is made from heated and dried malt and black tea as this is made from the heated and dried leaves following their fermentation, while the third group included foods like roast kumara. Testing also included a number of coffees as overseas data suggest these contain appreciable amounts of acrylamide, a result not confirmed by the original single New Zealand example tested.

Results obtained from this testing are shown in the table below.

Table 2 - Results from products re-tested using the modified method

Food	Acrylamide (µg/kg)
Potato Crisps (1): Salt and Vinegar	2320
Potato Crisps (2): Onion Crinkle Cut	2260
Potato Crisps (3): Thick Cut Salt & Vinegar	1580
Potato Crisps (4): Salt & Vinegar	1440
Potato Crisps (5): Salt & Vinegar	2110
Potato Crisps (6): Salt & Vinegar	910
Potato Crisps (7): Original	370
Corn Crisps (1): Nacho Cheese	340
Corn Crisps (2): Nacho Cheese	200
Cereal: wheat biscuits Oat Bran	260
Hot Chips (1)	300
Hot Chips (2)	230
Hot Chips (3)	510
Hot Chips (4)	510
Hot Chips (5)	440
Hot Chips (6)	330
Yeast extract marmite	190

The next table shows the additional foods tested for acrylamide in 2005. the results reported for most foods is the mean of the two determinations.

Table 3 - Additional Foods Tested for Acrylamide in 2005

Food	Acrylamide (µg/kg)
Coffee (1):	ND
Coffee (2)	10
Coffee (3)	10
Coffee (4)	40
Beer(1) Dark	ND
Beer (2) Lager	10
Beer (3)Lager	10
Beer (4) Dark	15
Beer (5) Draught	5
Beer (6) Bitter	30
Beer (7) Lager	10
Beer (8)	10
Tea (1) tea bag	5
Tea (2) tea bag	15
Tea (3) tea bag	ND
Tea (4) tea bag	20
Tea (5) tea bag	20
Coffee (1) Instant Coffee	55
Coffee(2) Instant Coffee	10
Coffee(3) Instant Coffee.	10
Coffee(4) Instant Coffee	0
Coffee(5) Instant Coffee	5
Red **kumara** - peeled. Baked for 0.5 hrs at 150°C. 5/5/05	35

Food	Acrylamide (µg/kg)
Red **kumara** - peeled. Baked for 1.0 hrs at 150°C. 5/5/05	15
Orange **Kumara** - peeled. Baked for 0.5 hrs at 150°C. 5/5/05	15
Orange **Kumara** - peeled. Baked for 1.0 hrs at 150°C. 5/5/05	10
Pizza: Ham & Pineapple, 500g BB 12/05, Heated in Oven	8
Pizza: Hawaiian Pizza, Heated in Oven	6

3.1 Comments on results

Results in table 3 that could be of interest include:

- The significantly higher acrylamide content of Beer (6) compared with the other beers. However, not too much significance should be taken from a single sample.
- The lower level of acrylamide in both types of roasted kumara after they had been cooked for the longer time.
- The wide difference in acrylamide contents between different brands of coffee. Although the highest in brewed coffee at 55 µg/kg is still quite low compared with some products, it could still be quite significant as the volume of coffee consumed can be quite large.

4. MODELLING NEW ZEALAND DIETARY ACRYLAMIDE INTAKES

Any action to reduce the dietary intake of acrylamide needs to focus on the most significant sources. In a number of countries this is being assessed by use of probabilistic modelling of possible intakes using actual diets and the actual range of acrylamide content of the component foods. This approach will obviously give the best indication of the more extreme acrylamide intakes within the community but requires both the compositional and individual diet information with the latter being available through the 1997 National Nutrition Survey and the more recent 2002 National Children Nutrition Survey. Methodologies for the first survey are described in Quigley and Watts (1997) and a similar approach with appropriate modifications was followed for the second.

4.1 Choice of Model

Obviously probabilistic modelling simulations of individual diets and compositional ranges gives the best information on the range of acrylamide intakes, especially those arising from less typical diets that may lead to abnormally high intakes of acrylamide. However, it requires a great deal of analytical data and is probably only warranted for New Zealand once there is international agreement on what is an acceptable acrylamide intake. With more limited information, the typical simulated diets used in the New Zealand Total Diet Survey provide a means of showing which are the major dietary sources of acrylamide and likely levels of intake of the average New Zealander.

Simulated diets do have limitations in that they only represent people with typical diets for the group being studied. They exclude people with distinctly atypical diets and exclude any bias that may be introduced by personal preferences to particular brands or varieties of food. For example, the seven samples of potato crisp tested had acrylamide contents that ranged from 370 µg/kg to 2300 µg/kg. If these differences represent real differences between brands related to the manufacturers choice of raw material, storage conditions used and manufacturing process employed rather than batch to batch differences, then any brand preference by the consumer could significantly bias their dietary intake of acrylamide away from the value represented by average values and the simulated diet. It is unlikely that the measured range from these 7 samples of potato crisps fully represents the range of acrylamide levels in potato crisps on the New Zealand market. Other brands and products will almost certainly have higher or lower levels.

Probabilistic models based on individual diets and distribution models of the component have the potential to provide a more complete picture than simulated diets of the potential range in dietary intakes of acrylamide. However, this also requires much more data on food composition and market share for that food together with a full range of individual diets. In New Zealand, the 24 hour diets from the National Nutrition Survey (MOH 1999) does provide the required individual diets although some

of the variation between short term 24 hour diets may overstate the variation between individuals that is relevant to acrylamide intakes in that average exposures over a number of days may be more significant than exposures based on individual 24 hour diets.

In the present case, the simulated diet model was selected as being more appropriate for the relatively limited amount of data available on individual New Zealand foods. In this model, the median value, rounded to no more than 2 significant figures, has been used where analytical values from more than one example of an individual food was available.

