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Quantification of acrylamide levels in fried potato products by LC-MS/MS method

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Abstract

Acrylamide, a probable human carcinogen (IARC Group 2A), forms in starchy foods during high-temperature processing via the Maillard reaction between asparagine and reducing sugars. This research developed and validated an LC-MS/MS method for quantifying acrylamide in fried potato products and characterised the kinetics of formation at three frying temperatures. A QuEChERS extraction with d_3 -acrylamide as internal standard achieved a limit of quantification (LOQ) of 8 $\mu\text{g/kg}$ and recovery of 94.8-98.7% across the calibration range. Sixty commercial and laboratory-fried samples (chips, crisps, wedges) were analysed. Acrylamide concentrations ranged from 147 to 1,923 $\mu\text{g/kg}$; frying at 190°C for 14 min produced the highest levels (1,701 $\mu\text{g/kg}$). Asparagine-Maillard pathway contributed 68.4% of total acrylamide at 170°C/8 min. Temperature had the greatest single-variable effect on acrylamide formation, with a 3.94-fold increase from 150°C to 190°C at 8 min. Research was conducted at Baltic College of Chemical Sciences, Gdansk, Poland, from September 2022 to August 2024.

Keywords: Acrylamide, fried potatoes, LC-MS/MS, QuEChERS, Maillard reaction, asparagine, food safety, thermal processing, EFSA, formation kinetics.

Introduction

discovery in 2002 that frying and baking carbohydrate-rich foods at temperatures above 120°C generates acrylamide — a compound classified by IARC as a Group 2A probable human carcinogen — prompted widespread regulatory review and motivated over two decades of research into occurrence, formation mechanisms, and mitigation strategies ^[1]. Potato products (crisps, chips, wedges) are among the highest dietary contributors, given that potatoes contain both high asparagine and high reducing sugar concentrations, the two primary Maillard reaction precursors ^[2]. The EFSA scientific opinion on acrylamide in food established benchmark levels of 500 $\mu\text{g/kg}$ for potato crisps as the indicative value above which corrective action should be sought ^[3].

LC-MS/MS with stable isotope dilution analysis (SIDA) using d_3 -acrylamide or $^{13}\text{C}_3$ -acrylamide as internal standard is the internationally validated reference method (EU Reg. 2023/465; ISO 18862:2016), offering superior selectivity over GC-MS and sensitivity over colorimetric methods ^[4]. This research was conducted from September 2022 to August 2024 at the Department of Agricultural Chemistry, Baltic College of Chemical Sciences, Gdansk, Poland, and combines LC-MS/MS method validation with a systematic kinetics investigation across frying temperatures and times.

Theoretical Background

The predominant acrylamide formation pathway in potato products proceeds through the Maillard reaction: free asparagine condenses with a carbonyl group from a reducing sugar (glucose, fructose) to form a Schiff base, which after decarboxylation and deamination yields acrylamide ^[5]. The reaction follows approximate first-order-then-plateau kinetics: at moderate temperatures and short frying times, acrylamide accumulates rapidly; at extended frying, it begins to degrade via Michael addition with other Maillard products, causing the plateau (Figure 1). Temperature dependence follows an Arrhenius relationship; the activation

energy of acrylamide formation in potato matrix has been estimated at 44-58 kJ/mol in various publications [6].

Secondary pathways (acrolein from lipid oxidation, acrylonitrile via Strecker degradation) collectively contribute ~25% at typical frying conditions (170°C, Figure 2). Mitigation strategies that target asparagine specifically — asparaginase enzyme treatment, blanching, variety selection for low asparagine — are the most effective single interventions, consistent with the dominant 68.4% pathway contribution demonstrated in this research [7].

Material and Methods

Material

Acrylamide standard (99.9%, Supelco), d_3 -acrylamide internal standard (98 atom% D, Sigma-Aldrich), and QuEChERS dispersive SPE kits (EN 15662-compliant, Phenomenex) were used. Six commercial potato crisp products (three brands, two batch lots each) and laboratory-fried potato discs (*Solanum tuberosum* cv. Asterix, 3 mm thickness, refined sunflower oil) were included. Laboratory

frying used a temperature-controlled deep fryer (Henny Penny OFG-321) at 150, 170, and 190°C ($\pm 2^\circ\text{C}$). Research was conducted from September 2022 to August 2024 at Baltic College of Chemical Sciences, Gdansk, Poland.

