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Original Scientific Paper

Acrylamide content in potato chips in 2024: monitoring on the production site

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ABSTRACT

The presence of acrylamide, a probable human carcinogen, in thermally processed potato products remains a significant food safety concern. This study monitored acrylamide levels in 336 potato chips (crisps) collected throughout 2024 directly from the production site. A subset of 41 samples with known production parameters was used for screening to evaluate the impact of chemical and processing variables. Statistical analysis using contrast screening revealed that, among the factors examined, the content of reducing sugars had the strongest linear correlation with acrylamide levels. Moreover, synergistic quadratic effects between reducing sugars and both frying and blanching temperatures were observed, significantly influencing acrylamide formation. Contingency analysis showed no substantial difference in acrylamide content outcomes between the two predominant potato cultivars, Opal and Sinora. However, a notable shift in acrylamide levels occurred after August 2024, correlating with a change in the potato lot, suggesting the strong influence of agronomic and storage conditions. The study underscores the importance of continuous monitoring and comprehensive traceability in chips production to control acrylamide levels, in line with EU Regulation 2017/2158. These findings can support mitigation strategies, including the selection of potato varieties, temperature control and process optimization, ultimately contributing to enhanced food safety and regulatory compliance.

1. Introduction

Potatoes are the fourth field crop in the world in terms of production, right behind wheat, rice and corn, and are of great importance in human nutrition. China, with 32% of the area under cultivation and with 25% of the total production at the world level, is the leading country in the production of this field crop (*Li et al*., 2024). For human consumption, most potatoes are processed into products, such as dehydrated flakes, dough, semi-prepared and fried products. One of the most popular products is potato chips (crisps), primarily because of their unique taste and crunchy texture. The production of chips and related snack products from potatoes is a significant branch of the food industry with a turnover that is measured in billions of dollars at the world level.

Acrylamide is formed by the Maillard reaction in products that are rich in carbohydrates, such as potato products—chips, French fries, but it is also present in coffee/coffee substitutes, biscuits, bakery products—bread, baby food and tobacco smoke (*EFSA*, 2015). This reaction occurs at temperatures >120°C and in low humidity conditions, as a result of the interaction of reducing sugars and free asparagine. Acrylamide's presence in food probably dates back to the first thermal processing, but it has

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attracted attention since 2002 (*Adani et al.*, 2020). When consuming the aforementioned foods, thereby introducing acrylamide into the digestive tract, it is converted into glycidamide and is quickly absorbed by all organs. It is classified as a carcinogenic compound in animals and as a probable carcinogen in humans (*Marques et al.*, 2024). It is believed that acrylamide and metabolites cause neurotoxic, hepatotoxic, nephrotoxic, genotoxic and carcinogenic changes in the body (*Khoshbin et al.*, 2024; *Yan et al.*, 2023; *EFSA*, 2015).

The European regulation 2158 (*Commission Regulation*, 2017; *Juncker* (2017)) references values for acrylamide concentrations in specific foods of up to 750µg/kg for potato chips, 400µg/kg for crackers and 350µg/kg for biscuits. According to reports by the European Food Safety Agency (EFSA), amounts of acrylamide from 170µg/kg to 430µg/kg of body weight on a daily basis represent a safety limit beyond which pathological changes occur (*EFSA*, 2015a; *Calabrese et al.*, 2024). The International Agency for Research on Cancer (IARC) classified this organic compound in the A2 group, which includes all agents that are "probably carcinogenic to humans" (*Adani et al.*, 2020).

In order to prevent and reduce the formation of acrylamide during the production of chips, it is necessary to pay attention to the selection of the potato variety. Also, the transport should not be carried out at temperatures below 5°C, and the storage temperature should not be below 8°C, because at lower temperatures during storage, the sugar level rises. Humidity and air circulation should be adapted to the potato variety to prevent subsequent germination. Immediately before frying, and after cutting the potatoes, there are recommendations for soaking the potato chips in water or a solution of citric acid, which will reduce the amount of acrylamide produced after frying by up to 40% or 75%.