4.2 Model Results for Dietary Acrylamide Intakes

Appendix 2 (table 6) shows results from combining the simulated diets used for the 2003/04 Total Diet Survey (Brinsdon 2004) with the mean levels of acrylamide found in these foods using New Zealand data where this is available and European and United States data for other foods. Table 4 below shows daily intakes of acrylamide estimated for the typical New Zealanders represented by the simulated diets used for the 2003 Total Diet Survey (Brinsdon 2004) and body weights for the typical consumer represented by these adult diets (MOH 1999) children diets (MOH 2003) and infant diets (NHMRC 2005). These infant body weights (NHMRC 2005) are Australian data but no equivalent New Zealand data could be located and New Zealand infants are likely to be of similar weight.

Table 4 - Acrylamide Intakes µg/kg bw per day

Simulated Diet	Acrylamide Intake (µg/day)	Weight (kg)	Acrylamide Intake µg/kg bw per day
25+ yrs (Male)	71	83	0.85
25+ yrs (Female)	52	71	0.74
19-24 yrs (Male)	77	78	0.99
11-14 yrs (Male)	84	54	1.56
11-14 yrs (Female)	77	55	1.41
5-6 yrs (M&F)	54	23	2.34
1-3 yrs (M&F)	29	13	2.25
6 - 12 mths (M&F)	15	9	1.72

These estimates of acrylamide intakes can be compared with those published by JECFA (2005) which estimated typical levels of acrylamide intakes for the general adult population of around 1 µg/kg bw per day with 4 µg/kg bw per day being the dietary intake for high level consumers. They also noted that intakes of children tend to be higher than for adults.

In table 4, adult males and females have acrylamide intakes typical of those found internationally. The intakes for children and infants are higher than adults and reflect the proportionally greater amount of food consumed by children relative to their body mass. In addition, inspection of the simulated child diets shows that they include a higher proportion of potato chips and crisps and this will also contribute to the increase in the total intake of acrylamide as these two foods are amongst the foods with the highest acrylamide content.

4.3 Most Significant Dietary Sources of Acrylamide

Table 6 in Appendix 2 shows that potato crisps and chips are significant sources of acrylamide in all simulated diets and that they contribute up to 36% of the total acrylamide in the diets of children aged 11-14 years. Other significant contributions of acrylamide to all the diets include bakery items, biscuits, cakes, scones and muffins and for adults, coffee and tea while foods such as wheat biscuits are significant sources for infants. In child diets, there is a proportionally higher intake of acrylamide coming from potato products and even in the diet representing infants of below 3 years of age; potato products are a very significant source.

Roast kumara is a food with significant sugar that is cooked at least in part to well above 100°C. Table 6 however, shows that it is of relatively low importance as a contributor to dietary acrylamide intake.

Table 5 shows a list in order of importance[3] of the ten foods that contribute most to dietary intakes of acrylamide. This table shows a list of the twelve foods that on average contribute most acrylamide to all diets placed in descending order of importance, together with the order of importance of each of these 12 foods in the individual diets. It should be noted that some of these 12 foods have relatively low importance in one or more of the individual diets, as shown by the order of importance of that food in that diet being less than the 12th most important.

In general, table 5 shows that the order of importance of many of these 12 foods listed is similar in most of the diets and tends to reflects the overall importance of that food as a source of acrylamide. There are some differences between adults and children in that biscuits and cakes are relatively more significant for children and between males and females in that potato based products slightly less significant as sources of acrylamide in the diets of females.

[3] This order of importance is based on an average of the orders of importance of these foods in each of the simulated diets. It deriving this list, the food in each diet that contributed most acrylamide to that diet was assigned an order of importance of 1, the next most significance 2, etc. The orders of importance for that food over all diets were then summed and the foods placed in ascending order based on this sum.

Table 5 - The Twelve Foods in Descending Order of Importance that Contribute most Acrylamide to the Diet

Food from Food List	Overall Order of Importance	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Potato, hot chips	1	1	2	1	1	3	3	1	1
Potato crisps	2	7	5	2	2	1	2	3	2
Potatoes, peeled, roast	3	2	7	4	3	2	1	5	5
Muffin/scone	4	3	1	11	6	4	5	6	8
Biscuit, chocolate	5	13	11	10	4	4	4	4	6
Wheat biscuits	6	11	12	12	5	7	6	2	3
Bread, white	7	15	14	14	8	8	7	10	11
Biscuit, cracker	8	19	13	21	12	12	9	7	7
Pasta, dried	9	16	14	8	11	15	13	14	10
Rice, white	10	12	9	7	9	14	9	23	24
Soup, prepared	11	10	10	9	14	13	15	21	20
Cake	12	9	8	5	19	11	21	16	25

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6. APPENDIX 1 - REDUCTION OF ACRYLAMIDE LEVELS IN FOODS

Acrylamide is formed when foods low in protein and high in carbohydrates are subjected to elevated temperatures during cooking or processing with significant amounts being formed if temperatures exceed 120°C (JECFA 2005). Under normal conditions, the temperature of food will not raise to significantly above 100°C, the boiling point of water, unless the moisture content is reduced significantly as occurs on the surface of food during frying or baking, or during cooking under pressure.

The amount of acrylamide formed depends on the exact time and temperature used to cook and process the food but may also show large variations between brands of similar products and between batches of the same product. Obviously, one approach to reduction of acrylamide formation would be a reduction in the temperature used for cooking and processing (JECFA 2005) but this could have other negative implications. For instance, University of Auckland and the Auckland Public Health Unit carried out a study of the amount of fat associated with potato chips and found that use of lower temperatures was associated with higher fat contents with frying temperatures used ranging from 136-233°C (Morley-John et al. 2002). They recommended that the desirable range for frying was 175-190°C as this minimised fat up-take while maintaining product appearance, whereas Fiselier and Grob (2005) have recommended frying temperatures of no higher than 170°C to minimise acrylamide formation.

