codex alimentarius commission

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

WORLD HEALTH ORGANIZATION

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Agenda Item 8 **CX/CF 08/2/8**
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JOINT FAO/WHO FOOD STANDARDS PROGRAMME
CODEX COMMITTEE ON CONTAMINANTS IN FOODS

Second Session

The Hague, The Netherlands, 31 March - 4 April 2008

PROPOSED DRAFT CODE OF PRACTICE FOR THE REDUCTION OF ACRYLAMIDE IN FOOD (N06-2006)

(At Step 3 of the Elaboration Procedure)

Governments and international organizations are invited to submit comments on the following subject matters no later than 10 March 2008, preferably in electronic format, for the attention of Ms. Tanja Åkesson, the Netherlands Secretariat of the Codex Committee on Contaminants in Foods, Fax No.:+31 70 3786141; E-mail:info@codexalimentarius.nl with a copy to the Secretary, Codex Alimentarius Commission, Joint FAO/WHO Food Standards Programme, Viale delle Terme di Caracalla, 00153 Rome, Italy (Fax +39.06.5705.4593; E-mail: mailto:Codex@fao.org).

BACKGROUND

1. The Codex Committee on Food Additives and Contaminants, at its 38th Session (April 2006), agreed to start new work to elaborate a Code of Practice for the Reduction of Acrylamide in Food and agreed to establish an electronic working group for preparation of an initial draft of the Code of Practice (ALINORM 06/29/12 para. 185 and Appendix XXIX).[1]

2. The new work proposal was approved by the 29th Session of the Codex Alimentarius Commission (July 2006) as N06-2006 (ALINORM 06/29/41, Appendix VIII).[2]

3. The Codex Committee on Contaminants in Foods, at its First Session (April 2007), discussed the proposed Draft Code of Practice for the Reduction of Acrylamide in Food (contained in CX/CF 07/1/15) and agreed to return the proposed Draft Code of Practice to Step 2 for redrafting by an electronic working group led by the United Kingdom and the Unites States of America (ALINORM 07/30/41 paras 94-97).[3]

4. The Committee, at its Second Session, is invited to consider the proposed Draft Code of Practice prepared by the above-mentioned working group, which is presented in ANNEX I to this document along with the report of the electronic working group presented in paragraphs 5 – 17.

REPORT OF THE ELECTRONIC WORKING GROUP

5. As agreed by the Codex Committee on Contaminants in Food, at its First Session,[3] the electronic working group led by the United States of America (USA)and the United Kingdom (UK) revised the Proposed Draft Code of Practice for the Reduction of Acrylamide in Foods, which is presented in ANNEX I. Australia, Canada, Chile, China, Cuba, Denmark, European Community, Germany, Greece, Ireland, Japan, Kenya, New Zealand, Philippines, Poland, South Africa, Sweden, Switzerland, Thailand, Turkey, FAO, WHO, CIAA, ICD, ICGMA, IFT and ISDI participated in the electronic working group. A list of the participants is presented in ANNEX II.

6. The first draft was prepared by the UK and the USA , using the previous draft presented in CX/CF 07/1/15, on the basis of the written comments received and the discussion in the *ad hoc* Working Group and in the First Session of the Committee (ALINORM 07/30/41 para. 97). The first draft was sent out in October 2007 to the participants of the electronic working group for comments. Comments were received from Canada, Chile, China, Denmark, EC, Germany, Greece, Japan, New Zealand, Poland, Switzerland, FAO, WHO, CIAA, and ICGMA.

Elements Considered

7. The electronic working group agreed not to include background detail and suggested that this format should be consistent throughout the document. It was also agreed that the revised draft would include those established minimisation techniques that have been demonstrated to be effective in a commercial setting.

8. The format of the document was changed to include tables of recommended practices which were then further expanded in the paragraphs following, as agreed by the electronic working group.