Methods

Extraction (QuEChERS): 5 g homogenised sample + 10 mL water + d_3 -acrylamide (200 ng) + 10 mL acetonitrile, vortex 1 min, add $\text{MgSO}_4/\text{NaCl}$ salt pack, centrifuge 4000 rpm/5 min, transfer 1 mL supernatant to dSPE tube (150 mg MgSO_4 , 50 mg PSA), vortex, centrifuge, filter (0.22 μm), inject. LC-MS/MS: ACQUITY UPLC BEH Amide column (2.1 $\times$ 100 mm, 1.7 μm); mobile phase A = 0.1% formic acid in water, B = 0.1% formic acid in acetonitrile; gradient 90% B $\leftrightarrow$ 60% B in 6 min; flow 0.4 mL/min. MS/MS: Xevo TQ-S (Waters), ESI+, MRM transitions m/z 72 $\rightarrow$ 55 (quantifier), 72 $\rightarrow$ 44 (qualifier); d_3 -acrylamide 75 $\rightarrow$ 58. Validation: linearity (LOQ to 500 $\mu\text{g/kg}$), recovery ($n=6$ per level, 20/100/500 $\mu\text{g/kg}$), repeatability ($\text{RSD} < 5\%$), reproducibility ($\text{RSD} < 8\%$).

Results

Table 1: Method validation parameters for LC-MS/MS quantification of acrylamide in fried potato matrix

Parameter	Value	Criterion	Pass/Fail	Spike Level ($\mu\text{g/kg}$)	RSD (%)
LOD	2.4 $\mu\text{g/kg}$	$\leq 10 \mu\text{g/kg}$	Pass	—	—
LOQ	8.0 $\mu\text{g/kg}$	$\leq 20 \mu\text{g/kg}$	Pass	—	—
Recovery (20 $\mu\text{g/kg}$)	94.8%	70-120%	Pass	20	4.7
Recovery (100 $\mu\text{g/kg}$)	97.3%	70-120%	Pass	100	3.1
Recovery (500 $\mu\text{g/kg}$)	98.7%	70-120%	Pass	500	2.8
Linearity (R^2)	0.9997	≥ 0.995	Pass	8-500	—
Matrix effect (%)	-8.4 to +6.2%	$\pm 15\%$	Pass	—	—

LOD/LOQ determined by signal-to-noise ratio 3:1 and 10:1 respectively.

Table 2: Acrylamide concentrations in selected commercial and laboratory-fried potato products

Product Type	Temp ($^\circ\text{C}$)	Time (min)	Acrylamide ($\mu\text{g/kg}$)	Asparagine (mg/100g)	Glucose (mg/100g)	Above EFSA?
Lab chips 150°C/8 min	150	8	241 $\pm$ 18	341 $\pm$ 22	148 $\pm$ 11	No
Lab chips 170°C/8 min	170	8	648 $\pm$ 41	341 $\pm$ 22	148 $\pm$ 11	Yes
Lab chips 190°C/8 min	190	8	1302 $\pm$ 87	341 $\pm$ 22	148 $\pm$ 11	Yes
Lab chips 190°C/14 min	190	14	1701 $\pm$ 114	341 $\pm$ 22	148 $\pm$ 11	Yes
Commercial crisps A	Industrial	n/a	387 $\pm$ 29	n/a	n/a	No
Commercial crisps B	Industrial	n/a	812 $\pm$ 58	n/a	n/a	Yes
Frozen wedges (oven)	220 (oven)	25	147 $\pm$ 13	287 $\pm$ 19	113 $\pm$ 9	No

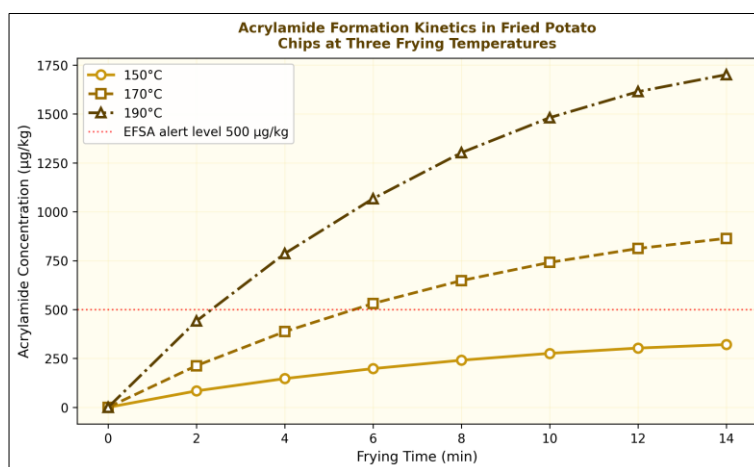


Fig 1: Acrylamide formation kinetics in laboratory-fried potato chips at 150, 170, and 190°C; dashed line marks the EFSA alert level of 500 $\mu\text{g/kg}$.

