Risk Assessment of Acrylamide Intake from Deep-Fat Fried Potatoes in Latvia

I. Murniece, D. Karklina, R. Galoburda, and D. Santare

***Abstract*—Consumption of fried potatoes in Latvia is the highest compared to Nordic and the other two Baltic countries. Therefore acrylamide intake from fried potatoes in the population might be high as well. The aim of the research was to analyse the risk assessment of acrylamide intake from deep-fat fried potatoes 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. Acrylamide was extracted from potatoes by solid phase extraction and the acrylamide content was determined by LC-MS/MS. Acrylamide content significantly differs ($p<0.05$) in potatoes by variety and by time. A male takes up 1.9 times more acrylamide from French fries than an adult female.**

***Index Terms*—Acrylamide, deep-fat frying, potatoes, risk assessment.**

I. Introduction

Evaluating the consumption of potatoes in the world in 2005, Latvia took eighth place with a consumption of 114 kg per capita [1] 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 [2]. Therefore, preparing potatoes by different cooking methods, it is important to pay attention not only to nutritional value of potatoes but also to harmful components, for instance acrylamide (AA, 2-propenamide, CAS RN 79-06-1). It has recently been reported that acrylamide is a compound classified as a probable carcinogen and is present in various foods processed at high temperature [3], [4].

Acrylamide is known to be neurotoxic and several toxicological studies have demonstrated its genotoxic carcinogenicity in animals, thus indicating potential human health risks [5], [6]. Numerous case-control and prospective cohort studies have investigated possible associations between dietary acrylamide intake and risk for several types of human cancers. Yet, most of the breast cancer research done today has not found an association with dietary acrylamide exposure [7]-[13].

In order to set the potential risk to the population, acrylamide dietary exposure has been evaluated in different countries, population and dietary habits [14].

Acrylamide is formed during the heating of food materials such as frying, deep-fat frying or baking [15].

The content of acrylamide in fried potato foods depends on potato genotype, growing (growing location, fertilisation, temperature and maturity) and storage conditions (temperature, relative humidity of the air and duration) as well as chemical composition [16].

The aim of the research was to analyse the risk assessment of acrylamide intake from deep-fat fried potatoes in Latvia.

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II. Materials and Methods

A. Raw Material

In cooperation with the State Priekuli Plant Breeding Institute (Latvia), five table potato varieties 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 the mid-late varieties. The Madara and Zile varieties were the oldest ones used in the research, developed in 1984, Brasla was developed in 1990, Lenora in 1995, while the newest variety Imanta was developed in 2006 [17]. A detailed description of each potato variety is presented in Table I.

TABLE I: Description of the Studied Potatoes

Potato variety	Shape of tubers	Colour 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

**B type – for frying, boiling (medium-mealy), C type – for most of meals (mealy), and BC type – for frying, boiling and other types of cooking.*

Tuber samples of varieties were analyzed after harvesting and after six months of storage. Potatoes were stored at an air

temperature of 5 ±1 ℃ and at a relative air humidity of 80 ± 5%.

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 with 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 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 [17].

Potato composition has a high affect on acrylamide formation and detailed information about the chemical composition of all the varieties used in current research is published by Murniece *et al*. [17]

B. Sample Preparation

Potato tubers of approximately similar size (4 – 6 cm) and weight of 200 ± 15 g each were selected, washed, hand-peeled and cut in three ways: for shallow frying potatoes were sliced into 0.6 × 0.6 cm and 4 – 5 cm long strips and deep-fat fried at a temperature of 180 ±5 ℃ for 4.0 ±0.3 min.

Sunflower seed oil "*Floriol*" produced in Hungary was used for frying. Oil ratio in a deep-fat fryer was 1:4.9.

Throughout the deep fat frying procedure, the time and temperature were recorded by USB TC-08 Thermocouple Data Logger PICO-Technologist equipment [17].

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 acrylamide analyses using the SPE columns: Isolute Multimode (500 mg) and Isolute ENV+ (500 mg) from International Sorbent Technology, (UK). LC-MS/MS equipment was used for determining the content of acrylamide. The HPLC column was Hypercarb (5 µm, 50 mm × 2.1 mm) from Termo Electron Corporation, Waltham, MA, USA. Acrylamide ((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 acrylamide analysis are described by Rosén *et al*. [18].

