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Impact of oil selection and cooking methods on acrylamide levels in different potato products

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Abstract

This study investigated the effects of frying method and oil type on acrylamide formation in different potato products. Acrylamide levels were analyzed in three types of potatoes: organic potatoes, pre-treated French fries, and wedge-style potatoes, using an LC-MS/MS method. All samples were cooked using three common methods in Macedonian cusine - air frying, oven baking and pan frying, and using two types of oil, palm oil and sunflower oil.

The highest acrylamide content was found in organic potatoes pan-fried in sunflower oil for 10 minutes (924.93 ± 0.66 µg/kg). French fries showed moderate acrylamide levels, while wedges generally had the lowest levels, particularly when pan-fried in palm oil (140.37 ± 0.47 µg/kg) for 5 minutes. The results from statistical correlations between sample type, cooking method, and oil type with acrylamide formation suggest that while cooking method and oil type may have a modest impact on acrylamide formation, the type of potato product plays a more significant role, with an inverse relationship observed. Additionally, due to the lack of standardized and controlled cooking conditions, such as precise temperature and time settings, home-cooked potatoes tend to have higher acrylamide levels compared to French fries prepared in fast-food restaurants. Thus, the current understanding provides adequate basis for future studies that target on improving cooking conditions to lower acrylamide levels in home-prepared foods.

Key words: acrylamide, potato, LC-MS/MS, cooking method, oil type

Introduction

Acrylamide is a chemical compound that forms through a natural chemical reaction (Maillard reaction) (Stadler et al., 2002) in plant-based food rich with reductive sugars and amino acids (mainly asparagine) during high-temperature (above 120 °C) cooking. Different types of cooking - frying, baking, and air frying may lead to different concentrations of acrylamide (Navruz-Varlı and Mortaş, 2023). Acrylamide forms in a variety of cooked, carbohydrate-rich foods, including potato crisps, French fries, bread, snacks, biscuits, and coffee. It is also known to be present in cigarette smoke. Orally administered acrylamide is absorbed from the gastrointestinal tract, distributed to all organs and extensively metabolized, mostly by conjugation with glutathione but also through epoxidation to glycidamide (GA), which is most likely the cause of gene mutations and tumors (EFSA, 2015).

In April 2002, the Swedish National Food Administration (SNFA) reported potential health risks associated with eating fried and baked foods such as potatoes and bread. Researchers at the University of Stockholm found high levels of acrylamide (up to 500

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times more acrylamide than allowed concentration in drinking water by the World Health Organization) (LÖFSTEDT, 2003). In 2010, the Joint Food and Agriculture Organization/WHO Expert Committee on Food Additives (JECFA) concluded that acrylamide is a human health concern, and suggested additional long-term studies of neurotoxicity and carcinogenicity on acrylamide and GA (WHO, 2010).

There is sufficient evidence that acrylamide is carcinogenic in rodents. However, studies on human subjects have provided limited and inconsistent evidence of increased risk of developing cancer. As a result, it was classified by International Agency for Research on Cancer (IARC) as a probable carcinogen (Group 2A) (Beland et al., 2013, 2015). A collaborative study, led by the Molecular Mechanisms and Biomarkers Group at the IARC reported a tumor-specific mutation spectrum introduced into the human genome by GA, which is metabolite of acrylamide (Zhivagui et al., 2019). Therefore, acrylamide is considered a public health risk.

Although, preventing acrylamide formation in food is impossible, the food industry has worked closely with scientist and regulators to mitigate its formation (Food Drink Europe, 2021). European Food Safety Authority (EFSA) created Panel on Contaminants in the Food Chain (CONTAM) which evaluated a total of 43 419 analytical results from food commodities. Acrylamide was found at the highest level in solid coffee substitutes and coffee, and in potato fried products. Depending on age group, chronic dietary exposure of children was between 0.5 and 1.9 μg/kg per day, and for adolescents, adults, elderly and very elderly was estimated to be on average between 0.4 and 0.9 μg/kg per day. The group of 'Potato fried products (except potato crisps and snacks)' was the main contributor to the total exposure of toddlers, other children, and adolescents, representing up to half the total exposure, followed by 'Soft bread', 'Breakfast cereals', 'Biscuits, crackers, crisp bread', 'Other products based on cereals', and 'Other products based on potatoes'. These food groups were also the main contributors to the total exposure of adults, the elderly, and the very elderly together with 'Coffee' (EFSA, 2015).

