Food ©2011 Global Science Books

Acrylamide in Home-prepared Roasted Potatoes – Influence of Growing Location and N-Fertilisation

Kerstin Skog[1*] • Gunilla Viklund[1] • Kerstin Olsson[2] • Ingegerd Sjöholm[1]

[1] Department of Food Technology, Engineering and Nutrition, Lund University, PO Box 124, SE-221 00 Lund, Sweden
[2] NordGen, Box 41, SE-23053 Alnarp, Sweden

Corresponding author: * **Kerstin.Skog@appliednutrition.lth.se**

ABSTRACT

Acrylamide is a probable human carcinogen that is formed during heating of carbohydrate-rich foods. The formation goes via the Maillard reaction between the precursors sugars and the amino acid asparagine, and at the same time brown colour, taste and crispiness are formed. Most mitigation strategies have been devoted to industrially prepared foods, and data on acrylamide in home-cooked foods are scarce. For national food authorities there is a need to collect such scientific data as a basis for advice to consumers on healthy cooking. In this study, the concentrations of the acrylamide precursors, asparagine and sugars (glucose, fructose and sucrose), were determined in four potato varieties ('Asterix', 'Bintje', Princess' and 'Superb'), grown at two different locations in the south of Sweden. Nitrogen had been given at two levels (60 and 120 kg N/ha) during growth. Potato wedges were prepared and roasted in two domestic ovens according to common home-cooking practices and analysed for acrylamide. The acrylamide concentrations ranged from 57 to 457 µg/kg dry matter. Nitrogen fertilisation had no significant effect on precursor content or acrylamide levels. The growth location had a large influence on the content of sugars in the tubers and on the content of acrylamide in the roasted potato wedges. The temperature profiles in the ovens fluctuated and differed between the ovens and our results indicate that there is a need for better temperature control in domestic ovens. For a 200 g portion of oven roasted potato wedges, the acrylamide content may be estimated to range from 3 to 27 µg giving a significant contribution to the dietary acrylamide intake.

Keywords: asparagine, domestic oven, home cooking, potato varieties, sugars

INTRODUCTION

The aims of this study were to examine the influence of growth location and N-fertilisation on the concentrations of asparagine and sugars in four potato varieties, and the amount of acrylamide in potato wedges after oven roasting using common domestic cooking practise. The potatoes were grown at two different locations in the south of Sweden and with two levels of nitrogen fertilization.

Acrylamide has been classed as a probable human carcinogen (IARC 1994) and therefore it was of great concern to the food industries when Swedish researchers reported high levels of acrylamide in carbohydrate rich food such as fried potato products (Tareke *et al.* 2002). Acrylamide formation routes have been investigated extensively and it is generally agreed that the main way of formation goes via the Maillard reaction between reducing sugars (glucose and fructose) and the amino acid asparagine (Mottram *et al.* 2002; Stadler *et al.* 2002; Amrein *et al.* 2003; Becalski *et al.* 2003; Yaylayan *et al.* 2003). The high levels of acrylamide in potato products (Becalski *et al.* 2004) result from a relatively high amount of acrylamide precursors in potatoes (Olsson *et al.* 2004; De Wilde *et al.* 2006). The genotype of the potato, together with soil, fertilization and weather conditions during growth, influence the initial sugar content (Burton *et al.* 1989; Olsson *et al.* 2004; Kumar *et al.* 2004), but the content of free amino acids, for example, asparagine that is the main nitrogen source in potato tubers, is mainly influenced by genotype (Olsson *et al.* 2004; Amrein *et al.* 2004; De Wilde *et al.* 2005).

Much work to minimize the content of acrylamide has been devoted to potato crisps and French fries (Stadler 2005; Pedreschi *et al.* 2007), but literature data for home-prepared potato dishes are rare (Biedermann-Brem *et al.* 2003; Jackson *et al.* 2005; Eerola *et al.* 2007; Skog *et al.* 2008; Romani *et al.* 2008). For national food authorities there is a need to collect scientific data on how to reduce the formation of acrylamide during home-cooking as a basis for advice on healthy cooking not only for households, but also for restaurants and catering enterprises.