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. The National Food Consumption Survey

Latvian national comprehensive food consumption survey was carried out during 2007-2009. The target population (*n*=1949; male – 46.1% and female – 53.9%) was defined as persons aged from 7 to 64 years domiciled in Latvia and living in private households, irrespective of nationality. Consequently, information on food intake was collected using two non-consecutive 24-h recalls in combination with food frequency questionnaire. Additional data on sociodemographic and lifestyle characteristics were obtained in a face-to-face interviewing process [19].

E. Risk Assessment of Dietary Acrylamide Intake

Based on the Latvian national comprehensive food consumption survey, acrylamide daily intake per day was calculated by equation (1):

$$Y_i = \sum_v (F_{v,i} \times C_v) \quad (1)$$

where Y_i is the daily intake of the subject i (mg/day), v is the food category, $F_{v,i}$ is the amount (g) of the food category v consumed by the subject i, and C_v is the median acrylamide content in the food category v, expressed in mg/kg.

To express the acrylamide daily intake (DI) in mg/kg bw/day, equation (2):

$$DI_i = Y_i / bw_i \quad (2)$$

where bw_i is the body weight (kg) of the subject i [20].

F. Data Processing

For statistical analysis, the data were processed using the S-PLUS 6.1 Professional Edition software. The 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 $\alpha = 0.05$.

III. Results and Discussion

The content of acrylamide in the potatoes, evaluating it by the types of frying used in the research, using the potatoes either just after harvesting (non-stored) or using stored potatoes, is considerably different (Table II).

TABLE II: Acrylamide Content of the Studied Potatoes, mg kg-1

Potato variety	1st study year		2nd study year	
	Before storage	After storage	Before storage	After storage
'Zīle'	170.242 ± 4.60	98.108 ± 3.12	419.258 ± 9.43	78.458 ± 6.91
'Brasla'	416.450 ± 43.87	529.717 ± 10.14	388.500 ± 28.60	165.550 ± 3.71
'Madara'	405.792 ± 13.61	267.175 ± 15.33	1191.150 ± 53.43	147.867 ± 8.39
'Lenora'	272.817 ± 17.63	552.100 ± 32.35	378.733 ± 16.87	143.092 ± 8.39
'Imanta'	155.950 ± 8.70	287.025 ± 23.20	894.242 ± 33.62	1324.417 ± 31.54

Evaluating the content of acrylamide in deep-fat fried potatoes significant differences were found among the potato varieties (p=0.004) and among freshly harvested and stored potatoes (p=0.013). Significant difference was found between the potato variety 'Zīle' and 'Imanta'.

In order to accurately evaluate the intake of acrylamide content in the human body from fried potatoes, the results were divided into quartiles (Table III).

The absolutely highest content of acrylamide was

determined in the Imanta variety (Q_4) – 1356.40 μg·kg^{-1} while the lowest content – in the Zīle variety (Q_0) – 71.30 μg·kg^{-1} when potatoes were stored and deep-fat fried.

TABLE III: ACRYLAMIDE CONTENT ACROSS QUARTILES, MG KG-1

Range of quartiles	Before storage	After storage
n	30	30
Q_0 (Min)	94.60	71.30
Q_1 (25%)	172.93	152.28
Mean	315.56	513.14
Q_2 50% (Median)	285.70	375.40
Q_3 (75%)	421.20	895.35
(Q_4) (Max)	577.50	1356.40

The content of acrylamide has increased after period of storage in mean, Q_2, Q_3 and Q_4 values.

The results are listed in Table IV which presents the acrylamide content in deep-fat fried potatoes reported by other authors from different countries. The results in Table IV are difficult to compare with the results obtained in the current research because of the lack of the information presented in the reports about the background of potato samples used for the analysis of acrylamide (description of the variety, freshly harvested and fried or stored and fried, storage conditions, frying time and temperature).

The highest value (Q_4) of acrylamide is presented in potatoes analysed in Brazil and afterwards in Latvia when potatoes were deep-fat fried after a period of storage.