The CONTAM Panel analyzed a dataset of manufacturers' measurements of acrylamide levels in 40 455 samples of freshly sliced potato crisps from 20 European countries. The data covering the years 2002 to 2011 showed a substantial downward trend in mean acrylamide levels, decreasing from 763 ± 91.1 μg/kg in 2002 to 358 ± 2.5 μg/kg in 2011. For other food categories, a similar downward trend was not observed. As a result, the Acrylamide Toolbox (Food Drink Europe, 2019) was created to investigate how acrylamide is formed and to explore possible methods for reducing acrylamide levels in foods, as low as reasonably achievable (ALARA). This initiative supports the implementation of Commission Regulation (EU) 2017/2158. However, consumers often use diverse cooking practices in their households (Mesias et al., 2020), which can result in relatively high acrylamide levels. In addition to cooking practices, oil selection is another key factor influencing acrylamide levels in potato products (Horneț et al., 2021). The most commonly used oils for cooking French fries are palm oil and sunflower oil. In commercial settings, such as food chains, palm oil is preferred for frying. However, in home cooking, sunflower oil is more commonly used, as is the case in our country. According to Abd Razak et al. (2021) vegetable oils with a balanced proportion of saturated and unsaturated fatty acids are more suitable for frying compared to oils high in unsaturated fatty acids. Oils like sunflower oil, which have a high content of unsaturated fatty acids, are more susceptible to oxidation and polymerization during frying. Therefore, this study aimed to investigate the impact of three common cooking methods representative of Macedonian cuisine – baking, air frying and pan frying, using two different types of oil, sunflower and palm oil, in three different potato products.

Material and methods

Materials

In this study, three types of potato products were used: fresh potato peeled and sliced on stripes, frozen pre-treated French fries, and frozen pre-treated wedge-style potato. Fresh potatoes were sourced from a local organic farm, and frozen products were purchased from a local market chain. Fresh potatoes were peeled using a mechanical potato-peeling knife and cut into strips with an automatic potato slicer yielding dimensions of 1 cm x 1 cm. The frozen French fries also had dimensions of 1 cm x 1 cm. For cooking of all potato samples, sunflower oil and palm oil, purchased from local market chain were used. Throughout the whole experiment, the cooking was conducted with the same oils. Palm oil was used for pan frying and oven baking. The wedges and French fries were pre-treated with palm oil, so palm oil was indirectly used for air frying these types. Sunflower oil was used for pan frying and oven baking. For air fryer cooking no additional oil was added. All materials were divided into seven groups, as shown in Table 1.

Additionally, during the study, four French fries from different fast-food restaurants were analyzed, to check if the acrylamide content during industrial cooking is above the benchmark.

Cooking methods

All potato products were cooked in three different methods - baking, air frying and, pan frying, using two different types of oil: sunflower and palm oil. Temperatures and duration of cooking for all three cooking methods are shown in Table 2. Frozen products were cooked without thawing, as recommended from the manufacturer's cooking instructions.

Table 1. Experimental plan for analyzing acrylamide under different cooking conditions across three different types of potato products

Potato type	Cooking method	Oil type
Fresh organic potato	Non cooked	No oil
	Oven baking	Sunflower
		Palm
	Air frying	No oil
	Pan frying	Sunflower
		Palm
Frozen pre-treated French fries	Non cooked	No oil
	Oven baking	Sunflower
		Palm
	Air frying	No oil
	Pan frying	Sunflower
		palm
Frozen pre-treated wedges	Non cooked	No oil
	Oven baking	Sunflower
		Palm
	Air frying	No oil
	Pan frying	Sunflower
		Palm

Table 2. Cooking conditions

Cooking type	Temperature (℃)	Time (min)
Oven baking	200	20
Air frying	180	20
Pan frying	130	5/10*

*The duration of the pan frying impacted the acrylamide level, providing variable results. Because 10 minutes of pan frying yielded acrylamide levels above the benchmark, 5 minutes of frying was used to check if the acrylamide level would decrease.

Every potato product was treated in eight different cooking combination, method-oil, and every combination was analyzed for acrylamide formation in triplicates. Acrylamide analysis was performed on non-cooked potato samples as well.

Oven baking. Oven-baking was performed in commercial oven (Electrolux, model EZB 3411 AOX, capacity 57 L, Poland), pre-heated at 200 ℃ for 15 min in static function. Each potato product (fresh potato, frozen French fries, and frozen wedges) was marinated with two tablespoons (10 g) of sunflower oil per 200 g of potatoes in separate bowls. The potato strips were then arranged in rows on a baking steel tray covered with greaseproof paper. The tray was placed in the middle of the oven and baked at 200 ℃ for 15 min. At the 7th min, the potatoes were removed from the oven and flipped to ensure even cooking. At the end of the baking process, the potatoes were taken out of the oven and transfered onto tissue paper to absorb extra oil. After cooling to room temperature, the baked potato strips were stored in separate packages acording to their type and analyzed the following day. The whole process was carried out the same for all potatoes types with the palm oil.

Air frying. For the air frying method, a commercial air fryer (Xiaomi Mi Smart Air Fryer 3.5 L, China) was used. The air fryer was pre-heated for 5 min to reach the temperature of 200 ℃. Each type of potato product was marinaded with one tablespoon (5 g) of sunflower oil per 100 g potatoes. The marinated potatoes were arranged in rows in the frying basket, which was lined with greaseproof paper. The potatoes were cooked at 200 ℃ for 15 min, as recommended by the air fryer program for French fries. At the 7th minute, the frying basked was removed and the potatoes were flipped to ensure even cooking. After the cooking process was complete, the frying basket was removed, and the potatoes were transferred onto tissue paper to absorb extra oil. Once cooled to room temperature, the air-fried potatoes were stored in separate packages according to their type and analyzed the following day. The entire air frying process was performed using a palm oil marinade with all three types of potatoes.