9. The electronic working group agreed that the focus of this draft Code of Practice should be predominantly on foods produced from potatoes and cereals, reflecting their importance in terms of dietary exposure to acrylamide. It was also agreed that, although coffee was also an important contributor to acrylamide exposure, no minimization techniques were included in the draft Code of Practice, as none were supplied.

10. It was suggested by several comments from the electronic working group members to include specific recommended practices for the reduction of acrylamide in cereals and potatoes. Consequently, those practices that were shown to work in a commercial setting were included

11. Editorial comments and comments related to formatting of the document which were made by more than one participant were included.

12. Where mitigation/production practices were specific to a member country, related comments were excluded from the final draft of the code of practice.

13. Several comments from the electronic working group members indicated that the recommendations needed to be more specific. This was taken into account when preparing the final draft.

14. References provided by JECFA for inclusion in paragraph 7 of the Annex as had been requested at the 1st session of the Codex Committee on Contaminants in food, were included.

15. Several comments from members of the electronic working group which sought to clarify mitigation measures or inform on commercial practices were incorporated.

16. This Code of Practice draws on a number of activities already undertaken, such as the “CIAA Acrylamide Toolbox,” a document produced by the Confederation of the Food and Drink Industries of the EU (CIAA), which contains potential acrylamide mitigation measures relevant to many food sectors.[4] The Toolbox is updated on a regular basis as new knowledge and progress in the different food sectors are reported.

17. In the section on Consumer Practices, comments referring to retailers were removed as the Code of Practice is aimed at manufacturers only.

ANNEX I

PROPOSED DRAFT CODE OF PRACTICE FOR THE REDUCTION OF ACRYLAMIDE IN FOOD

INTRODUCTION

1. Recent concern over the presence of acrylamide in food dates from 2002. Swedish scientists[5] reported that up to "mg/kg" quantities of acrylamide could be formed in carbohydrate-rich foods during high-temperature cooking, e.g., during frying and baking. These findings were rapidly confirmed by other researchers;[6] 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.[7,8,9,10,11,12] 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[a]" http://ec.europa.eu/food/food/chemicalsafety/contaminants/acryl_database_en.htm.

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;[13,14] acrylamide may also be formed *via* reactions involving 3-aminopropionamide.[15,16] 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)[11] 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[b], potato crisps[c], coffee, biscuits[d]/pastries, bread and rolls/toasted bread.

4. This draft Code of Practice will be divided into food groups: potatoes, cereals and coffee, all of which will cover three strategies (where information is available) for reducing acrylamide formation in particular products:
    i. Raw materials;
    ii. Control / addition of other ingredients;
    iii. Food processing and heating.

TOXICOLOGY

5. JECFA reviewed acrylamide at the request of CCFAC in 2005.[11,17] The following section summarises the major conclusions of the JECFA review.

6. Acrylamide is an important industrial chemical used since the mid 1950s as a chemical intermediate in the production of polyacrylamides, which are used as flocculants for clarifying drinking water and in other industrial applications. The neurotoxicity of acrylamide in humans is well known from occupational and accidental exposures. In addition, experimental studies with acrylamide in animals have shown reproductive, genotoxic, and carcinogenic properties.

7. JECFA analysed acrylamide occurrence data from 24 countries and national dietary intake data from 17 countries. The committee identified an average acrylamide intake of 1µg/kg bw/day for the general population and 4µg/kg bw/day for high-level consumers based on national intake estimates ranging from 0.3 – 2.0 µg/kg bw/day for average consumers and 0.6 –5.1 µg/kg bw/day for high level consumers (90 – 99th percentile).

8. JECFA concluded that the critical effects of acrylamide toxicity are genotoxicity and carcinogenicity. In order to estimate the level of concern of acrylamide exposure from food, JECFA calculated a Benchmark Dose Lower Limit (BMDL) for mammary tumour formation from rodent carcinogenicity studies and then calculated the margin of exposure (MOE) between the BMDL and human acrylamide intake. For

a A database containing information on projects and activities relating to acrylamide in the EU Member States.

b 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).

c Potato snack product that is thinly sliced and fried (includes foods called potato chips in some regions including North America).