The reduction of fat content by using the desired frying temperature is likely to be of greater benefit than any increase in the acrylamide content of the chips fried at this temperature compared with similar chips fried at lower temperatures. However the other recommendations of Morley-John et al. (2002), such as using thicker 12mm chips rather than thinner 6-10mm chips, will almost certainly help in lowering both the acrylamide and fat content of the chips.

The European Food Safety Authority, part of the European Commission Directorate-General for Health and Consumer Protection has a summary of research activities in Europe involving investigations of acrylamide in foods. Within this programme, Study Area 3 is directed at research into ways of reducing levels of acrylamide in food and in the February 2005 summary (EC 2005), there are 40 studies in this area. However, a number of studies appear to be similar and these are considered together in the list below. The type of studies being carried out in the European Union include one or more studies on:

- Acrylamide formation in potato products prepared from different raw materials and using different processing conditions.
- The formation of acrylamide in various model systems and evaluation of strategies for decreasing and avoiding its formation.
- The reduction of acrylamide formation in bread, potato products and cereals.
- The influence of a water-leaching step when processing chips and of processing temperature on chip quality and on acrylamide formation.

- The influence of flours and other ingredients on acrylamide formation in cereal products.
- Use of a pilot plant to investigate the effect of time temperature combinations and the effect of the other ingredients on acrylamide formation in bread and crisp breads.
- Reduction of reducing sugars in stored potatoes by means of site selection, agrometry, the variety of potato and storage conditions.
- Investigation of the mechanism of acrylamide formation in various food matrices with investigations to include baked goods, breakfast cereals, fried potato crisps and oil used in the frying process.
- The reduction of free asparagine content by investigation of milling technologies and selection of cereal species with a low asparagine content.
- The identification of the rate limiting substances in the raw materials used for frying and baking so as to develop better approaches to reduce acrylamide formation.
- A study on the formation of acrylamide during roasting of almonds.
- A study on the formation of acrylamide in typical situations of domestic food preparation.

Completed studies show:

- A reduction of acrylamide formation following blanching of potato slices to reduce their content of glucose and asparagine. The greatest reduction followed blanching at 50°C for 70 minutes (Pedreschi et al. 2004).
- A reduction of acrylamide formation by addition of flavonoid spices to foods prepared in heated fat (no report published).
- The influences of the frying oil and of additives designed to prolong the life of the cooking oil on the formation of acrylamide in deep fried potatoes (Matthaus et al. 2004).
- The effect of cooking temperature on the level of acrylamide formed in a starch based model system and in dry cereals. The amount formed went through a maximum at a cooking temperature of 180-210°C irrespective of the levels of glucose and asparagine present and the amount of acrylamide decreased with time except in the crust where it increased with time (Bråthen and Knutsen 2005).
- In oven-baked potatoes, acrylamide formation was strongly collated with the sugar content of the potato. The amount of acrylamide formed could be increased 10 fold while still maintaining time temperature combinations within the normally accepted range. Pretreatment by blanching (90°C for 4 minutes) or soaking (room temperature for 2 hours) reduced acrylamide formation by 10% and 20% respectively but it was also shown that blanching and pre-frying did not fully de-activate the enzymes liberating sugars (2005).
- That the storage of potatoes at around 4°C leads to a significant increase in acrylamide levels following frying or roasting of the potatoes (Amrein et al. 2003).
- That the optimisation of pre-treatment and end-frying can produce low acrylamide French fries. It is possible to produce French fries of high culinary

acceptability with less than 100 µg/kg of acrylamide (Grob 2003) and results from a pilot study of restaurants and from frozen pre-fabricated products using this approach have also been reported (Fiselier et al. 2004a). As a result, it was proposed that a legal limit for reducing sugars in pre-fabricates for French fries of 0.7 g/kg and a frying temperature of below 170°C should be introduced. This approach would reduce average acrylamide concentrations to below 50 µg/kg and be a simple and efficient means of limiting acrylamide intake from the diet (Fiselier and Grob 2005).

- That the coating of potato croquettes with egg/breadcrumb mixtures will reduce acrylamide formation in the product (Fiselier et al. 2004b).
- The influence of reducing sugars on acrylamide formation leading to a suggestion that potatoes sold for baking should contain less than 1 g/kg fresh weight of reducing sugars (Biedermann-Brem et al. 2003). The study noted that roast potatoes produced from potatoes with less than 0.2 g/kg of reducing sugar are unsatisfactory in terms of quality and that acrylamide levels of above 500 µg/kg are produced from potatoes containing more than 1 g/kg of reducing sugar.

These research efforts in a number of countries have identified a number of approaches that could be used to reduce acrylamide levels in foods and there are already some practical examples of these approaches being applied to potato products with reduction of reducing sugar appearing to be one of the better options. However, recommendations such as lowering the temperature of frying for French fries to 170°C to reduce acrylamide formation is not consistent with other recommendations of using temperatures in the range 175-190°C (Morley-Johns 2002) determined as being the optimum for reducing the fat content of the chips (French fries). In any approach to reducing acrylamide formation, consideration has to be given to other consequences, for instance are some of the suggested blanching and soaking regimes consistent with maintenance of, for instance, vitamin C levels in potato products?

6.1 Pilot Project Procedure to Reduce Acrylamide in Chips

The key points in the procedure for preparing high quality French fries, low in acrylamide, and used in the pilot project carried out by Fiselier et al (2004a) involved:

1. Use of potatoes low in reducing sugars, of intermediate starch content and with yellow flesh.
2. Sticks cut to at least 7mm.
3. Extraction of sticks in standing warm water for some 15 minutes or their blanching in hot water for several minutes.
4. Pre-frying in oil (e.g. 2-3 minutes at 140°C).
5. Frying in oil starting at about 170°C, which then drops to 145-150°C.
6. The stopping of frying when crispness is achieved and the points of the chips show slight browning (flavour) but before the onset of general browning.