Pan frying. Pan frying differs from deep frying in form, in that it uses less oil (just to cover the potatoes) and

the temperature is lower (130 °C), than deep frying, which is usually done at 175 °C. During the frying process, a stainless-steel pan with a 20 cm diameter was used. The pan was filled with 500 mL of sunflower oil and heated on a commercial stove (Electrolux, model EHF6240IOK, Poland) to a temperature of 130 °C (level 7). The temperature was monitored using a digital cooking thermometer (NAVA, model Acer, Greece). A 200 g sample from each potato product was fried separately in a fresh batch of sunflower oil as well as in palm oil. Each batch was fried for 5 min. After frying, the potatoes were removed from the oil using a strainer and placed onto tissue paper to absorb extra oil. Once cooled to room temperature, the fried potatoes were stored in separate packages according to their type and analyzed the following day.

Sample extraction

Before extraction, each sample was chopped and homogenized with a manual food chopper. Acrylamide extraction from the samples was carried out using a modified QuEChERS method (Mastovska and Lehotay, 2006). A 1 g sample was weighed into a 50 mL centrifuge tube from the Agilent Bond Elut QuEChERS Extraction Kit (CA, USA) using an analytical scale (Sartorius, Göttingen, Germany). The samples were spiked with 500 µL internal standard solution (acrylamide d_3) at a concentration of 1000 ng/mL. To remove fats, 5 mL of n-hexane (Rotidry ≥ 99%, Roth, Karlsruhe, Germany) was added to the tube, and the mixture was vortexed. Then, 10 mL of water was added to facilitate the extraction of acrylamide from the potatoes. Following this, 10 mL of acetonitrile, (LC-MS Ultra ≥ 99.9%, Chromasolv, Honeywell, Seelze, Germany) was added, along with the Agilent Bond Elut QuEChERS extraction salt mixture for acrylamides (p/n 5982-5850), which contains 4 g of $MgSO_4$ and 0.5 g of NaCl. This addition enabled the separation of the acetonitrile and water phases. The sample tubes were shaken for 3 min using a multitube vortexer (BenchMixer BV1010, USA) and then centrifuged at 5000 rpm for 10 min. The hexane layer was discarded and 1 mL of acetonitrile extract was transferred to a 2 mL Bond Elut QuEChERS AOAC Dispersive SPE tube (p/n 5982-5022). The tubes were vortexed for 30 sec. and then centrifuged at 5000 rpm for 3 min (Eppendorf 5425 R, Germany). Dispersive SPE (solid phase extraction), which contains 50 mg PSA (primary and secondary amine) and 150 mg $MgSO_4$, was employed for sample cleanup (p/n 5982-5022). The supernatant was filtered through 0.2 µm PTFE syringe filter (Millex-LG, Millipore, Germany) into an autosampler vial for LC-MS/MS analysis.

Chromatography analysis

Acrylamide analysis was conducted using a method, which was recommended in the application note from Agilent, for analyzing acrylamide in French fries (Al-Taher et al., 2012). This method utilized the Agilent Bond Elut QuEChERS AOAC Kit (p/n 5982-5850). The analysis was performed on an Agilent 1200 Series HPLC system coupled with an Agilent 6470A triple quadrupole LC-MS/MS system (Agilent technologies, Inc., CA, USA). Data processing was performed using Agilent MassHunter software.

Acrylamide separation was carried out on a reversed phase C18 column (Zorbax Eclipse Plus C18; 2.1 mm x 100 mm, 1.8 µm). Chemicals used for mobile phase (2.5% MeOH/97.5% of 0.1% formic acid) were purchased from Sigma-Aldrich, USA. Acrylamide standard (CRM purity = 99.5%) was also purchased from Sigma-Aldrich. The standard stock solution of acrilamide (1 mg/mL) was prepared by dissolving 100 mg of acrylamide standard in 100 mL of acetonitrile. and stored at 4 °C. All working solutions were freshly prepared daily by serial dilution in acetonitrile. For construction of the calibration curve, eight concentration levels were used: 2 ng/mL, 5 ng/mL, 10 ng/mL, 20 ng/mL, 30 ng/mL, 50 ng/mL, 70 ng/mL, and 100 ng/mL.

Table 3. LC-MS/MS conditions for analysis.

Column	Reversed C-18 column, 2.1 mm x 100 mm, 1.8 µm
Column temperature	30 °C
Isocratic mode (% B)	2.5% MeOH/97.5% of 0.1% formic acid
Flow rate	0.2 mL/min
Injection volume	10 µL
Run time	7 min
Post run time	3 min
Mass spectometer mode	Positive Electrospray Ionization (ESI) mode with jet stream techn.
Capillary voltage	3500 V
Nozzle voltage	500 V
Sheath gas temperature	325 °C at 10 L/min
Drying gas temperature	350 °C at 11 L/min
Nebulizer	45 psi

Statistical analysis

Statistical analysis was conducted using IBM SPSS Statistics 30.0 (The Statistical Package for Social Sciences-SPSS Inc., Chicago IL, USA). The data were evaluated based on descriptive characteristics, including arithmetic mean, standard deviation (SD), and coefficient of variation. The Kruskal-Wallis's test, a non-parametric alternative to ANOVA was used to compare groups. The assumption variance agreement was verified using the F-test (F). Pairwise differences in means were tested using the Bonferroni correction to adjust for multiple comparisons. Additionally, Pearson correlation analysis was used to assess the strength and direction of linear relationships between acrylamide, sample type, cooking method, and oil type.