MATERIALS AND METHODS

Potatoes

Three relatively new potato varieties, Asterix, Princess and Superb, and one well established variety, Bintje, were grown at two different locations, Ballingslöv (B) and Götala (G), in the south of Sweden. Fertilizers (120 kg N/ha or 60 kg N/ha), herbicides and fungicides against late blight had been applied according locally established practice (Hagman and Olsson 2006). The tubers were harvested in September 2006, and after wound healing for two weeks at 15°C, the storage temperature was slowly reduced. Then the potatoes were stored at 6°C at 98% relative air humidity for 6 weeks. The dry matter contents of the tubers were 20-23% for all varieties except for Princess, 15-16%.

Experimental methods

The oven roasting experiments were performed in two ordinary household ovens (size 35×30×45 cm; Cylinda and Electrohelios) according to recipes in common Swedish cookery books; conventional heating was used. Preliminary experiments were performed to establish proper cooking conditions to obtain good sensory properties. The potato wedges were weighed before and after cooking.

The length of the tubers was 6-8 cm. The potatoes were peeled and cut into six wedges. One wedge from each tuber was used for the analysis of glucose, fructose, sucrose and asparagine;

Received: 1 July, 2010. Accepted: 8 December, 2010.

Short Communication

Table 1 Contents of glucose, fructose, sucrose and asparagine in tubers before oven roasting expressed on dry matter basis (n=2), and acrylamide content in roasted wedges expressed as µg/kg dry matter (DM). The potatoes were grown at Ballingslöv (B) or Götala (G).

Variety			**Raw potatoes**					**Roasted wedges**	
Potato variety	**Fertilisation (Kg N/ha)**	**Growth place**	**Dry matter (%)**	**Glucose (mg/g DM)**	**Fructose (mg/g DM)**	**Sucrose (mg/g DM)**	**Asparagine (mg/g DM)**	**Acrylamide Oven 1 (µg/kg DM)**	**Acrylamide Oven 2 (µg/kg DM)**
Asterix	60	B	22	5	5	2	9	106	81
	120	B	21	3	3	3	9	88	68
	60	G	23	18	17	7	10	257	219
	120	G	23	20	21	11	10	357	286
Bintje	60	B	22	4	3	3	9	151	52
	120	B	21	4	3	3	9	81	72
	60	G	23	14	11	13	9	246	68
	120	G	23	15	14	25	10	456	104
Princess	60	B	16	30	24	5	11	283	255
	120	B	15	31	26	4	11	285	106
	60	G	17	33	32	7	11	424	213
	120	G	16	35	35	7	11	305	193
Superb	60	B	21	10	9	8	9	172	57
	120	B	20	12	12	7	11	236	80
	60	G	22	29	28	26	9	385	165
	120	G	21	35	35	31	12	457	154

these wedges were immediately frozen and stored at -18°C until analysis. The oven temperature was set to 200°C, and thermocouples, type K, 0.1 mm, were used to monitor the temperatures in the ovens and at the surface of the wedges. For each potato variety, the wedges were randomly divided and 250 g were put into an alminium tray; frying fat (Arla, butter and rapeseed oil, 15 mL) was poured over the wedges. Four trays at a time were put into the oven; the potato wedges were roasted for 60 min, and were turned over and partly mixed after 25 min. A skewer was used to confirm that the potatoes were cooked. The cooked potato wedges were frozen, freeze-dried and stored at -18°C before acrylamide analysis.

Analyses

The dry matter contents of the potatoes and the roasted potato wedges were determined as described previously (Viklund *et al.* 2007). The asparagine concentration was determined after derivatisation using HPLC and a fluorescence detector, and the glucose, fructose and sucrose concentrations using gas chromatography and a flame ionization detector (Olsson *et al.* 2004). The cooked potato samples were sent for determination of the acrylamide contents using HPLC.