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7. APPENDIX 2 – ACRYLAMIDE INTAKES ESTIMATED USING TDS SIMULATED DIETS.

7.1 Average Contribution of Acrylamide (µg/day) to the Daily Diet

Table 6 lists the amount of acrylamide in µg/day contributed by each food in the simulated diets. In calculating these amounts, it is assumed that intakes over the fourteen day period represented by the simulated diets can be averaged by assuming an equal contribution from each food on each day. In reality, only some foods will be eaten in approximately equal amounts every day while others will only be consumed occasionally. This assumption may not be appropriate if in the future, it is determined that in any dietary effects from acrylamide, the maximum consumption over a short time frame is more important than a longer term average consumption.

Table 6 - Contribution of Acrylamide to Daily Diets

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Apple based juice	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apples	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apricots, canned	0.04	0.04	0.02	0.02	0.03	0.04	0.04	0.05
Avocado	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bacon	0.29	0.14	0.32	0.16	0.07	0.07	0.11	0.07
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beans	0.09	0.08	0.08	0.07	0.05	0.03	0.01	0.02
Beans, baked	0.65	0.43	0.54	0.54	0.49	0.49	0.54	0.33
Beef,rump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beef, mince	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Beer	3.86	0.32	3.64	0.00	0.00	0.00	0.00	0.00
Beetroot	0.02	0.03	0.02	0.02	0.02	0.01	0.00	0.00
Biscuit, chocolate	1.93	1.50	2.14	6.64	5.36	4.29	2.46	0.96
Biscuit, cracker	1.10	1.10	0.63	1.10	1.10	1.10	0.94	0.79
Biscuit, plain sweet	0.40	0.34	0.46	0.49	0.51	0.51	0.94	0.37
Bran flake cereal, mixed	0.41	0.41	0.54	0.57	0.57	0.20	0.41	0.27
Bread, mixed grain	0.79	0.77	0.40	0.36	0.38	0.47	0.06	0.00
Bread, wheatmeal	0.77	0.60	0.60	0.63	0.38	0.32	0.25	0.16
Bread, white	1.67	1.00	1.51	2.51	1.81	1.71	0.61	0.38
Broccoli/Cauliflower	0.10	0.14	0.10	0.09	0.06	0.06	0.05	0.03
Butter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cabbage	0.14	0.12	0.10	0.10	0.07	0.04	0.01	0.01
Caffeinated beverage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cake	2.75	2.21	3.86	0.71	1.14	0.43	0.43	0.14
Canned fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capsicum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonated drink	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carrot	0.20	0.16	0.17	0.13	0.11	0.11	0.08	0.05
Celery	0.02	0.03	0.02	0.04	0.02	0.01	0.01	0.00
Cheese	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chicken	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chicken nuggets	0.02	0.02	0.07	0.06	0.04	0.03	0.04	0.02
Chinese takeaway dish	3.86	3.86	4.29	2.57	2.14	0.00	0.00	0.00
Chocolate beverage	0.36	0.36	0.36	0.64	0.57	0.57	0.21	0.07
Chocolate, plain milk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coffee beans ground	1.36	0.86	0.29	0.00	0.00	0.00	0.00	0.00
Coffee instant	3.00	3.39	1.25	0.07	0.11	0.00	0.00	0.00

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Confectionery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corn, canned	0.08	0.06	0.04	0.05	0.04	0.06	0.02	0.02
Corned beef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cornflakes	0.55	0.35	1.18	0.86	0.55	0.90	0.47	0.24
Courgette	0.03	0.03	0.02	0.03	0.01	0.01	0.01	0.01
Cream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cucumber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dairy dessert (Child)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish fingers (Child)	0.00	0.00	0.00	0.02	0.03	0.03	0.03	0.03
Fish in batter	0.30	0.21	0.43	0.21	0.13	0.17	0.10	0.05
Fish, fresh	0.60	0.39	0.43	0.36	0.15	0.10	0.06	0.03
Flavoured snacks (Child)	0.00	0.00	0.00	0.93	0.96	0.79	0.43	0.25
Fruit drink, powdered	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grapes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ham	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hamburger, plain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Honey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Icecream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Infant & Follow on formula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Infant weaning food, cereal based	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
Infant weaning food, custard / fruit dish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Infant weaning food, savoury dish	0.00	0.00	0.00	0.00	0.00	0.00	0.43	1.21
Instant noodles	1.25	0.75	1.07	1.07	1.64	1.07	0.57	0.18