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

average intakes (1µg/kg bw/day), the MOE was 300; for high intakes (4 µg/kg bw/day), the MOE was 75. For comparison, JECFA calculated the MOEs for average and high exposure to polycyclic aromatic hydrocarbons to be 25,000 and 10,000, respectively. For ethyl carbamate, the MOEs were 20,000 for average and 3,800 for high exposure**.**

9. JECFA also calculated MOEs for neurological effects of 200 and 50 for average and high intakes; for reproductive, developmental, and other non-neoplastic effects, JECFA calculated MOEs of 2000 and 500 for average and high intakes. Based on these MOEs, JECFA concluded that adverse neurological, reproductive, and developmental effects are unlikely for the average consumer, but that morphological changes in nerves cannot be excluded for some individuals with very high intake. The Committee also stated that ongoing studies of neurotoxicity and neurodevelopmental effects in rats will more clearly define whether neurotoxic or neurodevelopmental effects may arise from long-term, low doses of acrylamide.

10. In summary, JECFA considered these MOEs to be low for a compound that is genotoxic and carcinogenic and concluded that the MOEs may indicate a human health concern.

11. JECFA made the following recommendations:

    i. acrylamide should be re-evaluated when results of ongoing carcinogenicity and long-term neurotoxicity studies become available,
    ii. work should be continued on using pharmacologically based pharmacokinetic (PBPK) modelling to better link human biomarker data with exposure assessments and toxicological effects in experimental animals,
    iii. appropriate efforts to reduce acrylamide concentrations in food should continue, and
    iv. it would be useful to have occurrence data on acrylamide in foods as consumed in developing countries.

12. A number of studies have been commissioned following the 2005 JECFA review of acrylamide. As outlined in its Action Plan for Acrylamide in Food,[18] the United States Food and Drug Administration (FDA) and associated agencies are conducting a suite of studies on both acrylamide and glycidamide. Short-term studies on toxicokinetics, bioavailability, DNA adduct formation, and acrylamide in rodent feed have been completed,[19,20,21,22,23,24] but the results of long-term carcinogenicity assays and a developmental neurotoxicity assessment will not be available until later in 2008. The FDA has completed a physiologically based pharmacokinetic model (PBPK) for acrylamide that will allow better estimates of the levels of DNA damage resulting from dietary exposures to acrylamide and better extrapolation of human cancer risks from rodent carcinogenicity studies.[25] The PBPK model predicts a steady-state level of glycidamide-DNA adducts in human liver of 0.06 to 0.26 adducts/10^8 nucleotides.[26] A comparable FDA analysis without a PBPK model predicted a similar level of 0.06 to 0.3 adducts/10^8 nucleotides.[24] Other FDA studies completed in 2007 include an analysis of urinary excretion of acrylamide and metabolites[27] and an analysis of acrylamide-induced sister chromatid exchanges (SCEs), which concluded that SCEs correlate with glycidamide-DNA adducts.[28]

13. A large, prospective epidemiological cohort published in 2006 reported no association between acrylamide intake and colorectal cancer, and intake of specific foods high in acrylamide was not associated with elevated risk.[29] In 2007, several new acrylamide epidemiology studies reported finding no association between dietary acrylamide intake and renal cancer or breast cancer respectively.[30,31] A 2007 update of a study of workers in a U.S. acrylamide production facility confirmed earlier findings of no excess in overall mortality or in site-specific cancer mortality.[32] A second update of an independent study of acrylamide workers in the U.S. and the Netherlands, found no statistically significant increases in mortality for cancers implicated in animal studies of acrylamide,[33] and did not confirm previous suggestions of a potential increase in pancreatic cancer risk.[34]