Statistical analyses

Statistical analyses were performed using Minitab Statistical Software v.13 (Minitab Inc., Pennsylvania State College, USA). Significant differences were evaluated with the general linear model followed by Tukey's multiple comparisons test. A value of $P \leq 0.05$ was considered significant.

RESULTS AND DISCUSSION

In our study, all roasted potato wedges had an appetizing appearance with a golden yellow surface and the wedges were soft inside. Acrylamide was found in all cooked samples but at different concentrations, see **Table 1**. There was some temperature difference between the two ovens (data not shown), but generally the samples with the highest acrylamide content were the same in both ovens for all varieties. Performing cooking experiments in ordinary household ovens may give larger variations in acrylamide contents than in laboratory-scale experiments; but there is a need of more literature data on acrylamide in home-cooked potato dishes as a basis for advice on healthy cooking.

One of the aims of the study was to find out if the growth location and fertilisation level influence the precursor content, and thus the acrylamide content in the cooked product. **Table 1** gives the concentrations of the precursors glucose, fructose, sucrose and asparagine in the potatoes before oven roasting. The precursors in Asterix, Bintje and Superb, grown at location G, are at the same level as observed in a previous study (Skog *et al.* 2008). Comparing data within each of the two growth locations, it is clearly seen that the fertilisation level (60 or 120 kg N/ha) did not have any pronounced effect on the concentration of the precursors. This is in accordance with results from other studies (De Wilde *et al.* 2006; Viklund et al. 2007). The levels of glucose, fructose and sucrose showed large variations between the growth locations for all varieties except Princess, and were significantly lowest in potatoes grown at location B. Asterix and Bintje, grown at location B, had the lowest content of glucose and fructose. In a Norwegian study, two different potato varieties, Saturna and Paik, were grown at three different locations, without fertilisation, and some variations in the contents of reducing sugars were observed (Knutsen *et al.* 2009). The levels of asparagine did not differ significantly between varieties and growth locations. Other studies have also shown that the asparagine content is not significantly influenced by growth location and fertilisation levels (De Wilde *et al.* 2006; Meulenaer *et al* 2008; Knutsen *et al.* 2009). The impact of growth location is indeed interesting and shows that such information is important for the design of future studies on acrylamide in potato products.

The contents of acrylamide in the roasted wedges are shown in **Table 1**. The concentrations of acrylamide, ranging from 52 to 457 µg/kg dry matter with the highest levels found in wedges from Princess. The concentrations are at the same level as found in a previous study on oven roasted potato wedges (Skog *et al.* 2008). The results differ somewhat between the two house-hold ovens, and generally the acrylamide concentrations are higher in oven 1. However, the magnitude of the concentrations follows the same order with a few exceptions. Interestingly, the acrylamide concentrations in wedges made from potatoes grown at location B were lower than in wedges from growth location G. This is probably due to the much lower total sugar levels in these tubers. The sugar concentration has earlier been shown to have an impact on the acrylamide levels in for example French fries and crips; for example, the acrylamide content in French fries made from different potato varieties grown in Ireland was positively correlated to the content of fructose and glucose (Brunton *et al.* 2007). Our results indicate that if the sum of glucose and fructose is 10 mg/g per g dry matter or below, see for example Asterix and Bintje grown at location B, the acrylamide levels are less than 151 µg/g dry matter (oven 1) and 81 µg/g dry matter (oven 2). At higher sugar concentrations, a pronounced increase of the acrylamide concentrations was observed. This is in accordance with results from many other studies (for a review see Haase 2006). However, in our study we did not find a simple mathematical relation between sugar content and acrylamide levels.

Our data clearly show that oven roasted potato wedges may give a significant contribution to the acrylamide intake. The dry matter content of the wedges were 30–35% and thus an ordinary sized portion of oven roasted potato wedges (200 g), may contain 3 to 27 µg acrylamide. The intake of acrylamide varies with eating habits, and the mean values for adults have been reported to be around 0.2–0.5 µg acrylamide per kg body weight and day (for a review see Viklund 2007). In a Swedish report, it was found that potato crisps, French fries and fried potato products accounted for 36% of the acrylamide intake (Svensson *et al.* 2003).