Results and discussion

The potato model system was set up to investigate the effect of parameters, such as oil type and cooking method on different potato products and their potential influence on acrylamide formation. The R-squared value of 0.998 indicates that the model explains 99.8% of the variance in acrylamide levels, an exceptionally high value. This suggests that the factors and interactions considered in the model account for almost all observed variability in acrylamide levels. Pearson correlation was used to evaluate the strength and direction of linear relationships between acrylamide levels and investigated variables. The analysis revealed a significant negative correlation between sample type and acrylamide levels ($r = -0.396$, $p < 0.001$), a weak negative correlation between cooking method and acrylamide levels ($r = -0.279$, $p = 0.018$), and a weak positive correlation between oil type and acrylamide levels ($r = 0.276$, $p = 0.019$) (Fig.1 and 2). These results suggest that cooking method and oil type may have modest impacts on acrylamide formation, while sample type shows a stronger inverse relationship. This means that certain potato types tend to produce less acrylamide during cooking compared to others, which can be attributed to factors such as lower sugar content (i.e., wedge-style potatoes), or reduced sugar levels in pre-treated French fries, which undergo blanching or soaking processes before cooking. Additionally, wedge-style potatoes have less surface area exposed to heat compared to thinner French fries, leading to lower acrylamide formation.

The analytical determination of acrylamide in food products is most commonly carried out by high-performance liquid chromatography (HPLC) or gas chromatography (GC) coupled with mass spectrometric (MS) detection (Wenzl et al., 2003). These methods operate in either selected ion monitoring (SIM) mode or tandem mass spectrometry (MS/MS) in multiple reactions monitoring (MRM) mode, using isotope labelled standards for accuracy. In this study, an LC-MS/MS method previously used for analyzing acrylamide in French fries (Al-Taher, 2012), was employed. A linear calibration curve was obtained with a correlation coefficient (R^2) of 0.9997 and the equation y = 0.128649x+1.847523. Limit of detection (LoD) and limit of quantification (LoQ) of the method were found to be 6.13 µg/kg, and 18.57 µg/kg, respectively.

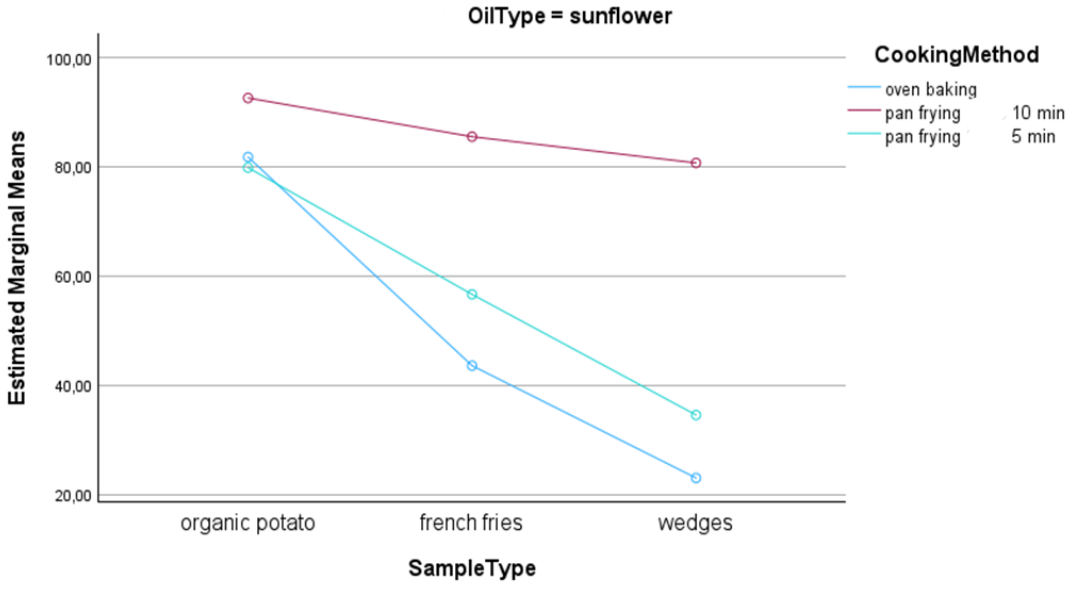

Fig. 1. Correlations between oil type (sunflower), sample type and cooking method.