14. Other groups are also continuing work on acrylamide toxicology, including recent work on adducts and urinary metabolites.[35,36] One 2007 study found that acrylamide intake did not correlate with acrylamide or glycidamide hemoglobin (Hb) adducts,[37] while a separate 2007 study found correlations between dietary intake and Hb adducts for smokers and nonsmoking men, but not nonsmoking women.[38] Another recent study reported that urinary metabolites did not correlate with total dietary intake, although metabolites increased after potato chip ingestion.[39]

15. In the area of neurotoxicity, it was argued that acrylamide causes neurotoxic effects via binding to sulfhydryl groups on nerve terminal proteins;[40] while it was reported elsewhere that combined prenatal and postnatal exposure to 5 mg/kg/d of acrylamide affected food-motivated behaviors in young rats.[41] Finally, it was reported that acrylamide and glycidamide affect kinesin-related proteins from mitotic/meiotic spindles.[42]

16. JECFA evaluated the safety of the enzyme asparaginase from *Aspergillus oryzae* expressed in *Aspergillus oryzae* for use as a food additive at its 68th meeting in June 2007.[43] Asparaginase has potential use in depleting levels of the acrylamide precursor asparagine in food. JECFA found that asparaginase had an Acceptable Daily Intake (ADI) that was "not specified" when used in the applications specified and in accordance with good manufacturing practice. ADI 'not specified' is used to refer to a food substance of very low toxicity which, on the basis of the available data (chemical, biochemical, toxicological and other) and the total dietary intake of the substance arising from its use at the levels necessary to achieve the desired effects and from its acceptable background levels in food, does not, in the opinion of JECFA, represent a hazard to health.[43]

GENERAL CONSIDERATIONS AND CONSTRAINTS IN DEVELOPING PREVENTATIVE MEASURES

17. 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,[44] polycyclic aromatic hydrocarbons,[45] chloropropanols,[46] ethyl carbamate,[47] furan,[48] heterocyclic aromatic amines and amino acid pyrolysates.[49]

    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. 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,[50] but there is contradictory information on this topic.[51,52]

    iv. 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.[53]

    v. Frying of potato products at too low a temperature may lead to an increased fat content of the final product.[4]

    vi. 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.[4] Combination of sodium bicarbonate and organic acids e.g., tartaric acid and citric acid, may result in a product with somewhat lesser leavening.[54] 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.[55]

    vii. When cooking French fries to a golden-yellow rather than a golden-brown colour it is essential to ensure that the final product is properly cooked.

    viii. 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.

18. Formal safety assessments, efficacy-in-use demonstration and regulatory approval may be needed for potential new additives and processing aids such as asparaginase. Two companies are now producing asparaginase for use in food products and as of September 2007, the following information was available on the regulatory status of these enzymes. The US FDA has stated that it does not object to the companies' conclusions that their enzyme preparations are Generally Recognized as Safe (GRAS) under the intended conditions of use.[56] In Europe, approval has been received for asparaginase in France and Denmark as a processing aid.

19. 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.[57]

20. 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. For optimal results, manufacturers should control asparagine and reducing sugar levels and have well-controlled heating elements before investigating possible minimisation strategies.

RECOMMENDED PRACTICES TO INDUSTRY FOR THE MANUFACTURE OF POTATO PRODUCTS (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 SUCCESFUL FOR YOUR OWN PRODUCT.

