# CODE OF PRACTICE FOR THE REDUCTION OF ACRYLAMIDE IN FOODS

**CAC/RCP 67-2009**

## INTRODUCTION

1. Recent concern over the presence of acrylamide in food dates from 2002. Swedish scientists reported that up to “mg/kg” quantities of acrylamide could be formed in carbohydrate-rich foods during high-temperature cooking, e.g. during frying, baking, roasting, toasting and grilling. These findings were rapidly confirmed by other researchers; subsequently, major international efforts have been mounted to investigate the principal sources of dietary exposure, assess the associated health risks and develop risk management strategies. Details of these global research initiatives are provided on the WHO/FAO Acrylamide Information Network (http://www.acrylamide-food.org/) and the "Acrylamide Information Base[1]" http://ec.europa.eu/food/food/chemicalsafety/contaminants/acryl_database_en.htm. There has also been work on acrylamide mitigation studies which are reported in English in the CIAA Acrylamide Tool Box and at http:// ec.europa.eu/food/food/chemicalsafety/contaminants/acrylamide_en.htm and http://www.ciaa.be/asp/documents/brochures_form.asp?doc_id=65.

2. Acrylamide is mainly formed in food by the reaction of asparagine (an amino acid) with reducing sugars (particularly glucose and fructose) as part of the Maillard Reaction; acrylamide may also be formed via reactions involving 3-aminopropionamide. Acrylamide formation primarily takes place under conditions of high temperature (usually in excess of 120 °C) and low moisture.

3. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has undertaken a comprehensive analysis of acrylamide occurrence data from 24 countries, the majority originating from Europe and North America. It was concluded that the major contributing food groups were French fries[2], potato crisps[3], coffee, biscuits[4]/pastries, bread and rolls/toasted bread. The full extent of acrylamide present throughout the diet remains unclear.

[1] A database containing information on projects and activities relating to acrylamide in the EU Member States.
[2] Potato products that are thickly sliced and fried (referred to as French fries in some regions including North America, or as chips in the UK).
[3] Potato snack product that is thinly sliced and fried (includes foods called potato chips in some regions including North America).

## SCOPE

4. This Code of Practice intends to provide national and local authorities, manufacturers and other relevant bodies with guidance to prevent and reduce formation of acrylamide in potato products and cereal products. The guidance covers three strategies (where information is available) for reducing acrylamide formation in particular products:
   i) Raw materials;
   ii) Control / addition of other ingredients; and
   iii) Food processing and heating.

## GENERAL CONSIDERATIONS AND CONSTRAINTS IN DEVELOPING PREVENTATIVE MEASURES

5. Measures aimed at reducing levels of acrylamide cannot be taken in isolation from other considerations. Precautions need to be taken to avoid compromising the existing chemical and microbiological safety of the food. The nutritional qualities of products also need to remain unimpaired, together with their organoleptic properties and associated consumer acceptability. This means all minimisation strategies need to be assessed with regards to their benefits and any possible adverse effects. For example:
   i) When preventative measures for acrylamide are considered, checks should be made to ensure that they will not result in an increase in other process contaminants. These include N-nitrosamines, polycyclic aromatic hydrocarbons, chloropropanols, ethyl carbamate, furan, heterocyclic aromatic amines and amino acid pyrolysates.
   ii) Preventative measures devised for acrylamide must not compromise the microbiological stability of the final product. In particular, regard needs to be paid to the moisture content of the final product.
   iii) Precautions should be taken to avoid detrimental changes to the organoleptic properties of the final product. The formation of acrylamide is intimately associated with the generation of the characteristic colour, flavour and aroma of cooked foods. Proposed changes to cooking conditions, or indeed raw materials and other ingredients, must be assessed from the perspective of the acceptability of the final product to the consumer.

6. Formal safety assessments, efficacy-in-use demonstration and regulatory approval may be needed for potential new additives and processing aids such as asparaginase. Some companies are producing asparaginase for use in food products and some countries have approved it as a processing aid.



[4] Baked cereal products (referred to as cookies in some regions, including North America).

7. It should be noted that the extent of acrylamide formation can be quite variable e.g. within a production batch made at the same manufacturing plant, or between plants using the same process, ingredients and formulations.