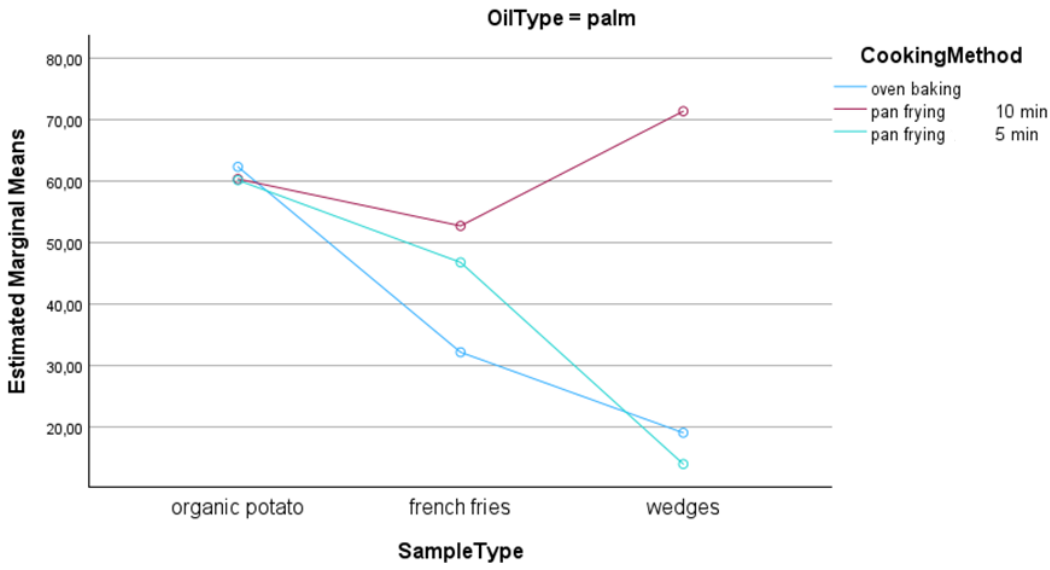

Fig. 2. Correlations between oil type (palm oil), sample type and cooking method.

The acrylamide levels in the investigated potato products, categorized by cooking techniques and oil type, are presented in Table 4. All results are expressed as the mean of triplicates ($n = 3$) ± SD. Pan frying, particularly with sunflower oil, generally resulted in the highest averages acrylamide levels. Sample type emerged as a significant factor influencing acrylamide formation, indicated by a very high F-statistic ($F = 1859.237$) and a *p-value* < 0.001, suggesting its critical role in determining acrylamide levels. Regardless of the cooking method, all potato products cooked in sunflower oil consistently led to higher acrylamide levels compared to palm oil. This finding aligns with Kuek et al. (2020), who reported elevated acrylamide levels in French fries fried in sunflower oil compared to those fried in palm oil. Oven baking produced moderate acrylamide levels (Mottram et al., 2002) with sunflower oil again contributing to higher levels than palm oil. This highlights the influence of both oil type and cooking method on acrylamide formation.

The Kruskal-Wallis H test for independent samples, along with pairwise comparisons for post-hoc analysis was used to compare the acrylamide levels across different cooking methods. The results indicate no significant difference in acrylamide levels between air frying, oven baking and pan frying for 5 min. However, comparisons between air frying and pan frying for 10 min revealed significantly lower acrylamide levels with air frying (adjusted *p-value* = *0.033*). Similarly, a significant difference was observed between pan frying for 5 min and pan frying for 10 min ($p = 0.033$), with longer frying times (10 minutes) leading to significantly higher acrylamide levels than shorter frying times (5 minutes) (Gökmen et al., 2006). This finding showed that both temperature and frying duration are critical factors influencing acrylamide formation, as both playing a key role in the reaction kinetics, underlying its development (Luning et al., 2016).

Air frying without oil results in moderate acrylamide levels and seems to be a relatively consistent cooking method exhibiting lower variability. The mean acrylamide level (439.16 ± 7.51 µg/kg) with a low standard deviation indicates consistent results across the three sample types. Although the difference in acrylamide levels between palm oil and sunflower oil was statistically significant before Bonferroni correction (p = 0.027), it became marginally insignificant after the correction ($p = 0.080$). This suggests that while the difference between these two oils is notable when considered independently, it does not meet the stricter significance threshold required after adjusting for multiple comparisons.

Organic potatoes consistently exhibited the highest acrylamide concentration, particularly when fried for extended time in sunflower oil (924.93 ± 0.66 µg/kg). This may be attributed to the lack of pre-treatment in organic potatoes, whereas the French fries and wedges used in this study were pre-treated (e.i., pre-fried and frozen). As shown in the study by Govindaraju et al. (2024), various mitigation strategies such as blanching, soaking in water with additives, or pre-frying can reduce acrylamide concentrations by 30-96%. Similarly, Guillén et al. (2017) concluded that frozen pan-fried potatoes had higher acrylamide levels than fresh potatoes pre-treated by soaking in acidified water (e.g., vinegar pH = 3.17). These findings align with previous studies (Govindaraju et al., 2024; Navruz-Varlı and Mortaş, 2023; Pedreschi et al., 2007), demonstrated that different pre-treatment methods generally reduce acrylamide formation in French fries, highlighting the importance of pre-treatment in mitigating acrylamide levels.

