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Risk Assessment of Acrylamide Intake from Roasted Potatoes in Latvia

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Abstract—From food consumption surveys has been found that potato consumption comparing to other European countries is one of the highest. Hence acrylamide (AA) intake coming from fried potatoes in population might be high as well. The aim of the research was to determine acrylamide content and estimate intake of acrylamide from roasted potatoes bred and cultivated in Latvia. Five common Latvian potato varieties were selected: Lenora, Brasla, Imanta, Zile, and Madara. A two-year research was conducted during two periods: just after harvesting and after six months of storage. Time and temperature (210 ± 5°C) was recorded during frying. AA was extracted from potatoes by solid phase extraction and AA content was determined by LC-MS/MS. estimated intake of acrylamide ranges from 0.012 to 0.496μgkg^{-1} BW per day.

Keywords—potato, roasting, variety, acrylamide, Latvia, risk assessment.

I. Introduction

EVALUATING the consumption of potatoes worldwide, Latvia took the eighth place with a consumption of 114kg per capita which increases yearly and from the results of the Norwegian research, it can be concluded that potatoes play a significant role in the balance of nutrients of the Latvian inhabitants, constituting about 70% of the total vegetable consumption [1], [2].

Potatoes (*Solanum tuberosum* L.) serve as major, inexpensive low-fat food sources providing energy (starch), high-quality protein, fiber and vitamins [3], and nutrient content depends on a number of factors, the potato variety is thought to be among the most significant factors [4]. Also different processing systems might influence nutritional quality of potato tubers significantly. One of the oldest and traditional cooking methods is frying and roasting.

Thermal processing of foods such as frying and roasting is indispensable to determine specific sensorial, in particular, color, texture, and flavor in foods. The color, texture, and flavor formation during heat treatment is caused by so called Maillard reaction. Beside these benefits, thermal treatment may also induce the formation of health-promoting components, such as antioxidants and antimicrobial agents in foods [5]–[7].

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Although reactions may be desirable in generating characteristic flavors identified with some cooked products, the nutritional value of the product will be compromised by protein damage and loss of amino acids, including lysine, l-arginine, and l-histidine. The loss of lysine is important due to its essentiality in diet. Maillard browning can be inhibited by decreasing moisture to very low levels [8], [9].

Meanwhile, hazardous component formation during heat processing occurs as well. The Swedish National Food Administration reported in 2002 the presence of relevant amounts of acrylamide in several carbohydrates rich foods baked at high temperatures [10], [11].

It has recently been reported that AA (2-propenamide, CAS RN 79-06-1) is a compound classified as a probable carcinogen and is present in various foods processed at high temperature [10]–[12].

The content of AA in fried potato foods depends on potato genotype, growing (growing location, fertilization, temperature, and maturity) and storage conditions (temperature, relative humidity of the air, and duration) as well as chemical composition [13], [14]. Also potato preparation before frying might be an important factor in the amount of acrylamide is formed. Acrylamide is formed in the surface layer of the potato product and therefore size and cut shape of the product (surface-to-volume ratio) will also influence final acrylamide contents. Accordingly, thinner and smaller cut sizes result in increased acrylamide formation upon final frying [15].

Several acrylamide intake studies indicate that fried potato products (especially French fries and potato crisps), bread and bakery products, coffee and breakfast cereals are the food commodities that contribute the most for dietary acrylamide exposure. Other food items contribute less than 10% of the total dietary intake [16]–[21].

The information about acrylamide content and estimated uptake from roasted potatoes in Latvia and Europe is still insufficient. Therefore, the aim of the research was to determine acrylamide content and estimate intake of acrylamide from roasted potatoes bred and cultivated in Latvia.

II. Materials and Methods

A. Raw material

In cooperation with the State Priekuli Plant Breeding Institute (Latvia), five table potato varieties (*Solanum tuberosum* L.) which can be used for the production of fried potato products were studied: Lenora, Brasla, Imanta, Zile, and Madara. Madara is an early maturity variety; Lenora is mid-early, while Zile, Brasla, and Imanta are representatives of mid-late varieties. The Madara and Zile varieties are the oldest ones used in the research, developed in 1984, Brasla was developed in 1990, Lenora in 1995, while the youngest variety Imanta was developed in 2006 [22]. Detailed description of each potato variety is presented in Table I.

TABLE I
DESCRIPTION OF THE STUDIED POTATOES

Potato variety	Shape of tubers	Color of skin and flesh of potato tubers	Suitability for Cooking type	Variety type
'Zīle'	oval	skin and flesh yellow	B-BC	medium-late
'Brasla'	round	skin and flesh yellow	BC	medium-late
'Madara'	round oval	skin yellow and flesh light yellow	B	early
'Lenora'	round oval	skin and flesh yellow	B	medium-early
'Imanta'	oblong oval	skin yellow with pink eyes flesh white	BC-C	medium-late

Tuber samples of varieties were analyzed after harvesting and after six months of storage. Potatoes were stored at an air temperature of 5 ± 1ºC and at a relative air humidity of 80 ± 5% [22].