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Jam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kiwi fruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kumara, roast	0.09	0.09	0.04	0.03	0.08	0.02	0.03	0.03
Lamb/Mutton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lambs liver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lettuce	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Margarine/Table spread	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Meat pie	0.73	0.28	1.82	0.77	0.69	0.43	0.19	0.11
Melon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milk, flavoured	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milk, trim (0.5%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milk, whole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milk, soy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muesli	0.26	0.29	0.29	0.11	0.10	0.04	0.04	0.00
Muffin/scone	4.29	5.25	1.93	3.64	5.36	3.00	1.50	0.75
Mushrooms	0.04	0.06	0.04	0.04	0.03	0.01	0.01	0.01
Mussels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nectarines	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onion	0.25	0.18	0.21	0.12	0.08	0.07	0.01	0.01
Orange juice	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oranges	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oysters	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pasta, dried	1.43	1.00	2.32	1.39	0.96	0.79	0.54	0.39
Peaches, canned	0.03	0.04	0.03	0.02	0.03	0.04	0.04	0.04
Peanut butter	0.21	0.11	0.21	0.50	0.32	0.43	0.14	0.00
Peanuts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Pears	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peas	0.18	0.14	0.14	0.12	0.09	0.06	0.04	0.03
Pineapple	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pizza	0.48	0.28	0.75	0.32	0.39	0.28	0.15	0.09
Pork chop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potato crisps	3.75	3.75	12.32	15.00	16.61	9.64	3.75	1.61
Potato, hot chips	9.54	4.71	17.79	15.00	12.00	6.86	4.50	1.93
Potatoes, peeled, boiled	0.89	0.46	0.56	0.22	0.21	0.17	0.14	0.09
Potatoes, peeled, roast	6.39	3.32	4.00	14.68	13.64	11.00	1.79	1.07
Potatoes, with skin	0.14	0.14	0.25	0.32	0.26	0.20	0.04	0.03
Prunes	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Pumpkin	0.14	0.10	0.07	0.04	0.04	0.03	0.06	0.05
Raisins/Sultanas	0.04	0.02	0.02	0.02	0.02	0.02	0.07	0.05
Rice, white	2.25	2.00	2.50	1.80	1.00	1.10	0.28	0.15
Rolled oats	1.70	0.75	0.30	0.38	0.40	0.35	0.60	0.35
Salad dressing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sausages, beef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silverbeet	0.05	0.05	0.06	0.03	0.02	0.02	0.01	0.01
Snack bars	0.43	0.43	0.43	1.71	1.64	1.64	0.43	0.29
Soup , prepared	2.50	1.86	2.29	1.07	1.07	0.71	0.36	0.21
Spaghetti in sauce (canned)	1.09	0.81	1.09	1.09	0.81	0.65	0.81	0.54
Strawberries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taro	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00
Tea	4.21	4.71	0.79	0.18	0.18	0.14	0.00	0.00
Tomato	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tomato sauce	0.09	0.05	0.18	0.08	0.05	0.03	0.04	0.02

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Tomatoes in juice	0.13	0.09	0.16	0.08	0.05	0.04	0.03	0.03
Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat biscuits	2.41	1.11	1.86	3.71	1.86	2.79	3.90	1.30
Wine, still red	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wine, still white	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yeast extract	0.34	0.27	0.34	0.27	0.20	0.27	0.34	0.34
Yoghurt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL µg/day	**70.75**	**52.11**	**77.40**	**83.86**	**76.73**	**54.48**	**29.19**	**15.44**

7.2 Proportion of acrylamide contributed by each food in the diet.

Table 7 shows the calculated proportion of acrylamide in the simulated diets that is contributed by each food and estimated as a percentage of the total acrylamide intake from that diet. Where the contribution is less than 0.5%, the contribution is essentially irrelevant to the intake from that diet. These values have been removed from the table so as to highlight better the contributions made by the more significant components. For all diets, these minor components contributed less than 5% of the total acrylamide.

Table 7 - Proportion of Acrylamide Contributed by each Food (%)

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Apple based juice								
Apples								
Apricots, canned								
Avocado								
Bacon								
Banana								
Beans								
Beans, baked	0.9	0.8	0.7	0.6	0.6	0.9	1.9	2.1
Beef, rump								
Beef, mince								
Beer	5.5	0.6	4.7					
Beetroot								
Biscuit, chocolate	2.7	2.9	2.8	7.9	7.0	7.9	8.4	6.2

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Biscuit, cracker	1.6	2.1	0.8	1.3	1.4	2.0	3.2	5.1
Biscuit, plain sweet	0.6	0.7	0.6	0.6	0.7	0.9	3.2	2.4
Bran flake cereal, mixed	0.6	0.8	0.7	0.7	0.7		1.4	1.7
Bread, mixed grain	1.1	1.5	0.5			0.9		
Bread, wheatmeal	1.1	1.2	0.8	0.8		0.6	0.8	1.0
Bread, white	2.4	1.9	2.0	3.0	2.4	3.1	2.1	2.5
Broccoli/Cauliflower								
Butter								
Cabbage								
Caffeinated beverage								
Cake	3.9	4.2	5.0	0.9	1.5	0.8	1.5	0.9
Canned fish								
Capsicum								
Carbonated drink								
Carrot								
Celery								
Cheese								
Chicken								
Chicken nuggets								
Chinese takeaway dish	5.5	7.4	5.5	3.1	2.8			
Chocolate beverage	0.5	0.7		0.8	0.7	1.0	0.7	
Chocolate, plain milk								
Coffee beans ground	1.9	1.6						
Coffee instant	4.2	6.5	1.6					
Confectionery								

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Corn, canned								
Corned beef								
Cornflakes	0.8	0.7	1.5	1.0	0.7	1.7	1.6	1.5
Courgette								
Cream								
Cucumber								
Dairy dessert (Child)								
Egg								
Fish fingers (Child)								
Fish in batter			0.6					
Fish, fresh	0.8	0.7	0.6					
Flavoured snacks (Child)				1.1	1.3	1.4	1.5	1.6
Fruit drink, powdered								
Grapes								
Ham								
Hamburger, plain								
Honey								
Ice cream								
Infant & Follow on formula								
Infant weaning food, cereal based								1.2
Infant weaning fruit based dish								
Infant weaning food, savoury dish							1.5	7.9
Instant noodles	1.8	1.4	1.4	1.3	2.1	2.0	2.0	1.2
Jam								
Kiwi fruit								

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Kumara, roast								
Lamb/Mutton								
Lambs liver								
Lettuce								
Margarine/Table spread								
Meat pie	1.0	0.5	2.4	0.9	0.9	0.8	0.7	0.7
Melon								
Milk, flavoured								
Milk, trim (0.5%)								
Milk, whole								
Milk, soy								
Muesli		0.5						
Muffin/scone	6.1	10.1	2.5	4.3	7.0	5.5	5.1	4.9
Mushrooms								
Mussels								
Nectarines								
Oil								
Onion								
Orange juice								
Oranges								
Oysters								
Pasta, dried	2.0	1.9	3.0	1.7	1.3	1.4	1.8	2.5
Peaches, canned								
Peanut butter				0.6		0.8		
Peanuts								