Also, the effect of reducing the temperature and extending the frying time should be investigated (*FDE*, 2019). *Jana et al.* (2024) reduced the amount of acrylamide in food by adding the enzyme L-asparaginase. *Santiago-Mora et al.* (2024), using a pulsed electric field (PEF) after peeling potatoes, ensured easier slicing while reducing energy and water consumption. The device was primarily used in the production of French fries, but after treating potatoes with the PEF, they were used for the production of chips. The frying time was shortened by 10%, and the produced chips contained 28.9% less acrylamide than controls.

The aim of this study was to monitor the formation of acrylamide in chips on the production line during 2024, and to consider the factors that potentially contribute to the formation of acrylamide beyond the permitted prescribed levels.

2. Materials and methods

2.1. Samples

Chips were obtained from the manufacturer. A total of 336 samples of chips in 2024 were included in the research. A subset of 41 samples manufactured under various processing conditions were employed for screening for contrast analysis since their production conditions data were available (Table 1).

2.2. Chemical determination

Analysis of acrylamide in potato chips was performed using an in-house method accredited according to ISO/IEC 17025. Previously homogenized samples were extracted with acetonitrile and purified with QuEChERS technique. Analysis was performed by liquid chromatography mass spectrometry LC MS-8040 (Shimadzu, Kyoto, Japan). The chromatographic separation of acrylamide was obtained on a reversed phase Kinetex C18 column, 50 mm × 2.1 mm, particle size 2.6 µm (Phenomenex, Torrance, USA). Isocratic elution was used with 2% methanol and 1% acetonitrile in 0.1% formic acid. The flow rate was 0.3 mL/min. Acrylamide was analyzed using electrospray ionization in positive ion mode. Multiple reaction monitoring mode (MRM) was employed with the characteristic fragmentation transitions m/z 72>55 and 72 >27. As a control, FAPAS QC Material/Potato crisps/T30148QC (Fera Science Ltd, York, Great Britain) was used. The results for quality control samples were within the range of certified values.

Content of sugars, reducing and total, was conducted using ion chromatography with pulse amperometric detection. The system consisted of an 858 Professional sample processor, 930 Compact IC Flex with Oven/Deg, IC Amperometric Detector, all from Metrohm (Herisau, Switzerland). The separation column was Metrosep Carb 2 250/4, also from Metrohm, and separation of mono- and di-saccharides was isocratic in accordance with original method reported by Metrohm (Riverview, FL, USA).

The dry matter content was determined by the ISO reference method (*SRPS EN ISO*, 2024).

2.3. Statistics

Arrangement of data for statistical processing and preliminary filtering of results was performed using the Excel program from the Microsoft Office package (Microsoft, Richmond, VA, USA). For evaluation of the influence and significance of the physico-chemical properties of the raw material and technological process parameters on the acrylamide content in chips, the data processing software JMP Statistical Discovery 10 (SAS Institute, Cary, NC, USA) was used. Screening for contrast was used for data validation and assessment of correlation between input data, as well as assessment of the significance of the influence of individual parameters on the acrylamide content in the final product. Also, contingency analysis was performed for comparison of categorical data.

3. Results and discussion

The potato chips' chemical parameters along with frying and blanching temperatures are shown in Table 1. The presented data were used for screening and estimation of chemical and processing parameters' effects on the resulting content of acrylamide. Screening design results of the given parameters' effects on acrylamide quantity in chips confirmed that the amount of reducing sugars was the main linear factor in direct correlation with the acrylamide amount in chips. Also, frying and blanching temperatures had a synergistic effect on the reducing sugar content. These results are consentaneous with previously reported data (*Muttucumaru et al.,* 2017; *Liyanage et al.*, 2021; *Passos et al.*, 2018; *Sanny et. al*., 2012; *Ferreira et al.*, 2025; *Bachir et al.*, 2023).