8. Manufacturers need to be aware that variability in incoming raw materials and poorly controlled heating devices can complicate trials of mitigation strategies, by obscuring changes in acrylamide levels.

## RAW MATERIALS

9. A number of factors influence reducing sugar levels including:
   i) Climatic conditions and fertilizer application rate – These factors are known to influence levels of reducing sugars, however, no specific information on reduction measures applicable to manufacturers are currently available.
   ii) Cultivar – Select cultivars with levels of reducing sugars as low as reasonably achievable taking into account regional and seasonal variability for high temperature cooking processes such as frying and baking.
   iii) Storage temperature and time – Control storage conditions from farm to factory; >6 °C has been identified as good practice for long storage for processing. Avoid using potatoes that have been subject to excessive low-temperature sweetening during storage (at, or below 4–6 °C) for frying, roasting and oven-baking. In cold weather protect potatoes from cold air. Avoid leaving deliveries of potatoes standing outside (unprotected) over night in freezing conditions. Some cultivars are less prone than others to low temperature sweetening. Information on some cultivars is contained in a database available from the European Cultivated Potato Database and the German Federal Office of Plant Varieties.
   iv) Reconditioning temperature and time – Potatoes that have been stored at low temperatures should be reconditioned over a period of a few weeks at higher temperatures (e.g. 12–15 °C). The decision to recondition stored potatoes, as well as decisions on the length of time needed for reconditioning, should be made on the basis of the results of fry testing.
   v) Tuber size/immature tubers – Immature tubers have higher reducing sugar levels and produce darker fried products with potentially higher levels of acrylamide. The presence of immature tubers should be avoided by selecting, sorting or grading of potatoes at some stage before processing.

## RECOMMENDED PRACTICES TO INDUSTRY FOR THE MANUFACTURE OF POTATO PRODUCTS (E.G. FRENCH FRIES, POTATO CRISPS, POTATO SNACKS)

**The mitigation measures discussed in the following sections are not listed in order of priority. It is recommended that all reduction measures are tested to identify the most successful for your own product.**

| Production stage | Reduction measures |
|---|---|
| Raw materials | Select potato cultivars with levels of reducing sugars as low as reasonably achievable taking into account regional and seasonal variability.<br>Test incoming deliveries of potatoes for levels of reducing sugars, or fry test them (aim for a light golden colour). |
| | Avoid using potatoes stored below 6 °C. Control storage conditions from farm to factory and in cold weather, protect potatoes from cold air. Avoid leaving deliveries of potatoes outside (unprotected) in freezing conditions for long periods of time, e.g. overnight. Recondition potatoes from low-temperature storage at higher temperatures (e.g. 12–15 °C) for a period of weeks. |
| Control / addition of other ingredients | In the case of potato-based snacks produced from doughs, where possible, replace some of the potato with other ingredients with lower reducing sugar/asparagine content e.g. rice flour.<br>Avoid addition of reducing sugars (e.g. as browning agent, spice carrier or coating). |
| | The addition of asparaginase in some cases has been shown to reduce asparagine and thus acrylamide in potato dough based products. |
| | Treatment of French fries with sodium pyrophosphate and treatment of potato products with di-and trivalent cations e.g. calcium salts before processing can contribute to the reduction of acrylamide. |
| Food processing and heating | **French fries:**<br>Blanch potato strips in water to lower levels of reducing sugars before cooking.<br>Lowering the pH with addition of sodium acid pyrophosphate during the latter stages of blanching can reduce levels further.<br>Cut thicker strips; 14x14mm strips have been shown to have lower acrylamide levels than fine cut strips (8x8mm). If appropriate, par fry french fries. |
| | **Potato crisps:**<br>Optimise time, temperature and cooker settings to produce a crisp product with a golden yellow colour.<br>If available, consider vacuum frying to process high reducing sugar potatoes.<br>Rapid cooling is recommended if flash frying is being used.<br>Carry out in line colour sorting to remove dark crisps. |

10. Sprout suppressant is often essential in stores held at temperatures over 6 °C, although regional regulations in some cases do not permit the use of sprout suppressants.