The tubers of selected varieties were produced in the fields of the State Priekuli Plant Breeding Institute. The potatoes were grown in sandy loam soil with a pH_{KCl} of 6.1 and an allowable amount of phosphorus and potassium. In the first year the ratio of N:P:K was 13:10:15, but in the second year it was 11:19:20. The soil cultivation was performed using the agrotechnology according to the existing crop management.

Comparing the years of potato growing, the atmospheric temperature during the growing season was very similar, but the rainfall level differed in both growing years [22].

B. Roasting

Potato tubers of approximately similar size (4–6cm) and weight of 200 ± 15g each were selected, washed, hand-peeled and cut. Potatoes prepared for roasting were cut horizontally into halves and roasted at a temperature of 210 ± 5°C for 25 ± 1.0min.

Sunflower seed oil "*Floriol*" produced in Hungary was used for frying. Oil amount used for potato roasting was 1:0.009 (potato and oil ratio).

Throughout the roasting procedure, the time and temperature was recorded by USB TC-08 Thermocouple Data Logger PICO-Technologist equipment [22].

C. Acrylamide Analysis

Determination of acrylamide was performed at the laboratory of the Chemistry Division 1, National Food Administration.

Solid phase extraction (SPE) was used in preparing potato samples for AA analyses using the SPE columns: Isolute Multimode (500mg) and Isolute ENV+ (500mg) from International Sorbent Technology, (UK). LC-MS/MS equipment was used for determining the content of AA. The HPLC column was Hypercarb (5µm, 50mm × 2.1mm) from Termo Electron Corporation, Waltham, MA, USA. AA (assay (GC) ≥ 99.9%), and methanol (gradient grade) were supplied by Merck, Darmstadt, Germany. Acetonitrile (HPLC-grade) was obtained from Lab-Scan, (Dublin, Ireland). Detailed description of the sample preparation for the analysis and settings of AA analysis are described by Rosén et al. [23].

During analysis the quality aspects were taken into account with regard to sample handling, analytical methods, equipment and analytical procedure. The obtained results were accepted in those cases when the difference between values did not exceed 5%.

D. Dry Matter

Dry matter (DM) content of potato tubers was determined by ISO 6496:1999 [24].

E. Statistical Analysis

For statistical analysis, the data were processed using the S-PLUS 6.1 Professional Edition software. Data are presented as a mean ± standard deviation (SD). The differences between independent groups were specified by two way analysis of variance (ANOVA) and values of $P<0.05$ were regarded as statistically significant. In case of establishing statistically significant differences, homogeneous groups were determined by Tukey's multiple comparison test at the level of confidence $\alpha = 0.05$.

Risk assessment of dietary acrylamide intake is shown in quartiles (Q).

III. RESULTS AND DISCUSSION

According to several authors, the most suitable potatoes are those, whose DM is above 20% [25], [26]. Previously published results [22] of certain varieties show that the potato varieties with DM lower than 20% are 'Madara' (18.93%) and 'Lenora' (19.48%) (Table II). The content of dry matter (DM) is particularly substantial if the potatoes are to be used for frying. The DM content in potato tubers increases during the growing season. Maximum values are reached at different times depending on potato variety and environmental condition. The results of the analysis of research data indicate that there is a considerable difference in the DM content in freshly harvested and stored potatoes (p=0.005). The DM content in potatoes after a six-month storage period increase by 10.71% on average. Increase of the DM is related to the metabolic respiration [27].

TABLE II
DRY MATTER CONTENT OF THE STUDIED POTATOES

Type of frying method	Potato variety	1st study year		2nd study year	
		Before storage	After storage	Before storage	After storage
Uncooked (raw)	'Zīle'	20.16±0.06	23.14±0.06	24.42±0.12	24.82±0.08
	'Brasla'	23.36±0.03	26.86±0.08	25.60±0.09	25.85±0.04
	'Madara'	18.93±0.07	25.83±0.07	21.77±0.01	22.54±0.01
	'Lenora'	19.48±0.10	22.54±0.18	20.31±0.01	25.21±0.06
	'Imanta'	24.72±0.05	25.58±0.03	24.42±0.12	24.61±0.01
Roasted	'Zīle'	31.26±0.09	30.67±0.14	37.59±0.01	34.38±0.04
	'Brasla'	36.04±0.08	37.56±0.23	33.36±0.06	34.26±0.06
	'Madara'	28.46±0.07	39.06±0.14	35.83±0.07	31.29±0.13
	'Lenora'	24.35±0.11	34.73±0.17	27.55±0.05	33.66±0.06
	'Imanta'	34.70±0.07	43.05±0.20	32.71±0.08	33.40±0.07

The increase of dry matter in fried potatoes is connected with moisture evaporation from the outer layer of potatoes during the process of frying, thus forming a crispy crust [28]. It is also influenced by the conditions and length of storage. The potatoes which are cut into smaller pieces have a greater surface area and due to that more water evaporates from the product during the frying process.

