Preplanned Studies

Exposure to Acrylamide in the Sixth Total Diet Study — China, 2016–2019

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Summary

What is already known about this topic?

Acrylamide (AA) is toxic and potentially carcinogenic and could be formed during the cooking process. It is understood that almost all foods cooked at high temperature contain AA, especially fried foods. The exposure of AA in food threatens human health.

What is added by this report?

In the Sixth China Total Diet Study (TDS), AA was detected in 73.3% samples of the 12 food categories with the concentrations ranging from undetected to 176.90 μg/kg. The average dietary intake of AA was 0.175 μg/kg body weight per day and a significant decrease (45.1%) was observed compared with the Fifth China TDS. Among the 12 food categories, vegetables (59.0%), cereals (18.9%), and potatoes (10.1%) were the main contributors to AA exposure at 88.0%.

What are the implications for public health practice?

This study highlighted the need to continuously monitor dietary acrylamide exposure in China, including changing food processing methods and making reasonable selection of foodstuffs in the daily diet.

Acrylamide (AA) is widely used in dam and tunnel construction, paper manufacturing, the oil industry, cosmetics, and pharmaceuticals. It has been reported to be a rodent carcinogen (Group 2A) and a probable carcinogen to humans, possibly having toxic effects on the nervous system along with adverse reproductive and developmental effects. Although there is no limit standard for AA in food, relevant control measures have been implemented by several countries. In 2012, the China National Center for Food Safety Risk Assessment released the "Risk Assessment Report of Acrylamide in Food," which evaluated its toxicity, formation, and possible human exposure, and proposed suggestions for its control and prevention (*1*).

Figure 1 showed the contributions of 12 food categories to the overall dietary exposure as analyzed in the Sixth Total Diet Study (TDS), the methodology of which was presented in the Foreword of this issue (*2*). Vegetables (59.0%) and cereals (18.9%) were the predominant contributors of AA intake, accounting for approximately 80% of the overall estimated dietary intake (EDI). In addition, potatoes were also an important source of AA exposure (10.1%).

Using mean EDI value (0.175 μg/kg body weight per day) with the no observed adverse effect level (NOAEL) value (0.2 mg/kg body weight per day), calculated margin of exposure (MOE) value was 1,142. This result indicates the MOE was well below 10,000. Following the conclusions of European Food Safety Authority (EFSA) committee, a potential human health risk should be concerned.

DISCUSSION

In this study, an up-to-date AA database of the Sixth TDS was established to estimate AA exposure for Chinese adults. We found that cereals and vegetables were 100% contaminated with AA, while water and beverages and alcohol beverages had the lowest contamination rates (Table 1). The highest contamination level of AA was found in potatoes from Jiangxi (176.90 μg/kg), followed by the vegetables from Guizhou (154.85 μg/kg) and sugar from Hebei (129.31 μg/kg). Foods cooked at high temperatures (above 120 ℃) upon frying, roasting, and baking were found to produce large amounts of acrylamide, especially starchy foods such as potatoes. The mean concentration of potatoes was 17.74 μg/kg, which was only half of our last TDS (*3*). It was lower than the mean level of non-fried products of potatoes (108 μg/kg) in the report of EFSA (*4*), and also much lower than the mean level of potato snacks (554.5 μg/kg) in a survey conducted in the Republic of Korea (*5*). According to the commission regulation European Union (EU) 2017/2158, the AA benchmark levels of potato products (750 μg/kg), barley and rice-

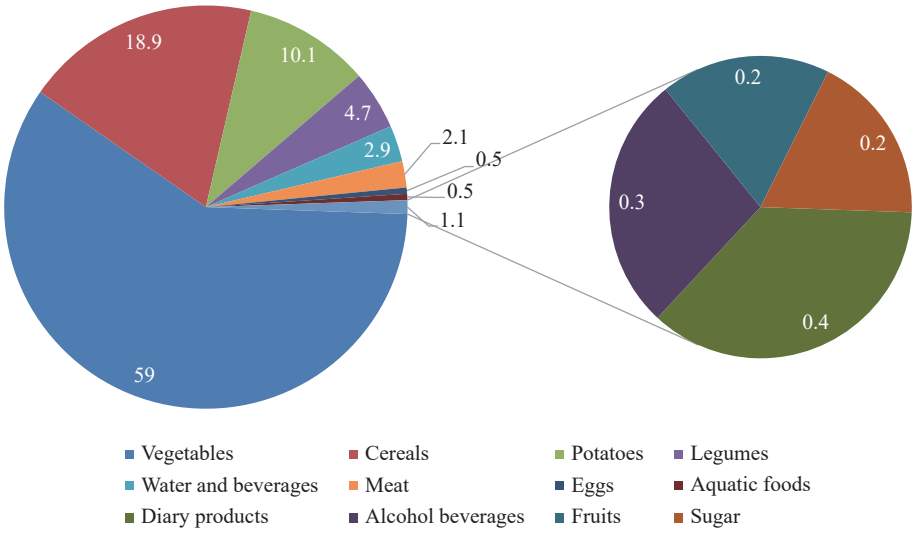

FIGURE 1. Daily intake of the different food groups to dietary acrylamide intakes for Chinese general population (%).

based products (150 μg/kg), roast coffee (400 μg/kg), and baby foods (40 μg/kg) were reported, which were above levels found in the Sixth TDS. Due to the differences in eating habits, cooking methods, heating temperature, and amount of amino acids and carbohydrates, the levels of AA in the same food category varied between different provincial-level administrative divisions (PLADs).