11. Manufacturers of French fries and potato crisps should where feasible screen incoming lots by measuring reducing sugar content or assessing the colour of a fried sample. In particular, fry test potatoes that have been stored at low temperatures for long periods of time. When using cultivars with not sufficiently low reducing sugar contents, reconditioning and blanching before high temperature cooking processes, and vacuum frying for heating may lower the level of acrylamide.

## CONTROL/ADDITION OF OTHER INGREDIENTS

12. For reconstituted or formed potato-based snacks produced from potato doughs, other ingredients with lower reducing sugar/asparagine content can sometimes be used in some products to partially replace the potato e.g. rice flour.

13. Addition of the enzyme asparaginase has been shown to reduce asparagine and thus acrylamide levels in potato products made from potato doughs.Asparaginase may be best suited for food products manufactured from liquidised or slurried materials. In practice asparaginase can functionally reduce acrylamide in prefabricated potato crisps, however, the amount of asparagines in the raw potato product is generally so high that in order to achieve a meaningful reduction in acrylamide a large amount of asparaginase must be added. This may preclude the use of the enzyme for some potato products.

14. Treatment with various other reagents e.g., sodium pyrophosphate and calcium salts prior to the frying stage has also been demonstrated to reduce acrylamide formation. Additives should be used according to the appropriate national or international legislation.

15. The use of reducing sugars as a browning agent, spice carrier or coating should also be avoided where possible because they can cause the formation of significant levels of acrylamide.

## FOOD PROCESSING AND HEATING

16. Decrease of the surface area can be employed; for example in French fries, by cutting potatoes into thicker slices; 14x14mm strips have been shown to have

lower acrylamide levels than fine cut strips (8x8mm) or removal of fines (fine pieces of potato) before or after frying to reduce levels of acrylamide in fried or roasted potatoes.

17. Washing, blanching or par-boiling treatments can be employed to leach the asparagine/reducing sugar reactants from the surface of the potato before the cooking step. Various reagents for lowering pH can also be added during the latter stages of blanching to further reduce levels of acrylamide, these include, treatment of French fries with sodium acid pyrophosphate, treatment with calcium salts, and the salts of a number of other di- and trivalent cations (this method has been shown to reduce acrylamide formation in French fries made from potato dough) and blanching in sodium chloride solution (though this method may increase dietary exposure to sodium).
    i) Blanching or soaking potatoes has shown to reduce acrylamide levels but can also have an adverse effect on the flavour and texture of the final product. Blanching can also lead to leaching of vitamin C and minerals from potatoes. A blanching step before frying/roasting may lower the fat content of the final product, but there is contradictory information on this topic.
    ii) Blanching may also be unsuitable for some products e.g. potato crisps, as it may cause unacceptable moisture uptake, leading to loss of consistency/ crispness or possible microbiological spoilage.

18. Acrylamide levels in potato crisps can be reduced by controlling the thermal input. Vacuum frying might offer the opportunity to reduce acrylamide levels in crisps made from potatoes with high reducing sugar content. Rapid cooling potato crisps that are cooked by flash frying can also reduce levels of acrylamide in the final product. The use of in-line optical sorting to remove dark coloured crisps has been proved to be an effective measure to reduce acrylamide. Par cooking far-infrared heating and dry steam treatments used to make low fat crisps may also reduce acrylamide.

19. In order to achieve significant reductions in the acrylamide content of French fries, when cooking the product immediately prior to consumption, set the initial oil temperature to no more than 170-175 °C and cook to a golden-yellow rather than a golden-brown colour. Depending on the heating power of the fryer, the amount of potato immersed in the oil should aim to give an actual frying temperature starting from about 140 °C and ending at about 160 °C. A bigger long-lasting temperature drop after addition of the potato will increase the fat uptake, and a higher end temperature will result in excessive acrylamide formation.

20. Manufacturers of prefabricated par fried French fries should ensure that their on-pack cooking instructions are consistent with the need to minimise acrylamide

formation. Where frying is one of the on-pack suggestions for “Prefabricated” French fries, the recommended frying temperature should not be greater than 175 °C. The cooking instructions should also mention that consumers should reduce the cooking time when cooking small amounts and that they should cook fries to a golden-yellow colour.