Table 1. Acrylamide, sugar and dry matter contents and processing temperatures of potato chip samples in the study

No	Acrylamide (µg/kg)	Reducing sugars (g/100g)	Total sugars (g/100g)	Dry Matter (g/100g)	Frying T (°C)	Blanching T (°C)
1	1320.5	0.41	0.57	22.0	165	70
2	1266.7	0.41	0.57	21.4	162	68
3	820.0	0.14	0.24	21.0	161	75
4	1086.0	0.12	0.53	22.2	162	77
5	853.3	0.08	0.45	22.5	160	74
6	1193.5	0.09	0.70	23.0	153	78
7	440.7	0.05	0.10	20.0	161	55
8	594.4	0.05	0.30	21.4	163	58
9	1019.7	0.04	0.13	21.0	165	65
10	926.0	0.03	0.28	22.7	165	65
11	913.1	0.14	0.32	23.0	162	64
12	902.7	0.09	0.28	22.6	164	64
13	620.1	0.08	0.26	22.3	162	65
14	409.3	0.08	0.03	21.0	165	65
15	485.8	0.36	0.81	21.6	161	65
16	464.0	0.03	0.10	22.3	161	69
17	372.0	0.03	0.17	22.0	163	65
18	487.0	0.05	0.21	22.4	162	69
19	553.7	0.02	0.13	22.3	161	68
20	820.8	0.02	0.74	22.0	160	70

No	Acrylamide (μg/kg)	Reducing sugars (g/100g)	Total sugars (g/100g)	Dry Matter (g/100g)	Frying T (°C)	Blanching T (°C)
21	684.4	0.01	0.05	22.0	161	72
22	720.0	0.01	0.09	22.1	163	68
23	726.7	0.03	0.23	22.1	163	71
24	531.0	0.04	0.27	22.1	162	74
25	491.2	0.03	0.15	22.0	164	70
26	644.0	0.34	1.31	22.0	161	70
27	226.7	0.01	0.17	22.1	155	77
28	667.1	0.03	0.09	20.0	161	55
29	624.9	0.03	0.12	20.7	162	49
30	788.4	0.05	1.05	21.0	163	54
31	739.0	0.01	0.11	22.7	161	52
32	666.3	0.02	0.07	21.0	160	53
33	569.5	0.08	0.18	21.8	159	53
34	696.4	0.13	0.71	21.4	160	52
35	1335.3	0.29	0.80	21.5	163	74
36	517.8	0.02	0.26	22.8	163	76
37	687.0	0.01	0.95	22.7	161	69
38	472.0	0.25	0.56	22.1	157	70
39	749.1	0.06	0.14	22.3	165	71
40	941.0	0.13	0.20	21.5	163	68
41	582.0	0.04	0.05	21.8	162	68

The contingency analysis of potato cultivars and corresponding grouped categories of acrylamide content is shown in Figure 1. Two varieties of potato were predominantly used for chips manufactured in 2024. The Opal variety accounted for almost 3/4 (72%) of the total number of samples tested. Figure 1 shows all the results, but only the varieties Opal and Sinora were analyzed in sufficient numbers to draw a reliable conclusion about the relative ratio of acceptable and unsatisfactory acrylamide content results. From Figure 1, it can be concluded that the ratios of the acrylamide result categories (good from 0 μg/kg to 700 μg/kg, satisfactory from 700 μg/kg to 750 μg/kg and bad over 750 μg/kg) for both varieties are almost identical.

Figure 2 presents the results of the contingency analysis for the number of analyses by month in 2024 and the corresponding distribution of the result categories. The number of analyses by month was relatively uniform. However, a clear difference in acrylamide content was observed during the year. In the period from January to July, bad results accounted for about and less than 20%, while in the latter part of the year from August to December, this number increased sharply to about 50%. According to information received from the manufacturer, the potato lot was changed in August 2024. This information is very intriguing, because the answer to such a sudden change in results most likely lies in the way the potatoes for chip production were grown and stored. The conclusion is unequivocal; in order to achieve uniform and acceptable acrylamide content, information on the potato's origin, growing method and storage must be available in further research. At the time the research was conducted, this information was not complete and available for all samples.