Summary

Production Stage	**Reduction Measures**
Raw Materials	Choose potato cultivars with low concentrations of reducing sugars (target less than 0.3% sugar on a fresh weight basis for crisps and 0.4% for French Fries; subject to regional and seasonal variability). 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 that have been standing outside (unprotected) in freezing conditions for long periods of time, e.g. overnight. Recondition potatoes that have been stored at low temperatures over a period of a few weeks at higher temperatures (e.g., 12 – 15 °C). Fry test potatoes that have been stored at low temperatures for long periods of time.
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 Avoid addition of reducing sugars (e.g., as browning agent, spice carrier or coating).
	The addition of asparaginase has been shown to reduce asparagine and thus acrylamide in potato dough based products.
	Treatment of French fries with sodium acid pyrophosphate and treatment of potato products with di-and trivalent cations e.g. calcium before processing can contribute to the reduction of acrylamide.
Food Processing and heating	**French Fries:** Blanch potato strips in water to lower levels of reducing sugars before cooking. Lowering the pH with addition of sodium acid pyrophosphate during the latter stages of blanching can reduce levels further. 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: Optimise time, temperature and cooker settings to produce a crisp product with a golden yellow colour. If available, consider vacuum frying to process high reducing sugar potatoes. Rapid cooling is recommended if flash frying is being used. Carry out in line colour sorting to remove dark crisps

Raw materials

21. A number of factors influence reducing sugar levels including:

    i. Climatic conditions [58,59] and fertilizer application rate[60] – 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[58] - Select cultivars with reducing sugar contents of less than 0.3 % for crisps, 0.4% for French fries on a wet weight basis for high temperature cooking processes such as frying and baking.[4]

    iii. Storage temperature and time[61] – Control storage conditions from farm to factory; >6° C has been identified as good practice for long storage for processing.[4,62] Avoid using potatoes that have been subject to excessive low-temperature sweetening during storage (at, or below 4-6 °C[63]) 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.[4] Some cultivars are less prone than others to low temperature sweetening.[64,65] Information on some cultivars is contained in a database available from the European Cultivated Potato Database [93] and the German Federal Office of Plant Varieties.[66]

    iv. Reconditioning temperature and time[59,62] - 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).[59,62]

    v. Tuber size/immature tubers[67] - 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.

22. Sprout suppressant is often essential in stores held at temperatures over 6 °C,[68] although regional regulations in some cases do not permit the use of sprout suppressants.

23. Manufacturers of French fries and potato crisps should screen incoming lots by measuring reducing sugar content or assessing the colour of a fried sample.[4,62] 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

24. For reconstituted or formed potato-based snacks produced from potato doughs, where possible, include other ingredients with lower reducing sugar/asparagine content to replace some of the potato[62] e.g., rice flour.

25. Addition of the enzyme asparaginase has been shown to reduce asparagine and thus acrylamide levels in potato products made from potato doughs.[62,69,70]Asparaginase may be best suited for food products manufactured from liquidised or slurried materials.[69]

26. Treatment with various other reagents i.e., sodium pyrophosphate and calcium salts[4,62] prior to the frying stage has also been demonstrated to reduce acrylamide formation.

27. 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.[53]

Food processing and heating

28. Decrease the surface area; for example, 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.[62,71,72]

29. 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.[73,74] Various reagents 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,[4,62] treatment with calcium salts,[62] 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[75]) and blanching in sodium chloride solution[76] (though this method may increase dietary exposure to salt).

30. Acrylamide levels in potato crisps can be reduced by controlling the thermal input.[4] 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.[4] Par cooking and dry steam treatments used to make low fat crisps may also reduce acrylamide.[62]

31. In order to achieve significant reductions in the acrylamide content of French fries, when cooking the product immediately prior to consumption, set the temperature of the oil at the start of frying to no more than 175 °C and cook to a golden-yellow rather than a golden-brown colour.[77,78] Depending on the relative proportions of raw potato to cooking oil, the temperature of the frying oil will drop after the raw French fries are added. Such a decrease in temperature may help to reduce acrylamide formation, although too great a temperature drop will adversely affect the culinary quality of the product.[79]

32. “Oven” French fry manufacturers should ensure that their on-pack cooking instructions are consistent with the need to minimise acrylamide formation.[4] Where frying is one of the on-pack suggestions for “Oven” French fries, the recommended frying temperature should not be greater than 175 °C.[80] The cooking instructions should also mention that consumers should reduce the cooking time when cooking small amounts.[4]

33. 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[81] 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.