Table 4. Acrylamide levels in different potato products according to cooking methods and oil type

Sample type	Oil type	Cooking method	Mean ± SD (μg/kg)
Organic potato	Without	Non cooked	2.89 ± 0.05
		Air fryer 180 °C - 20 min	498.59 ± 1.50
	Sunflower	Oven baking 200 °C - 20 min	817.03 ± 1.13
		Pan frying 130 °C - 5 min	797.59 ± 0.99
		Pan frying 130 °C - 10 min	924.93 ± 0.66
	Palm	Oven baking 200 °C - 20 min	622.89 ± 2.23
		Pan frying 130 °C - 5 min	601.21 ± 0.04
		Pan frying 130 °C - 10 min	603.02 ± 2.66
French fries	Without	Non cooked	58.98 ± 0.01
		Air fryer 180 °C - 20 min	464.21 ± 0.66
	Sunflower	Oven baking 200 °C - 20 min	435.37 ± 0.77
		Pan frying 130 °C - 5 min	565.77 ± 0.81
		Pan frying 130 °C - 10 min	854.17 ± 1.02
	Palm	Oven baking 200 °C - 20 min	321.87 ± 0.14
		Pan frying 130 °C - 5 min	467.73 ± 0.92
		Pan frying 130 °C - 10 min	526.98 ± 2.64
Wedges	Without	Non cooked	5.25 ± 0.02
		Air fryer 180 °C - 20 min	354.68 ± 1.37
	Sunflower	Oven baking 200 °C - 20 min	229.90 ± 0.10
		Pan frying 130 °C - 5 min	345.06 ± 0.44
		Pan frying 130 °C - 10 min	806.19 ± 2.85
	Palm	Oven baking 200 °C - 20 min	191.11 ± 0.03
		Pan frying 130 °C - 5 min	140.37 ± 0.47
		Pan frying 130 °C - 10 min	713.14 ± 2.20

French fries showed moderate acrylamide levels, while wedges typically had the lowest levels overall, particularly when pan-fried with palm oil (140.37 ± 0.47 μg/kg). This may be attributed to differences in shape, size, and starch content, which affect heat distribution and acrylamide formation.

As shown in Table 4, over 70% of the cooked potatoes in this study had acrylamide concentrations exceeding the benchmark level for French fries (500 μg/kg) (EC 2017/2158). Fig. 3 shows that all sample types cooked using pan frying for 10 min (> 600 μg/kg) surpassed the benchmark level. Similarly, Fig. 4 demonstrates that organic potatoes consistently exceeded the recommended acrylamide level of 500 μg/kg. Regarding oil type (Fig. 5), cooking with sunflower oil resulted in a wide range of acrylamide levels. While some samples remained within the benchmark level, a significant proportion exceeded it. These findings indicate that acrylamide formation is influenced not only by the type of oil used but also by the sample type and cooking method.

Due to the high acrylamide levels observed in most samples (over the benchmark level) (Official Gazette 239/2019), the study was expanded to include four additional French fries' samples purchased from different local fast-food chains. The results, presented in Table 5, showed that three out of the four had acrylamide concentrations below the benchmark level. This outcome can be attributed to the use of standardized and controlled cooking conditions, such as precise temperature and time settings. As demonstrated in the study of Sanny et al. (2013), adhering to standardized procedures can significantly reduce acrylamide formation.

Table 5. Acrylamide levels in French fries (FF1-FF4) from different fast-food restaurants

Sample	Acrylamide levels (Mean ± SD)
FF1	213.42 ± 3.23
FF2	167.45 ± 8.65
FF3	233.96 ± 2.87
FF4	961.45 ± 9.38

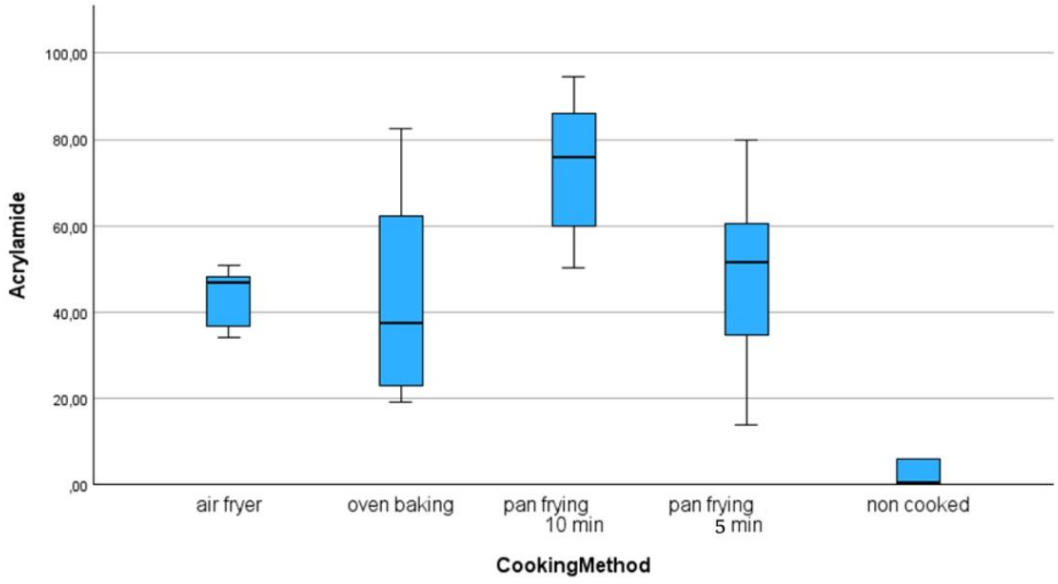

Fig. 3. Kruskal-Wallis test for cooking method.