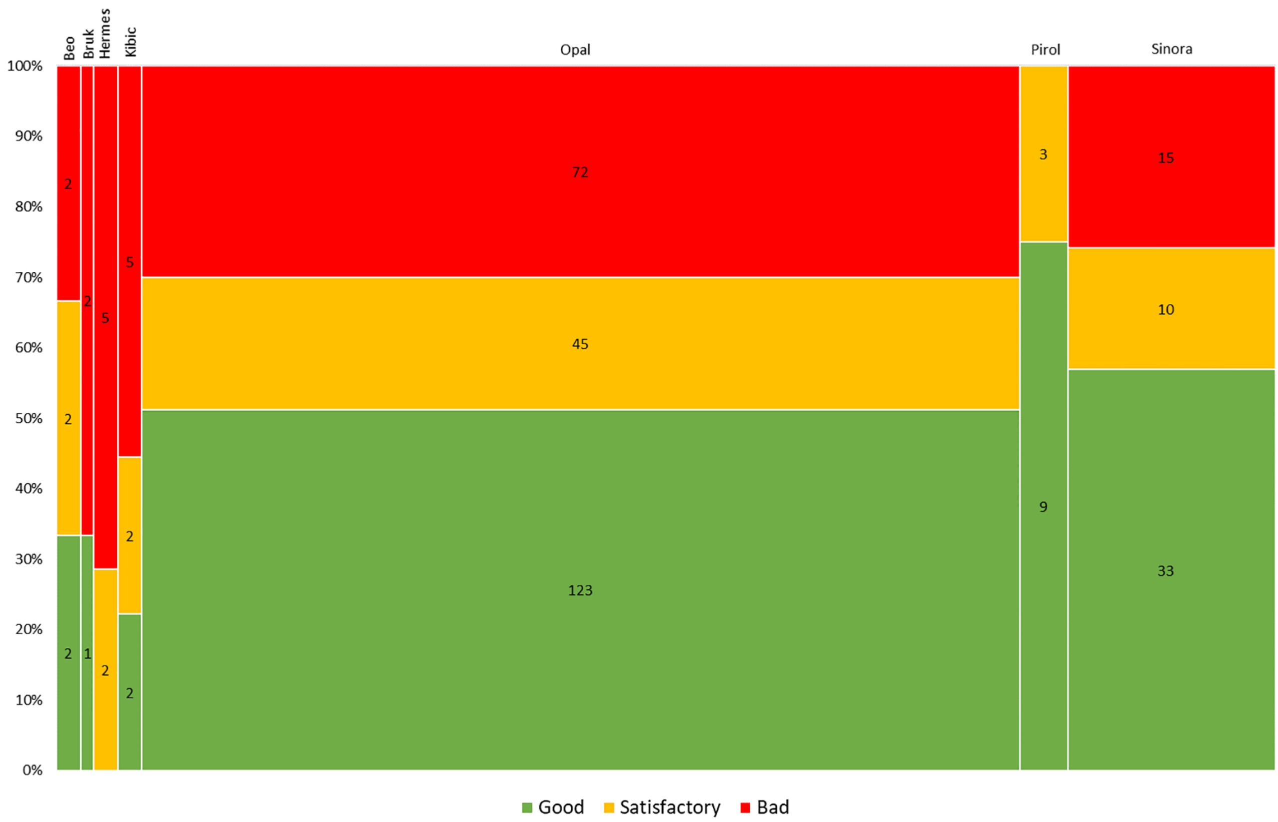

Figure 1. Distribution of acrylamide content category and potato cultivar in 2024