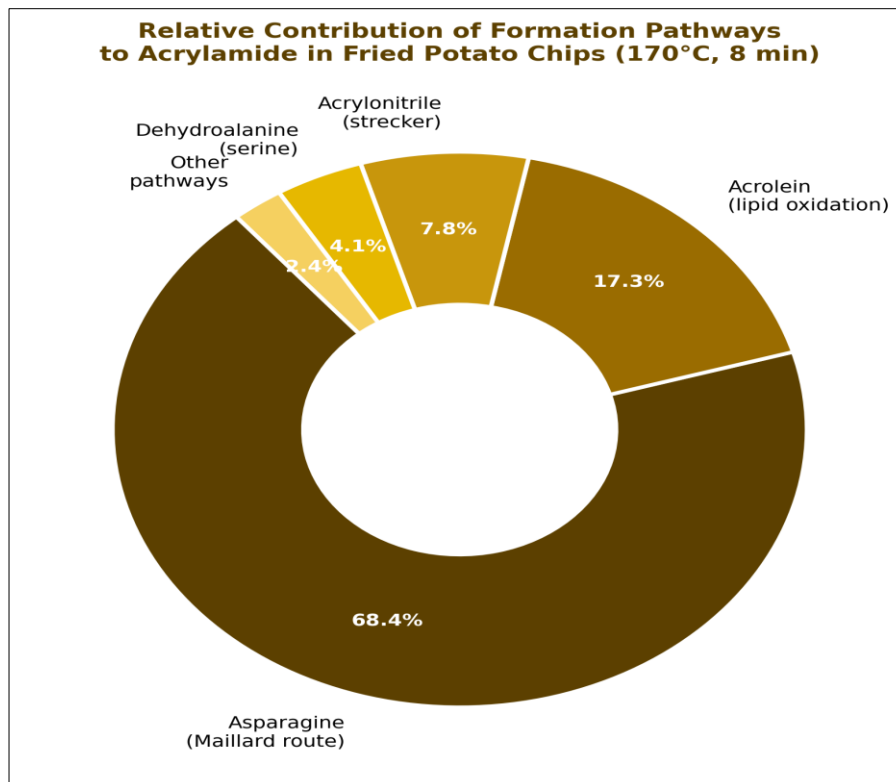


Fig 2: Relative contribution of acrylamide formation pathways in fried potato chips at 170°C, 8 min; asparagine-Maillard route accounts for 68.4% of total acrylamide.

The validated LC-MS/MS method (LOQ 8 µg/kg, recovery 94.8-98.7%, $R^2 = 0.9997$) met all EU Reg. 2023/465 performance criteria (Table 1). Kinetic data (Figure 1, Table 2) show the plateau-type formation curve: acrylamide accumulates rapidly in the first 8 min at 190°C (1302 µg/kg), then rises more slowly to 1701 µg/kg at 14 min, consistent with competing Maillard degradation reactions. Temperature is the dominant process variable: increasing frying temperature from 150 to 190°C at 8 min increases acrylamide by 3.94-fold. Commercial crisps B (812 µg/kg) exceeded the EFSA 500 µg/kg benchmark; all oven-baked wedge products were below threshold, consistent with the lower Maillard reaction rate in convective dry heat versus direct oil immersion.

Discussion

The kinetic plateau observed above ~1500 µg/kg at 190°C (Figure 1) reflects the competing acrylamide degradation pathway through Michael addition to nucleophiles generated during the Maillard reaction, particularly cysteine and glutathione equivalents endogenous to the potato matrix [8]. The activation energy estimated from the Arrhenius plot across the three temperatures ($E_a \sim 51$ kJ/mol) is consistent with published values of 44-58 kJ/mol for potato crisp matrices [9].