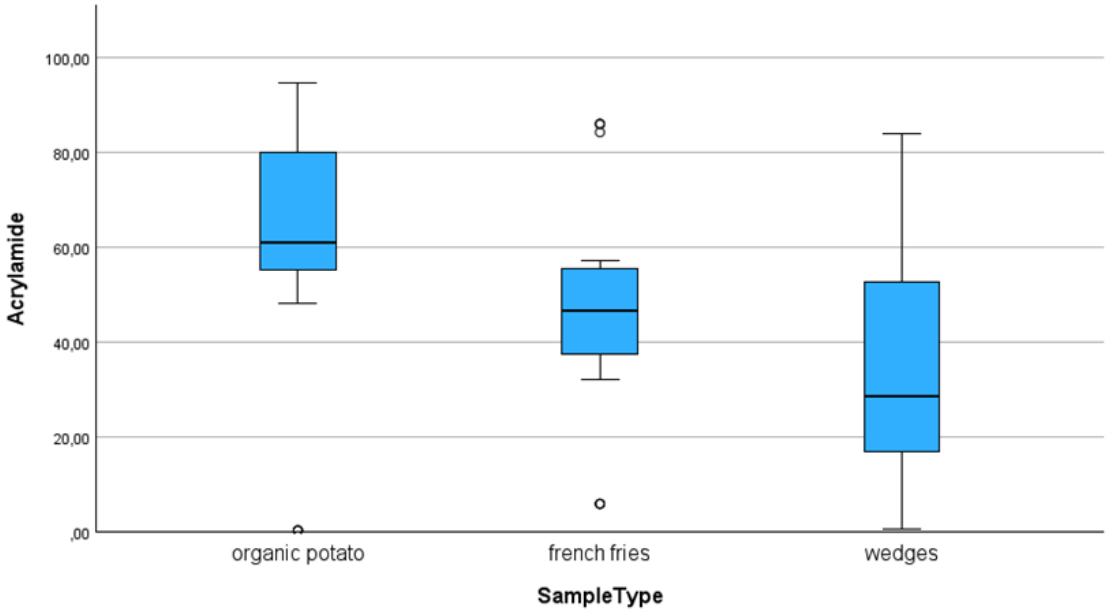

Fig. 4. Kruskal-Wallis test for sample type.

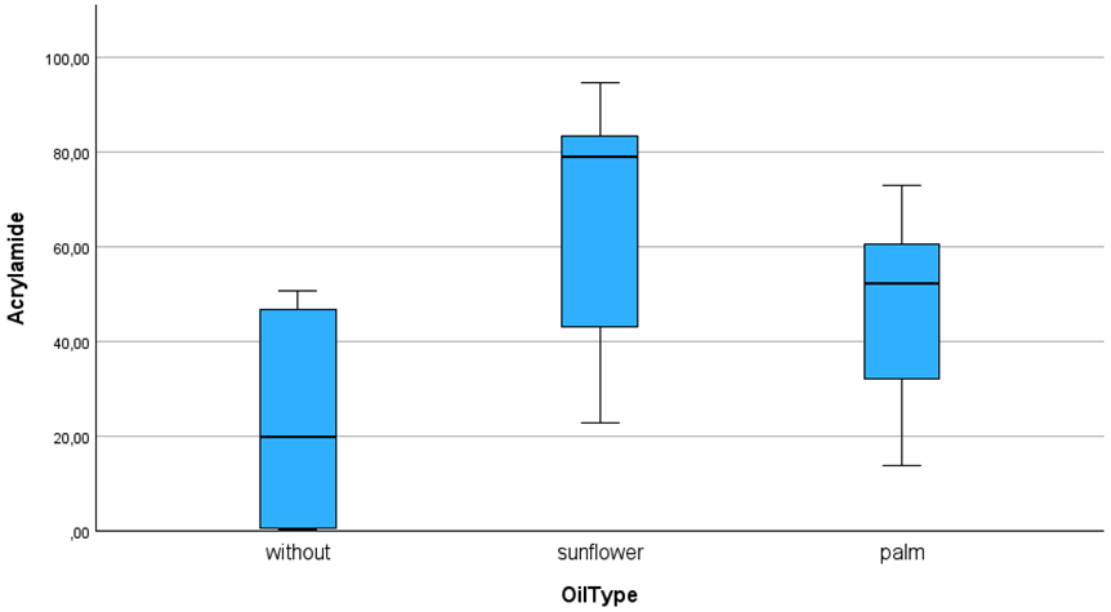

Fig. 5. Kruskal-Wallis test for oil type.