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Pears								
Peas								
Pineapple								
Pizza	0.7	0.5	1.0		0.5	0.5	0.5	0.6
Pork chop								
Potato crisps	5.3	7.2	15.9	17.9	21.6	17.7	12.8	10.4
Potato, hot chips	13.5	9.0	23.0	17.9	15.6	12.6	15.4	12.5
Potatoes, peeled, boiled	1.3	0.9	0.7					0.6
Potatoes, peeled, roast	9.0	6.4	5.2	17.5	17.8	20.2	6.1	6.9
Potatoes, with skin								
Prunes								
Pumpkin								
Raisins/Sultanas								
Rice, white	3.2	3.8	3.2	2.1	1.3	2.0	0.9	1.0
Rolled oats	2.4	1.4			0.5	0.6	2.1	2.3
Salad dressing								
Sausages, beef								
Silver beet								
Snack bars	0.6	0.8	0.6	2.0	2.1	3.0	1.5	1.9
Soup, prepared	3.5	3.6	3.0	1.3	1.4	1.3	1.2	1.4
Spaghetti in sauce (canned)	1.5	1.6	1.4	1.3	1.1	1.2	2.8	3.5
Strawberries								
Sugar								
Taro								
Tea	6.0	9.0	1.0					

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Tomato								
Tomato sauce								
Tomatoes in juice								
Water								
Wheat biscuits	3.4	2.1	2.4	4.4	2.4	5.1	13.4	8.4
Wine, still red								
Wine, still white								
Yeast extract		0.5					1.2	2.2
Yoghurt								

7.3 Food Intakes from the Simulated Diets

Table 8 shows the weight, or volume, of each food consumed over the fourteen day period represented by the simulated diets for each age group and sex. These food intakes are taken direct from the paper by Brinsdon S. (2004), titled *Simulated typical diets for the 2003/2004 New Zealand Total Diet Survey* and published by the New Zealand Food Safety Authority, Wellington, New Zealand.

Table 8 – Simulated Diets (Weight/volume (g/ml) of foods per 14 Day period)

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Apple based juice	250	200	750	50	80	80	380	130
Apples	840	720	590	960	1010	1050	350	270
Apricots, canned	50	50	30	30	45	60	60	70
Avocado	30	50	30	30	30	20	20	20
Bacon	80	40	90	45	20	20	30	20
Banana	470	470	500	360	260	420	490	420
Beans	115	100	100	90	60	40	15	20
Beans, baked	120	80	100	100	90	90	100	60
Beef,rump	290	160	300	200	150	90	50	30
Beef, mince	530	260	400	280	140	150	120	80
Beer	5400	450	5100	0	0	0	0	0
Beetroot	30	40	30	30	30	10	0	0
Biscuit, chocolate	90	70	100	310	250	200	115	45
Biscuit, cracker	70	70	40	70	70	70	60	50
Biscuit, plain sweet	70	60	80	85	90	90	165	65
Bran flake cereal, mixed	30	30	40	42	42	15	30	20

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Bread, mixed grain	370	360	185	170	175	220	30	0
Bread, wheatmeal	360	280	280	295	175	150	115	75
Bread, white	1170	700	1060	1760	1265	1195	425	265
Broccoli/Cauliflower	140	200	140	130	90	80	70	40
Butter	233	148	319	100	70	70	55	40
Cabbage	200	170	140	140	100	60	15	15
Caffeinated beverage	350	350	1400	200	150	0	0	0
Cake	385	310	540	100	160	60	60	20
Canned fish	70	60	40	40	40	14	20	25
Capsicum	40	40	50	40	40	15	10	0
Carbonated drink	2000	1150	3850	1370	1150	570	300	125
Carrot	280	230	240	180	150	160	115	70
Celery	30	40	30	50	30	15	15	0
Cheese	260	205	290	205	205	100	145	105
Chicken	450	380	660	670	440	340	60	40
Chicken nuggets	30	30	100	90	60	45	50	25
Chinese takeaway dish	180	180	200	120	100	0	0	0
Chocolate beverage	500	500	500	900	800	800	300	100
Chocolate, plain milk	85	70	170	180	130	100	20	10
Coffee beans ground	1900	1200	400	0	0	0	0	0
Coffee instant	4200	4750	1750	100	150	0	0	0
Confectionery	45	45	60	190	130	95	35	20
Corn, canned	105	90	60	70	50	85	30	30
Corned beef	130	100	100	80	50	50	35	25
Cornflakes	70	45	150	110	70	115	60	30
Courgette	40	40	30	40	20	15	10	10
Cream	80	65	70	40	30	14	20	10
Cucumber	35	60	40	40	20	15	15	15

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Dairy dessert (Child)	0	0	0	75	130	290	460	130
Egg	310	245	290	220	190	160	110	60
Fish fingers (Child)	0	0	0	20	30	40	40	30
Fish in batter	140	100	200	100	60	80	45	25
Fish, fresh	280	180	200	170	70	45	30	15
Flavoured snacks (Child)	0	0	0	130	135	110	60	35
Fruit drink, powdered	600	400	1800	970	700	1200	830	350
Grapes	40	50	30	20	30	40	20	10
Ham	130	80	60	180	100	70	70	20
Hamburger, plain	200	150	800	300	265	100	80	40
Honey	70	40	70	40	22	32	20	20
Icecream	220	140	190	470	370	370	150	80
Infant & Follow on formula	0	0	0	0	0	0	200	4900
Infant weaning food, cereal based	0	0	0	0	0	0	0	260
Infant weaning food, custard / fruit dish	0	0	0	0	0	0	0	170
Infant weaning food, savoury dish	0	0	0	0	0	0	120	340
Instant noodles	350	210	300	300	460	300	160	50
Jam	75	60	60	40	30	30	20	15
Kiwi fruit	50	80	40	20	40	80	50	15
Kumara, roast	80	80	40	30	70	20	30	30
Lamb/Mutton	230	130	90	100	80	45	40	30
Lambs liver	30	30	30	0	0	0	0	0
Lettuce	220	200	200	190	130	30	15	0
Margarine/Table spread	175	105	130	125	95	85	35	30
Meat pie	340	130	850	360	320	200	90	50