The experiments were performed using "controlled" domestic cooking practices and the recorded temperature profiles showed that none of the ovens had enough heating capacity to reach the set temperature 200°C within 15 min after loading 1 kg of wedges. Generally, the consumer is not aware of the actual oven temperature which often can be different from the temperature setting. There is a need for better temperature control in domestic ovens as recommendations regarding oven temperature are one of the most critical means to reduce the formation of acrylamide in roasted potato products.

CONCLUSIONS

In conclusion, there is a large difference between potato varieties concerning sugar content and ability to form acrylamide during heating. Our results show that the growth location had high impact on the sugar concentrations in the tubers and on the acrylamide levels in the roasted wedges. The sugar content was not influenced by N-fertilisation. The asparagine content did not differ significantly between the potato varieties irrespective of growth location and fertilisation. The oven temperature which is an important factor in the formation of acrylamide may fluctuate in domestic ovens and differ from the set temperature. An ordinary sized portion of oven roasted potato wedges may give a significant contribution to the intake of acrylamide.

ACKNOWLEDGEMENTS

This work was carried out with support from the European Commission, Priority 5 on Food Quality and Safety (Contract no. FOOD-CT-2003-506820, Specific Targeted Project), "Heat-generated food toxicants – identification, characterisation and risk minimisation". This publication reflects the authors' views and not necessarily those of the EC. The information in this document is provided as is and no guarantee or warranty is given that the information is fit for any particular purpose. We are grateful to the support from the Nordic Innovation Centre project 04005 Acrylamide precursors; Limiting substrates and in vivo effects (Nordacryl). The authors would like to thank Mrs Rita Svensson, at Svalöf Weibull AB, Svalöv, for skilful technical assistance with the analysis of sugars and free amino acids.

REFERENCES

Amrein TM, Bachmann S, Noti A, Biedermann M, Ferraz Barbosa M, Biedermann-Brem S, Grob K, Keiser A, Realini P, Escher F, Amadó R (2003) Potential of acrylamide formation, sugars, and free asparagine in potatoes: A comparison of cultivars and farming systems. *Journal of Agricultural and Food Chem*istry **51**, 5556-5560

Amrein TM, Schönbächler B, Rohner F, Lukac H, Schneider H, Keiser A, Escher F, Amadó R (2004) Potential for acrylamide formation in potatoes: Data from the 2003 harvest. *European Food Research and Technology* **219**, 572-578

Becalski A, Lau BP, Lewis D, Seaman SW (2003) Acrylamide in foods: Occurrence, sources, and modeling. *Journal of Agricultural and Food Chemistry* **51**, 802-808

Becalski A, Lau BP, Lewis D, Seaman SW, Hayward S, Sahaigan M, Ramesh M, Leclerc Y (2004) Acrylamide in French fries: Influence of free amino acids and sugars. *Journal of Agricultural and Food Chem*istry **52**, 3801-3806

Biedermann-Brem S, Noti A, Grob K, Imhof D (2003) How much reducing sugar may potatoes contain to avoid excessive acrylamide formation during roasting and baking? *European Food Research and Technology* **217**, 369-373

Burton WG (1989) *The Potato* (3rd Edn), John Wiley and Sons, New York, pp 354-355

De Meulenaer B, De Wilde T, Mestdagh F, Govaert Y, Ooghe W, Fraselle S, Demeulemeester K, Van Peteghem C, Calus A, Degroodt JM, Verhé R (2008) Comparison of potato varieties between seasons and their potential for acrylamide formation. *Journal of the Science of Food and Agriculture* **88 (2)**, 313-318

De Wilde T, De Meulenaer B, Mestdagh F, Govaert Y, Vandeburie S, Ooghe W, Fraselle S, Demeulemeester K, Van Peteghem C, Calus A, Degroodt JM, Verhé R (2005) Influence of storage practices on acrylamide formation during potato frying. *Journal of Agricultural and Food Chem*istry **16**, 6550-6557