34. The use of sugar dips to give par-cooked potato products an even golden colour should be avoided because the sugar in these dips can enhance acrylamide formation.[53]

RECOMMENDED PRACTICES TO INDUSTRY FOR THE MANUFACTURE OF CEREAL BASED PRODUCTS (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 SUCCESFUL FOR YOUR OWN PRODUCT.

Summary

Production Stage	Reduction Measures
Raw Materials	Sulphur deficient soil should be avoided, or well fertilised.
Control / addition of other ingredients	**General:** 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. Consider part replacement of wheat flour by rice flour.
	Biscuits/bakery wares: When ammonium containing raising agents are used, consider replacements with other raising agents e.g. potassium and sodium containing raising agents. In the production of gingerbread replace fructose with glucose. 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: Avoid using reducing sugars in the recipe. The addition of calcium salts, e.g. calcium carbonate may reduce the formation of acrylamide.
	Breakfast Cereals: Minimise reducing sugars in the cook phase. Consider the contribution of other inclusions e.g. roasted nuts, dried fruits.
Food Processing and heating	**Biscuits/bakery wares:** Do not over bake.
	Bread: Adjust the time-temperature profile of the baking process, i.e., decrease temperatures of the final stages when product reaches low moisture phase. Extend fermentation times of bread doughs.
	Crispbread: Control the final moisture content. In non-fermented crispbread control the process temperature and oven speed.
	Breakfast cereals: Do not over-bake or over-toast. Manage the toasting to achieve a uniform colour for the product.

Raw materials

35. 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[82] and from 15 to 25 mg/kg in rice.[83] 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.

36. Deficiencies in the sulphur content of soil can cause an increase in asparagines levels in wheat and barley.[84] Therefore, sulphur deficient soil should be avoided, or well fertilised.

37. 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.

Control/addition of other ingredients

38. 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.[85] However, lowering the wholemeal content will reduce the nutritional benefits of the final product.

39. Ammonium bicarbonate has been shown to increase the potential yield of acrylamide from a baked product.[85,86] Thus, manufacturers need to consider whether the use of ammonium-containing raising agents can be reduced. Replacement leavening agents used commercially include:[85,55]

    i. Sodium bicarbonate + acidulants;

    ii. Disodium diphosphate, sodium bicarbonate and organic acids;

    iii. Potassium bicarbonate + potassium bitartrate;

    iv. Sodium bicarbonate + sodium acid pyrophosphate (SAPP).

40. 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.[85] 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.[4] The replacement of reducing sugars by sucrose is another effective way to significantly reduce acrylamide in sweet baked goods if browning is less important.[54]

41. The addition of asparaginase has been shown to reduce asparagine and thus acrylamide in hard, wheat-dough based products such as cookies and crackers.[4,62]

42. 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.

43. 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.[83] Conversely, nutmeg has been shown, in some cases, to result in a decrease in acrylamide.[87] In order to reduce acrylamide levels in final products, manufacturers could investigate the effect of different spices in their own recipes.

44. Use of rework (the practice of re-using scraps) has been shown to increase acrylamide levels in some cases, but not in others.[4] 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

45. Yeast fermentation of wheat bread doughs reduces the free asparagine content.[88] Fermentation for two hours utilises most of the asparagine in wheat flour dough models; shorter times are less effective, as is sourdough fermentation.
46. Acrylamide formation can be reduced by modifying the time–temperature profile of the baking process,[85] 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.[83]

COFFEE

47. No commercial measures for reducing acrylamide in coffee are currently available.
48. Studies have shown that acrylamide is not stable in coffee powder in closed containers over extended storage periods[4,89,90,91] 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[4,87,92]

CONSUMER PRACTICES

49. 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.
50. National and local authorities should also consider encouraging consumers to avoid storing potatoes intended for high-temperature cooking under cold and/or refrigerated conditions.

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