Foods cooked at home, or prepared by catering services and restaurants account for approximately 50% of overall acrylamide intake, as reported in study of Dybing et al. (2005). Numerous studies have focused on the search for strategies to mitigate acrylamide formation in fried potatoes (Maan et al., 2022; Medeiros et al., 2012; Shi et al., 2024), many of which have been compiled into the Acrylamide Toolbox as recommendations for food companies to develop effective mitigation strategies. However, these strategies are less applicable in domestic settings, where cooking variables such as temperature, time, and preparation methods can vary significantly from home to home, from time to time, or even individual to individual.

The large variation and high acrylamide concentrations in home-prepared French fries can due to the absence of standardized frying controls and the diverse practices of food handlers (Sanny et al., 2012). In recent years, some educational initiatives have been launched to address this issue. For example, the European Association of Potato Processors introduced the 'GoodFries' (https://goodfries.eu/en/) initiative to educate food services and consumers about proper frying practices. Similarly, the Food Standards Agency in the United Kingdom launched the 'Go for Gold' campaign in 2017 (FSA, 2017), and the Spanish Food Safety Agency introduced the 'Golden and Not Toasted' initiative in 2015 (AECOSAN, 2015) (Hurtado et al., 2017). These programs aimed to raise consumer awareness and provide practical guidance on minimizing acrylamide exposure in home-cooked foods. The current study found that Macedonian potato frying practices result in relatively high acrylamide generation, posing challenges for applying standardized mitigation techniques in private kitchens.

Conclusion

Acrylamide formation varied significantly depending on the type of potato, cooking method, and oil used. Expectedly, uncooked samples showed no acrylamide formation. The findings emphasized the impact of oil selection and cooking techniques on acrylamide levels, offering valuable insights for those aiming to reduce their exposure to this potentially harmful compound. The results suggest that consumers can lower acrylamide intake by choosing specific cooking methods, such as air frying or oven baking, and by using oils like palm oil, especially when preparing certain types of potatoes. Palm oil appears to be a better choice for minimizing acrylamide formation across various cooking methods and food types, consistently yielding lower acrylamide levels compared to sunflower oil. Among cooking methods, pan frying tends to produce the highest acrylamide levels, particularly when performed at higher temperatures and for extended durations. In contrast, oven baking and air frying without oil typically result in more moderate and consistent acrylamide levels, with air frying generally emerging as the more favorable option.

The complexity of these interactions emphasizes the importance of tailored cooking recommendations based on the specific combination of factors involved. The data revealed correlations between sample type, cooking method, and oil type with acrylamide formation, though

the strength of these relationships varies. Sample type showed a moderate negative correlation with acrylamide, suggesting that certain potato preparations are less likely to produce acrylamide. Cooking method exhibited a weak negative correlation with acrylamide, indicating that while certain oils may slightly increase acrylamide formation, this effect is relatively minor. The independence of these factors (sample type, cooking method, and oil type) provides a clear path for further investigation, as each factor can be studied individually without concern about significant interdependencies.

These findings offer valuable insights for future research aimed at optimizing cooking conditions to reduce acrylamide intake, particularly by focusing on sample preparation and cooking methods. Building on the experiences of UK and Spain, efforts can be made to develop a national strategy for lowering acrylamide levels in home-prepared foods. This strategy could include practical recommendations to help consumers minimize their exposure to acrylamide in everyday cooking practices.

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Резиме

Влијание на изборот на масло и методите на готвење врз нивоата на акриламид во различни производи на компир

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Клучни зборови: акриламид, компир, LC-MS/MS, начин на готвење, вид на масло

Овој труд го истражуваше влијанието на начинот на готвење и видот на користеното масло врз формирањето акриламид во различни типови компир (органски компир, помфрит и пекарски компир). Во овие примероци, акриламид беше определен со течно масена хроматографија. Сите примероци беа подготвени на три вообичаени методи на готвење во македонската кујна: со готвач на топол воздух, рерна и пржење во тава, при што беа користени две различни масла, палмино и сончогледово масло.

Највисоката концентрација на акриламид беше измерена во органскиот компир, којшто беше пржен со сончогледово масло во тава за време од 10 минути (924.93 ± 0.66 μg/kg). Помфритот покажа средно ниво на формиран акриламид, додека пекарскиот компир најниска вредност за акриламид, особено кога беше пржен во тава со палмино масло за време од 5 минути (140.37 ± 0.47 μg/kg). Добиените резултати од статистичките корелации меѓу типот на примерокот, начинот на готвење и типот на маслото сугерираат дека начинот на готвење и видот на маслото со кое се подготвуваат компирите имаат скромен придонес во формирањето акриламид, додека типот на компирот значајно влијае врз нивото на формиран акриламид. Дополнително, домашно подготвените компири покажуваат повисоки вредности на акриламид споредено со помфритот што е подготвен во ресторaните за брза храна поради отсуство на стандардизирани и контролирани услови за готвење во домот, како што се прецизна температура и подесување на време. Оттука произлегува дека моменталното знаење претставува соодветна база за понатамошни истражувања со цел подобрување на начинот на кој се подготвува храната во домашни услови за да се намали количеството на формиран акриламид при готвење.