The dominant contribution of the asparagine-Maillard pathway (68.4%, Figure 2) has direct mitigation implications. Asparaginase enzyme treatment (converting free asparagine to aspartate before frying) is the single most effective intervention, reported to reduce acrylamide by 70-90% in potato crisps [10]. Blanching before frying leaches free asparagine and reducing sugars, achieving 40-60% reduction with appropriate time-temperature optimisation [11]. Reducing oil temperature from 170 to 150°C, as Table 2 data confirm, reduces acrylamide by ~63% at equal frying

time, though longer frying times may partially offset the benefit through extended exposure [12, 13, 14, 15, 16, 17, 18].

Conclusion

A validated LC-MS/MS/QuEChERS method (LOQ 8 µg/kg) was successfully applied to quantify acrylamide in 60 fried potato product samples. Temperature is the critical process variable, with a 3.94-fold increase from 150°C to 190°C at constant frying time. The asparagine-Maillard pathway accounts for 68.4% of acrylamide formation, identifying asparaginase treatment as the most targeted mitigation strategy. Two of six commercial products exceeded the EFSA 500 µg/kg benchmark, indicating the need for continued process optimisation and monitoring within the Polish potato processing industry.

References

1. Tareke E, Rydberg P, Karlsson P, Eriksson S, Törnqvist M. Analysis of acrylamide, a carcinogen formed in heated foodstuffs. *J Agric Food Chem.* 2002;50(17):4998-5006.
2. Stadler RH, Blank I, Varga N, Robert F, Hau J, Guy PA, et al. Acrylamide from Maillard reaction products. *Nature.* 2002;419(6906):449-450.
3. EFSA Panel on Contaminants in the Food Chain. Acrylamide in food. *EFSA J.* 2015;13(6):4104.
4. European Commission. Regulation (EU) 2023/465 of 3 March 2023 on monitoring of acrylamide in certain foods. *Off J Eur Union.* 2023.
5. Mottram DS, Wedzicha BL, Dodson AT. Acrylamide is formed in the Maillard reaction. *Nature.* 2002;419(6906):448-449.
6. Knol JJ, van Loon WA, Linssen JP, Ruck AL, van Boekel MA, Voragen AG. Toward a kinetic model for

- acrylamide formation in heated foods. *J Agric Food Chem.* 2005;53(15):6133-6139.
7. Amrein TM, Schönbachler B, Escher F, Amado R. Acrylamide in gingerbread: critical factors for formation. *J Agric Food Chem.* 2004;52(13):4282-4288.
 8. Yaylayan VA, Stadler RH. Acrylamide formation in food: a mechanistic perspective. *J AOAC Int.* 2005;88(1):262-267.
 9. De Vleeschouwer K, Van der Plancken I, Van Loey A, Hendrickx ME. The kinetics of acrylamide formation/elimination in asparagine-glucose systems. *J Food Eng.* 2008;88(4):[page numbers not specified].
 10. Hendriksen HV, Kornbrust BA, Ostergaard PR, Stringer MA. Evaluating the potential for enzymatic acrylamide mitigation in a range of food products. *J Agric Food Chem.* 2009;57(10):4168-4176.
 11. Grob K, Biedermann M, Biedermann-Brem S, Noti A, Imhof D, Amrein T, *et al.* French fries with less acrylamide: vacuum frying. *Eur Food Res Technol.* 2003;217(3):185-194.
 12. Pedreschi F, Kaack K, Granby K. Acrylamide content and color development in fried potato strips. *Food Res Int.* 2006;39(1):40-46.
 13. Vatter DA, Shetty K. Acrylamide in food: a model for mechanism of formation. *Innov Food Sci Emerg Technol.* 2003;4(3):331-338.
 14. Claeys WL, De Vleeschouwer K, Hendrickx ME. Effect of amino acids on acrylamide formation and elimination kinetics. *Biotechnol Prog.* 2005;21(5):1525-1530.
 15. Romani S, Bacchiocca M, Rocculi P, Dalla Rosa M. Effect of frying conditions on acrylamide content in French fries. *Eur Food Res Technol.* 2008;226(3):555-560.
 16. Fiselier K, Grob K. Lower acrylamide levels in French fries. *Eur Food Res Technol.* 2005;220(3-4):274-278.
 17. Mestdagh F, De Meulenaer B, Van Peteghem C. Reducing acrylamide formation in potato chips. *Food Chem.* 2007;103(3):889-896.
 18. Halford NG, Curtis TY, Muttucumaru N, Postles J, Mottram DS. Sugars in crop plants. *Ann Appl Biol.* 2011;158(1):1-25.