Moisture content is an important factor influencing the rate of the browning reaction. Browning occurs at low temperatures and intermediate moisture content; the rate increases with increasing water content [29], [30].

The content of AA in the potatoes, evaluating potatoes either just after harvesting (non-stored) or using stored potatoes, is considerably different (Table III).

TABLE III
ACRYLAMIDE CONTENT OF THE ROASTED POTATOES

Potato variety	1st study year		2nd study year	
	Before storage	After storage	Before storage	After storage
'Zīle'	136.500±6.41	9.567±0.23	316.958±5.66	72.592±5.38
'Brasla'	63.392±1.75	19.092±2.61	139.642±4.23	16.850±2.84
'Madara'	87.875±1.40	110.592±5.59	115.650±0.86	281.017±24.77
'Lenora'	68.275±2.33	273.367±8.39	280.867±8.08	71.658±2.90
'Imanta'	26.100±2.73	132.517±5.49	170.192±5.33	33.533±11.89

The greatest difference between the potatoes fried just after harvesting and the potatoes fried after storage is found in the potato variety 'Zīle' 9.567–316.958µgkg^{-1} FW.

In the statistical data analysis has been found that there is no significant difference in acrylamide content of roasted potatoes nor between varieties used in the research, nor when potatoes were fried before storage (after harvesting) and after a period of storage and nor between research years ($p>0.05$).

Other authors' findings present the range of acrylamide content in roasted potatoes (prepared in oven) from 42 to 2779µgkg^{-1} [31] and Boon et al reported AA content in oven baked potatoes from 10 to 1890µgkg^{-1} [32] while the results of particular research show that AA content before storage ranges from 9.30 to 280.63µgkg^{-1} FW and after a period of storage – 14.00 to 322.15µgkg^{-1} FW (Table IV).

TABLE IV
ACRYLAMIDE CONTENT ACROSS QUARTILES, µG·KG^{-1}

Range of quartiles	Before storage	After storage
n	30	30
Q_0 (Min)	9.30	14.00
Q_1 (25%)	27.34	69.37
Mean	92.73	149.90
Q_2 50% (Median)	78.44	126.49
Q_3 (75%)	128.47	267.59
(Q_4) (Max)	280.63	322.15

The sources of literature, compared to the results obtained in current research, are different, and these sources do not reflect the comparative information on the published results, since it is not indicated whether the potatoes which were analyzed were stored or they were used just after harvesting.

After harvesting, tubers are stored up to several months in order to maintain supplies of potatoes throughout the year but during storage period chemical composition in potato tubers changes significantly [33]–[35], [22]. Increase in acrylamide content after a period of storage can be explained by increase of reducing sugars during storage which differs per variety and is strongly affected by storage temperature [36]–[39].

Since potato preparation in oven is very common methods not only in Latvia but all over the Europe and Worldwide, it is important to estimate potential risk of AA uptake by locally available potato varieties prepared in the oven–roasted potatoes.

From the obtained results, estimated intake of acrylamide consuming roasted potatoes in average is in Latvian female uptakes from 0.014 to 0.496µgkg^{-1} BW day^{-1} while male from 0.012 to 0.430µg kg^{-1} BW day^{-1} (Table V).

TABLE V
ESTIMATED INTAKE OF ACRYLAMIDE IN ADULT MAN AND FEMALE CONSUMING ROASTED POTATOES, $\mu g \cdot kg^{-1}$BW DAY^{-1}

Range of quartiles	Before storage	After storage	Before storage	After storage
	Female (weight 65 kg)		Male (weight 75 kg)	
n	30	30	30	30
Q_0 (Min)	0.014	0.022	0.012	0.019
Q_1 (25%)	0.042	0.107	0.036	0.092
Mean	0.143	0.231	0.124	0.200
Q_2 50% (Median)	0.121	0.195	0.105	0.169
Q_3 (75%)	0.198	0.412	0.171	0.357
(Q_4) (Max)	0.432	0.496	0.374	0.430

In regard to the potato products, in many research papers can be easily found acrylamide content and estimated exposure in humans from French fries and chips but in very few research papers baked potatoes are presented. Even more, the results from other research papers are not comparable with the results from this research because of the fact that background information about the potato samples is missing.

Any promising mitigation strategy and regulatory resolutions should be assessed with regard to the possible impact on consumer exposures as exemplified by several authors [16], [32], and [40].

IV. CONCLUSION

The content of AA in roasted potatoes is from 60 to 173µgkg^{-1} FW and estimated intake of acrylamide ranges from 0.012 to 0.496µgkg^{-1} BW per day.

There is still missing information about acrylamide content and exposure from different product groups per country and therefore it is crucial to continue to do research in this particular area and make it available for public with the main goal to lower the risk and exposure of acrylamide daily intake.

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