TABLE IV: LEVEL OF ACRYLAMIDE IN DEEP-FAT FRIED POTATOES PER COUNTRY, MG KG-1

Country / Organisation	Acrylamide, μg·kg^{-1}			Source
	Q_0	Q_2	Q_4	
Saudi Arabia	n. i.	206	n. i.	[21]
Canada	n. i.	670	n. i.	[22]
The Netherlands	60	351	1220	[23]
Belgium	56	254	729	[24]
Brazil	n. i.	264	2528	[25]
Sweden	300	410	1100	[26]

The data of food consumption survey in Latvia (2007–2009, number of respondents n = 1949) shows that on average an adult woman consumes around 20 g and an adult man consumes 45 g of French fries daily.

That indicates that on average a daily intake of acrylamide from French fries, which have been fried before storage, for an adult female is 6.31 μg·kg^{-1} and 0.097 μg·kg^{-1} from body weight (BW) per day, but from stored and deep-fat fried potatoes it is – 10.26 μg·kg^{-1} and 0.158 μg·kg^{-1} BW per day respectively. For an adult male the daily acrylamide intake from deep-fat fried potatoes prepared before storage on average is 14.20 μg·kg^{-1} and 0.189 μg·kg^{-1} from BW per day, and – 23.09 μg·kg^{-1} and 0.308 μg·kg^{-1} from BW if potatoes have been stored prior to frying (Table V and Table VI).

In Latvia the average body weight of a female is 65 kg while that of male is 75 kg.

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 analysed were stored or they were used just after harvesting. The value of the Q_2 (median) content of acrylamide of the research results on average (without specifying gender and whether potatoes were just harvested or stored) is higher than it is shown in the results published in Sweden ((n=1200; age group 18-74; BW 70 kg, deep-fat fried consumption 12 g per day) (Q_2 (Q_0-Q_4), 8.8 (0.0-88) respectively)) and in Belgium ((n=341; age group 13-18; BW 70 kg; deep-fat fried consumption 39.88 g per day)) (Q_2 (Q_0-Q_4), 10.1 (0.0-128.2) respectively)), but the maximum value (Q_4) in the obtained results of the research, compared to (Q_4) values of the above mentioned countries, is lower [24], [26].

TABLE V: ESTIMATED INTAKE OF ACRYLAMIDE FROM DEEP-FAT FRIED POTATOES, MG KG-1 PER DAY

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)	1.89	1.43	4.26	3.21
Q_1 (25%)	3.46	3.05	7.78	6.85
Mean	6.31	10.26	14.20	23.09
Q_2 50% (Median)	5.71	7.51	12.86	16.89
Q_3 (75%)	8.42	17.91	18.95	40.29
(Q_4) (Max)	11.55	27.13	25.99	61.04

TABLE VI: ESTIMATED INTAKE OF ACRYLAMIDE FROM DEEP-FAT FRIED POTATOES, MG KG-1 FROM BODY WEIGHT

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)	0.029	0.022	0.057	0.043
Q_1 (25%)	0.053	0.047	0.104	0.091
Mean	0.097	0.158	0.189	0.308
Q_2 50% (Median)	0.088	0.116	0.171	0.225
Q_3 (75%)	0.130	0.275	0.253	0.537
(Q_4) (Max)	0.178	0.417	0.347	0.814

The obtained results indicate that, compared to the acrylamide intake in Belgium (0.155 μg·kg^{-1} BW per day from 39.88 g of deep-fat fried potatoes) [24] or Canada (0.136 μg·kg^{-1} BW per day from 12 g of deep-fat fried potatoes (n=600; age group 6-11; BW 26 kg,)[22] (without specifying gender and whether potatoes were just harvested or stored), a Latvian inhabitant has the highest daily intake of acrylamide content from French fries per BW, thus indicating a higher intake of the carcinogenic compound.

IV. CONCLUSION

The obtained results show that a Latvian inhabitant takes up to 62% more acrylamide in his/her body from French fries which are prepared from stored potatoes than from the French fries prepared from freshly harvested potatoes. A male takes up to 1.9 times more acrylamide from French fries than an adult female.

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