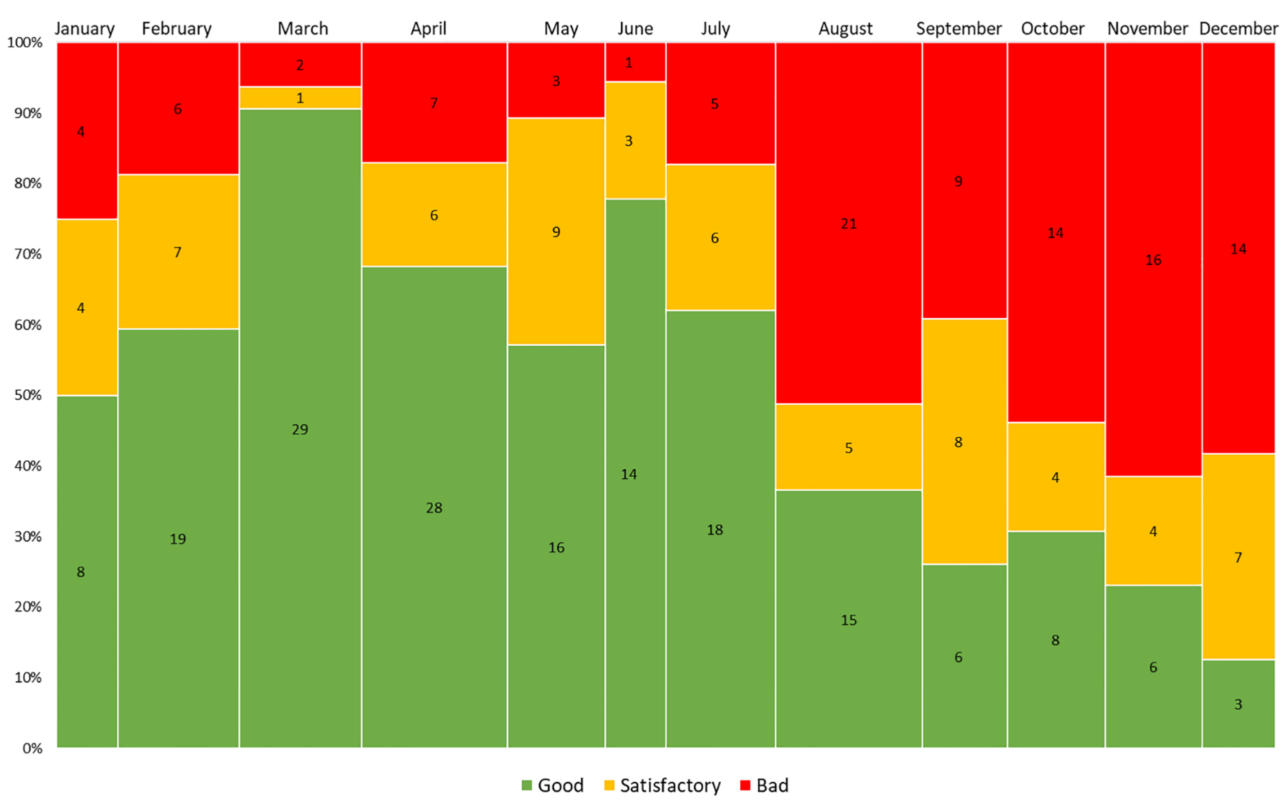

Figure 2. Acrylamide content result category by month in 2024

4. Conclusion

Screening design was applied to estimate the effect of some parameters (reducing and total sugar contents, dry matter, and frying and blanching temperatures) on acrylamide levels in potato chips. Results showed that the content of reducing sugars is the main linear factor in direct correlation with the acrylamide amount in chips. It was confirmed by screening that frying and blanching temperatures had a synergistic effect on the content of reducing sugars in the chips.

Two varieties of potato, Opal and Sinora, were predominantly used for chips manufactured in 2024. They had a sufficient number of analyses to draw a reliable conclusion about the relative ratio of acceptable and unsatisfactory acrylamide contents. The ratios of the result categories (good, satisfactory and bad) for both varieties are almost identical.

Through the whole research period in 2024, the number of analyses by month was relatively uniform. The greatest number of analyses was in April and August, with fewer analyses in January and June. A distinctive difference in acrylamide content was observed during the year. From January to July, the bad category accounted for about and less than 20%, while from August to December, this number increased to approximately 50%. Such a sudden change in results most likely lies in the way the potatoes for chip production are grown and stored. In order to achieve as low an acrylamide content as possible, information on the origin, growing method and storage must be available in further research.

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