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Melon	30	40	30	20	30	40	30	30
Milk, flavoured	100	100	650	200	200	150	130	0
Milk, trim (0.5%)	1545	1370	1090	320	300	230	200	0
Milk, whole	2470	1850	2630	2290	1560	2010	3410	960
Milk, soy	350	400	150	150	250	150	100	0
Muesli	90	100	100	40	35	15	15	0
Muffin/scone	200	245	90	170	250	140	70	35
Mushrooms	50	90	50	60	40	15	15	15
Mussels	45	15	30	15	15	0	0	0
Nectarines	250	280	90	100	90	130	30	50
Oil	180	110	215	85	60	40	35	10
Onion	270	190	230	130	85	70	15	10
Orange juice	350	300	850	50	80	80	280	110
Oranges	260	360	380	430	710	610	260	110
Oysters	50	30	30	0	0	0	0	0
Pasta, dried	400	280	650	390	270	220	150	110
Peaches, canned	40	60	40	30	45	60	50	50
Peanut butter	30	15	30	70	45	60	20	0
Peanuts	35	20	40	20	20	20	0	0
Pears	130	200	170	120	150	120	70	50
Peas	250	190	200	165	130	90	60	40
Pineapple	70	80	60	25	30	70	20	20
Pizza	225	130	350	150	180	130	70	40
Pork chop	180	110	250	110	80	45	20	20
Potato crisps	35	35	115	140	155	90	35	15
Potato, hot chips	445	220	830	700	560	320	210	90
Potatoes, peeled, boiled	1251	647	788	308	287	231	190	120
Potatoes, peeled, roast	179	93	112	411	382	308	50	30

Food from Food List	25+ yrs (Male)	25+ yrs (Female)	19-24 yrs (Male)	11-14 yrs (Male)	11-14 yrs (Female)	5-6 yrs (M&F)	1-3 yrs (M&F)	6 - 12 mths (M&F)
Potatoes, with skin	200	200	350	450	360	280	60	40
Prunes	40	30	20	15	20	20	20	15
Pumpkin	200	140	100	60	50	45	80	65
Raisins/Sultanas	50	30	30	30	30	30	99	65
Rice, white	450	400	500	360	200	220	55	30
Rolled oats	340	150	60	75	80	70	120	70
Salad dressing	50	50	50	30	30	20	0	0
Sausages, beef	220	140	250	300	200	200	150	70
Silverbeet	75	70	85	40	30	25	20	15
Snack bars	30	30	30	120	115	115	30	20
Soup , prepared	350	260	320	150	150	100	50	30
Spaghetti in sauce (canned)	200	150	200	200	150	120	150	100
Strawberries	50	50	25	20	45	15	20	10
Sugar	350	235	250	95	95	55	25	15
Taro	30	20	30	0	0	0	0	0
Tea	5900	6600	1100	250	250	200	0	0
Tomato	430	420	180	240	280	80	65	40
Tomato sauce	130	70	250	115	75	45	50	30
Tomatoes in juice	180	130	230	110	65	50	45	40
Water	3050	4150	2950	4860	4880	5180	3500	2080
Wheat biscuits	130	60	100	200	100	150	210	70
Wine, still red	280	300	200	0	0	0	0	0
Wine, still white	280	400	200	0	0	0	0	0
Yeast extract	25	20	25	20	15	20	25	25
Yoghurt	160	180	120	200	260	260	870	770

7.4 Acrylamide Contents of Food in the Simulated Diets

Table 9 is a list of the 122 foods represented in the simulated diets used for the 2003/04 New Zealand Total Diet Survey and the acrylamide level assigned to each of these foods and used for calculating dietary intakes of acrylamide. Wherever possible, New Zealand data from the current project has been used and this is identified as ESR 2005 or ESR 2004. It is noted that all the samples with the exception of bread, from the 2004 data set that had more than minimum levels of acrylamide (greater than 10 µg/kg) were re-tested in 2005 following discovery of a analytical problem that tended to give high results and these 2005 results have been used in the table. Although bread results were above 10 µg/kg, this food was not re-tested as the 2004 New Zealand results were already amongst the lowest reported internationally for bread and therefore unlikely to have been affected by additional acrylamide being generated at injection into the gas chromatograph.

In most cases, analytical results indicate that for any particular food the acrylamide content may cover a significant range in values. As an example, the New Zealand data on potato crisps shows acrylamide levels ranging between 370 and 2320 µg/kg. It is therefore important that a number of examples of each food be tested for acrylamide so as to obtain an indication of the range within that food.

The New Zealand testing has concentrated on testing examples of the New Zealand foods more likely to contribute greater amounts of acrylamide to the diet rather than testing a single example of each the 122 foods in the simulated diets. For those foods not tested, acrylamide levels have been assigned using overseas data from similar foods and these overseas sources are identified in the table. In many cases, for instance canned pineapple, this overseas data may well be from the same products range as sold in New Zealand.

The values in table 9 have been taken as the median value of the measured values available. Uncooked foods such as uncooked fruit, and foods such as meat known to contain no carbohydrates, have been assigned an acrylamide content of zero.