21. Some “Oven” French fries or prefabricated potato products are manufactured with a view to storage under refrigerated rather than frozen conditions. Storage at these conditions may be conducive to low-temperature sweetening due to residual amylase activity which leads to reducing sugar formation from starch. Should this be the case, blanching must be adapted (longer time and/or higher temperature) in order to fully inactivate the amylase activity.

## RAW MATERIALS

22. Typically, asparagine can range from 75 to 2200 mg/kg in wheat, from 50 to 1400 mg/kg in oats, from 70 to 3000 mg/kg in maize, from 319 to 880 mg/kg in rye and from 15 to 25 mg/kg in rice. This level of variation suggests that there may be scope for reducing acrylamide by exploiting the variability of asparagine content in the cultivar pool. However, as in the similar case for potatoes, such approaches are likely to have a significant lead time, and other factors, such as yield and resistance to fungal infections (field mycotoxin formation), would need to be considered.

23. Deficiencies in the sulphur content of soil can cause an increase in asparagine levels in wheat and barley. Therefore, sulphur deficient soil should be avoided, or well fertilised. High nitrogen content in soils may result in higher asparagine content in cereals and excessive nitrogen fertilization should be avoided.

24. In mixed cereal products, there may be scope for reducing the proportion of the predominant source of acrylamide by incorporating cereals with lower asparagine content. For example, this strategy could include replacing rye and wheat with rice, however, nutritional and organoleptic implications must be considered.

## RECOMMENDED PRACTICES TO INDUSTRY FOR THE MANUFACTURE OF CEREAL BASED PRODUCTS (E.G. BREAD, CRISPBREAD, BISCUITS/BAKERY WARES, BREAKFAST CEREALS)

**The mitigation measures discussed in the following sections are not listed in order of priority. It is recommended that all reduction measures are tested to identify the most successful for your own product.**

| Production stage | Reduction measures |
|---|---|
| Raw Materials | Sulphur deficient soil should be avoided, or well fertilised.<br>Excessive nitrogen fertilization should be avoided. |
| Control / addition of other ingredients | **General:**<br>Consider the type of flour to be used. High extraction flours contain significantly less asparagine than wholemeal flours. However, lowering the wholemeal content will reduce the nutritional benefits of the final product.<br>Consider part replacement of wheat flour by rice flour. |
| | **Biscuits/bakery wares:**<br>When ammonium containing raising agents are used, consider replacements with other raising agents e.g. potassium and sodium containing raising agents.<br>In the production of gingerbread replace fructose with glucose.<br>The addition of asparaginase has been shown to reduce asparagine and thus acrylamide in hard, wheat-dough based products such as cookies and crackers. |
| | **Bread:**<br>Avoid using reducing sugars in the recipe. The addition of calcium salts, e.g. calcium carbonate may reduce the formation of acrylamide. |
| | **Breakfast cereals:**<br>Minimize reducing sugars in the cook phase. Consider the contribution of other inclusions e.g. roasted nuts, dried fruits and whether they are necessary if they are in a form that potentially can add a significant level of acrylamide. |
| Food processing and heating | **General:**<br>Do not over bake. |
| | **Bread:**<br>Adjust the time-temperature profile of the baking process, i.e., decrease temperatures of the final stages when product reaches low moisture phase.<br>Extend fermentation times of bread doughs. |
| | **Crispbread:**<br>Control the final moisture content.<br>In non-fermented crispbread control the process temperature and oven speed. |
| | **Breakfast cereals:**<br>Do not over-bake or over-toast.<br>Manage the toasting to achieve a uniform colour for the product. |

## CONTROL/ADDITION OF OTHER INGREDIENTS

25. Thought should be given to the type of flours used in products. High extraction flours contain significantly less asparagine than wholemeal flours. Part replacement of wheat flour by rice flour has been shown to reduce acrylamide in short sweet biscuits and gingerbread. However, lowering the wholemeal content will reduce the nutritional benefits of the final product. Types of flours vary in asparagine content and choice should be balanced between nutritional value and minimization of acrylamide formation.