De Wilde T, De Meulenaer B, Mestdagh F, Govaert Y, Vandeburie S, Ooghe W, Fraselle S, Demeulemeester K, Van Peteghem C, Calus A, Degroodt JM, Verhé R (2006) Influence of fertilisation on acrylamide formation during frying of potatoes harvested in 2003. *Journal of Agricultural and Food Chem*istry **54**, 404-408

Eerola S, Hollebekkers K, Hallikainen A, Peltonen K (2007) Acrylamide levels in Finnish foodstuffs analysed with liquid chromatography tandem mass spectrometry. *Molecular Nutrition and Food Research* **2**, 239-247

Haase NU (2006) The formation of acrylamide in potato products. In: Skog K, Alexander J (Eds) *Acrylamide and Other Hazardous Compounds in Heat-Treated Foods*, Woodhead Publishing, Cambridge, pp 41-59

Hagman J, Olsson K (2006) Ge rätt mängd kväve till matpotatis. *Viola* **20**, 6-17 (in Swedish)

IARC (1994) *Monographs on the Evaluation of Carcinogenic Risks to Humans, Some Industrial Chemicals*, International Agency for Research on Cancer, Lyon, 389 pp

Jackson LS, Al-Taher F (2005) Effects of consumer food preparation on acrylamide formation. *Advances in Experimental Medicine and Biology* **561**, 447-465

Knutsen SH, Dimitrijevic S, Molteberg EL, Segtnan VH, Kaaber L, Wicklund T (2009) The influence of variety, agronomical factors and storage on the potential for acrylamide formation in potatoes grown in Norway. *LWT - Food Science and Technology* **42 (2)**, 550-556

Kumar D, Singh BP, Kumar P (2004) An overview of the factors affecting sugar content in potatoes. *Annals of Applied Biology* **145**, 247-256

Mottram DS, Wedzicha BL, Dodson AT (2002) Acrylamide is formed in the Maillard reaction. *Nature* **419**, 448-449

Olsson K, Svensson R, Roslund CA (2004) Tuber components affecting acrylamide formation and colour in fried potato: Variation by variety, year, storage temperature, and storage length. *Journal of Agricultural and Food Chemistry* **84**, 447-458

Pedreschi FB, Mery D, Moyano P, Kaack K, Granby K (2007) Color kinetics and acrylamide formation in NaCl soaked potato chips. *Journal of Food Engineering* **79**, 786-793

Romani S, Bacchiocca M, Roccul P, Dalla Rosa M (2008) Effect of frying time on acrylamide content and quality aspects of French fries. *European Food Research and Technology* **226 (3)**, 555-561

Skog K, Viklund G, Olsson K, Sjöholm I (2008) Acrylamide in home-prepared roasted potatoes. *Molecular Nutrition and Food Research* **52**, 307-312

Stadler RH (2005) Acrylamide formation in different foods and potential strategies for reduction. *Advances in Experimental Medicine and Biology* **561**, 157-169

Stadler RH, Blank I, Varga N, Robert F, Hau J, Guy PA, Robert MC, Riediker S (2002) Acrylamide from Maillard reaction products. *Nature* **419**, 449-450

Svensson K, Abramsson L, Becker W, Glynn A, Hellenäs KE, Lind Y, Rosén J (2003) Dietary intake of acrylamide in Sweden. *Food and Chemical Toxicology* **41**, 1581-1586

Tareke E, Rydberg P, Karlsson P, Eriksson S, Törnqvist M (2002) Acrylamide a cooking carcinogen? *Chemical Research in Toxicology* **13**, 517-522

Viklund G (2007) Acrylamide in potato crisps – a three year study on Swedish-grown potatoes. PhD thesis, Lund University, pp 1-64

Viklund G, Mendoza F, Sjöholm I, Skog K (2007) An experimental set-up for studying acrylamide formation in potato crisps. *LWT - Food Science and Technology* **40**, 1066-1071

Yaylayan VA, Wnorowski A, Perez Locas C (2003) Why asparagine needs carbohydrates to generate acrylamide. *Journal of Agricultural and Food Chemistry* **51**, 1753-1757