Table 9 - Acrylamide Level and Source of Data

Food from Food List	Data source	Acrylamide content (µg/kg)
Apple based juice	Not cooked	0
Apples	Not cooked	0
Apricots, canned	FDA 2004 (pineapple)	10
Avocado	Not cooked	0
Bacon	EFSA 2003 (Finland 0-75 µg/kg)	50
Banana	Not cooked	0

Food from Food List	Data source	Acrylamide content (µg/kg)
Beans	FDA 2004 (Canned beans)	11
Beans, baked	FDA 2004 (70-83 µg/kg)	76
Beef, rump	No carbohydrate present	0
Beef, mince	No carbohydrate present	0
Beer	ESR 2005	10
Beetroot	FDA 2004 (canned beet)	10
Biscuit, chocolate	FDA 2004 (10 and 620 µg/kg)	300
Biscuit, cracker	ESR 2004	220
Biscuit, plain sweet	EFSA 2003 (Finland)	80
Bran flake cereal, mixed	FDA 2004	189
Bread, mixed grain	ESR 2004	30
Bread, wheatmeal	ESR 2004	30
Bread, white	ESR 2004	20
Broccoli/Cauliflower	FDA 2004 (typical vegetable)	10
Butter	Not cooked	0
Cabbage	FDA 2004 (typical vegetable)	10
Caffeinated beverage	Not cooked	0
Cake	FDA 2004, One et al. 2003	100
Canned fish	No carbohydrate present	0
Capsicum	Not cooked	0
Carbonated drink	Not cooked	0
Carrot	FDA 2004 (typical vegetable)	10
Celery	FDA 2004 (typical vegetable)	10
Cheese	Not cooked	0
Chicken	No carbohydrate present	0
Chicken nuggets	FDA 2004	10
Chinese takeaway dish	One et al. 2003 (fried noodles 51 - 581 µg/kg)	300
Chocolate beverage	FDA 2004	10
Chocolate, plain milk	FDA 2004	0
Coffee beans ground	FDA 2004	10
Coffee instant	FDA 2004 (3 - 500 µg/kg)	10
Confectionery	No protein present	0
Corn, canned	FDA 2004 (typical vegetable)	10
Corned beef	No carbohydrate present	0
Cornflakes	ESR 2005	110
Courgette	FDA 2004 (typical vegetable)	10
Cream	Not cooked	0
Cucumber	Not cooked	0
Dairy dessert (Child)	Not cooked	0

Food from Food List	Data source	Acrylamide content (µg/kg)
Egg	No carbohydrate present	0
Fish fingers (Child)	FDA 2004	12
Fish in batter	FDA 2004	30
Fish, fresh	FDA 2004	30
Flavoured snacks (Child)	FDA 2004 (17 - 300 µg/kg)	100
Fruit drink, powdered	Not cooked	0
Grapes	Not cooked	0
Ham	No carbohydrate present	0
Hamburger, plain	FDA 2004	0
Honey	Not cooked	0
Ice cream	Not cooked	0
Infant and follow-on formula	FDA 2004	0
Infant weaning food – cereal based	FDA 2004	10
Infant weaning food, custard / fruit dish	FDA 2004	0
Infant weaning food – savoury dish	FDA 2004	50
Instant noodles	FDA 2004 (17 - 136 µg/kg)	50
Jam	FDA 2004	0
Kiwi fruit	Not cooked	0
Kumara	WHO 2002 (170 - 2287 µg/kg)	15
Lamb/Mutton	No carbohydrate present	0
Lambs liver	No carbohydrate present	0
Lettuce	Not cooked	0
Margarine/Table spread	Not cooked	0
Meat pie	FDA 2004 (sweet pies)	30
Melon	Not cooked	0
Milk, flavoured	FDA 2004	0
Milk, trim (0.5%)	FDA 2004	0
Milk, whole	FDA 2004	0
Milk, soy	FDA 2004 (soy infant formula)	0
Muesli	ESR 2004	40
Muffin/scone	FDA 2004 (10 and 620 µg/kg)	300
Mushrooms	FDA 2004 (typical vegetable)	10
Mussels	No carbohydrate present	0
Nectarines	Not cooked	0
Oil	No carbohydrate present	0
Onion	FDA 2004	13
Orange juice	Not cooked	0
Oranges	Not cooked	0
Oysters	No carbohydrate present	0

Food from Food List	Data source	Acrylamide content (µg/kg)
Pasta, dried	FDA 2004 (17 - 136 µg/kg)	50
Peaches, canned	FDA 2004 (pineapple)	10
Peanut butter	FDA 2004	100
Peanuts	FDA 2004	0
Pears	Not cooked	0
Peas	FDA 2004 (typical vegetable)	10
Pineapple	Not cooked	0
Pizza	FDA 2004	30
Pork chop	No carbohydrate present	0
Potato crisps	ESR 2005	1500
Potato, hot chips	ESR 2005	300
Potatoes, peeled/boiled/mashed	ESR 2004 (boiled)	10
Potatoes, peeled/roast or baked	FDA 2004 (baked chips)	500
Potatoes, with skin	ESR 2004 (boiled)	10
Prunes	FDA 2004 (typical vegetable)	10
Pumpkin	FDA 2004 (typical vegetable)	10
Raisins/Sultanas	FDA 2004 (same as olives)	500
Rice, white	FDA 2004 (typical cereal)	70
Rolled oats	FDA 2004 (typical cereal)	70
Salad dressing	Not cooked	0
Sausages, beef	FDA 2004	0
Silver beet	FDA 2004 (typical vegetable)	10
Snack bars	FDA 2004 (not potato)	200
Soup/prepared	FDA 2004	100
Spaghetti in sauce (canned)	Same as baked beans	76
Strawberries	Not cooked	0
Sugar	Not cooked	0
Taro	FDA 2004 (typical vegetable)	10
Tea	Takatsuki et al. 2003	10
Tomato	Not cooked	0
Tomato sauce	FDA 2004 (typical vegetable)	10
Tomatoes in juice	FDA 2004 (typical vegetable)	10
Water	Not cooked	0
Wheat biscuits	ESR 2005	260
Wine, still red	Not cooked	0
Wine, still white	Not cooked	0
Yeast extract	ESR 2005	190
Yoghurt	Not cooked	0

7.5 References for Sources of Acrylamide Data

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