26. Ammonium bicarbonate has been shown to increase the potential yield of acrylamide from a baked product. Thus, manufacturers need to consider whether the use of ammonium-containing raising agents can be reduced. Additives should be used according to the appropriate national or international legislation. Replacement leavening agents used commercially include:
    i) Sodium bicarbonate + acidulants;
    ii) Disodium diphosphate, sodium bicarbonate and organic acids;
    iii) Potassium bicarbonate + potassium bitartrate;
    iv) Sodium bicarbonate + sodium acid pyrophosphate (SAPP).
    v) Replacement of ammonium-containing raising agents with those containing sodium may increase dietary exposure to sodium and may also adversely affect the physical properties of gingerbread and the organoleptic qualities of biscuits. Combination of sodium bicarbonate and organic acids e.g. tartaric acid and citric acid, may result in a product with somewhat lesser leavening. The amount of organic acids added needs to be limited because an acidic taste may be developed and gas release in the dough may be too fast.
    vi) Greater amounts of acrylamide are formed if the reducing sugar is fructose rather than glucose. Commercial investigations have shown removal of sources of fructose or replacement by glucose in the product ingredients (sugar syrups, fruit puree, honey) to be successful in reducing acrylamide formation. If glucose syrup (also known as corn syrup in North America) is necessary, the level of fructose in this syrup should be as low as possible. The replacement of reducing sugars by sucrose is another effective way to significantly reduce acrylamide in sweet baked goods if browning is less important.

27. The addition of asparaginase has been shown to reduce asparagine and thus acrylamide in hard, wheat-dough based products such as cookies and crackers.

28. Care should also be exercised in the usage of reducing sugars during the manufacture of breakfast cereals. When such sugars are used they are usually added after the baking process, in which case no additional acrylamide formation

will occur. However, addition of reducing sugars prior to baking represents an avoidable source of acrylamide formation.

29. Other minor ingredients can also have an influence. Increases in acrylamide formation have been shown to occur in some recipes when ingredients such as ginger, honey and cardamom are added during biscuit production. Conversely, nutmeg has been shown, in some cases, to result in a decrease in acrylamide. In order to reduce acrylamide levels in final products, manufacturers could investigate the effect of different spices in their own recipes.

30. Use of rework (the practice of re-using scraps) has been shown to increase acrylamide levels in some cases, but not in others. Manufacturers need to examine production processes for individual products to determine whether reducing rework can be used to mitigate acrylamide levels in their products.

## FOOD PROCESSING AND HEATING

31. Yeast fermentation of wheat bread doughs reduces the free asparagine content. Fermentation for two hours utilises most of the asparagine in wheat flour dough models; shorter times are less effective, as is sourdough fermentation.

32. Acrylamide formation can be reduced by modifying the time–temperature profile of the baking process, in particular by decreasing the temperature of the final stages when the product reaches the crucially vulnerable, low moisture phase. Compensation by increasing the temperature of the earlier stages of baking should not lead to a significant increase in acrylamide, since the moisture content at this stage should be sufficiently great so as to prevent acrylamide formation. Careful control of oven temperatures and time profiles can be effective in reducing acrylamide levels. These principles have been applied successfully in both a biscuit model and in non-fermented crispbreads.

## COFFEE

33. No commercial measures for reducing acrylamide in coffee are currently available.

34. Studies have shown that concentrations of acrylamide decline in storage in coffee powder in closed containers over extended storage periods and work is underway to identify the underlying mechanisms that may provide future opportunities for mitigation. However, any changes to the roasting profile, or deliberate use of

extended storage, to decrease acrylamide levels are likely to have a significant impact on the organoleptic properties and consumer acceptability of the product.

## CONSUMER PRACTICES

35. National and local authorities should consider advising consumers to avoid over-heating potato and cereal-based foodstuffs when using high temperature cooking processes. Such advice could include recommendations that French fries and roast potatoes be cooked to a golden-yellow rather than golden-brown colour, whilst still ensuring that the food is fully cooked. Similarly, the consumer could be advised to aim for a light brown colour when toasting bread and related products.

36. National and local authorities should also consider encouraging consumers to avoid storing potatoes intended for high-temperature cooking under cold and/or refrigerated conditions.

37. Where relevant, industry should endeavour to provide advice to consumers on appropriate cooking and handling instructions that can help to mitigate acrylamide formation in the product.