The main contributing food group based on the Sixth TDS results was vegetables, followed by cereals, potatoes, legumes and nuts, water and beverages and meat, which was consistent with the Fifth TDS results but different from other international studies. For instance, Japan's main contributor of AA exposure was beverages, followed by confectioneries, vegetables, potatoes and starches, and cereals (*6*). While for EU countries, the main contributors were potato fries, followed by bread, other potato products, biscuits, crackers and crispbreads, coffee, and other cereal products (*7*).

The dietary exposure to AA in the Third, Fourth, Fifth, and Sixth TDSs was 0.188, 0.286, 0.319, and 0.175 μg/kg body weight per day, respectively (*2*). The mean EDIs of AA for the previous 3 studies showed a significant increasing trend, while a significant decrease of 45.1% (compared with the Fifth TDS) was observed in this study, and the values were the lowest since 2000. According to the 4 TDS results, vegetables were consistently the main contributor of AA intake, and the results were all relatively stable with more than 0.1 μg/kg body weight per day, followed by cereals, potatoes, and legumes (Table 2). The EDI of cereals decreased significantly compared with the previous three times, resulting in the lowest mean dietary exposure to AA in the Sixth TDS. Furthermore, the EDIs of individual PLADs were compared between the Fourth, Fifth, and Sixth Chinese TDS (Figure 2). The EDIs varied in different PLADs, but fortunately, half of the PLADs' EDI values decreased to the lowest level from 2005 to 2019. For some areas, such as Heilongjiang, Hebei, and Hubei, the main contributors (cereals) decreased compared with the previous study, resulting in a dramatic drop of TDS in these PLADs. The value obtained in the current study was much lower than most international studies (*3*,*6*,*8*), which indicated that the national dietary exposure risk to AA is at a low level compared to the world.

The MOE approach was employed to estimate the risk of AA exposure by Joint Expert Committee for Food Additives (JECFA) in 2021. Based on the NOAEL value for morphological nerve changes (0.2 mg/kg body weight per day), the overall Chinese MOE of the Sixth TDS was 1,142. According to the conclusions of EFSA committee, an MOE value of 10,000 or higher would be of low public health concern. Hence, the current value (1,142) is far below 10,000, indicating a potential human health risk that should be of concern for Chinese population. Notably, the MOE value for Guizhou was very low (191), which was lower than the value (310) reported by JECFA. Therefore, efforts should be made to reduce dietary exposure to AA, both by changing food processing methods and promoting healthy eating habits. However, there are several limitations of this study, such as food coverage, food processing method

TABLE 1. Levels of acrylamide (μg/kg) in food composites from the Sixth Chinese Total Diet Study, 2016–2019.

Food composites	HL	LN	HE	BJ	JL	SX	SN	HA	NX	NM	QH	GS	SH	FJ	JX	JS	ZJ	SD	HB	SC	GX	HN	GD	GZ	Mean*
Cereals	5.69	1.93	3.21	2.78	6.38	2.14	3.00	2.52	2.57	7.39	2.58	0.14	2.28	1.77	7.76	2.26	0.11	3.15	1.79	2.25	2.27	2.64	1.82	2.47	2.95
Legumes	3.11	10.62	7.32	3.10	2.44	6.49	3.12	11.98	4.56	3.84	1.89	14.20	6.54	4.19	6.37	28.14	3.44	11.56	13.74	9.84	2.83	10.08	1.75	3.51	7.28
Potatoes	2.04	5.36	3.52	16.51	33.90	2.91	6.83	40.22	10.42	30.20	7.75	14.53	6.08	8.34	176.90	3.75	18.96	10.48	5.15	2.42	7.25	5.57	0.08	6.68	17.74
Meat	2.84	0.10	3.01	2.36	1.57	2.69	0.09	2.08	3.23	3.73	4.85	3.82	2.87	2.91	2.41	0.08	3.30	0.09	14.70	4.91	0.08	3.76	0.10	4.13	2.90
Eggs	0.08	0.11	2.53	1.21	0.09	0.11	1.86	1.83	2.92	3.32	4.00	1.24	1.64	1.98	4.21	2.58	2.03	2.34	7.23	2.52	1.79	4.52	1.09	2.05	2.22
Aquatic foods	4.53	0.12	1.63	1.09	3.09	2.96	5.10	2.26	0.08	2.83	8.67	4.47	1.31	1.17	2.25	0.08	2.85	3.58	3.23	3.90	0.08	3.91	1.56	2.45	2.63
Diary products	3.50	0.08	3.60	1.28	1.48	1.46	0.08	1.06	2.21	0.08	1.63	0.08	2.02	0.08	2.61	1.59	3.52	1.21	1.22	1.37	0.08	1.50	2.22	1.89	1.49
Vegetables	21.57	11.29	20.26	7.01	34.24	4.90	3.31	35.15	29.30	11.66	10.29	5.56	4.53	6.38	10.06	1.86	10.98	15.69	4.23	12.52	3.28	3.69	22.06	154.85	18.53
Fruits	1.30	1.13	0.08	1.28	0.08	1.46	0.08	0.08	0.09	0.08	0.08	0.08	0.08	1.16	0.08	0.08	0.08	0.08	1.00	1.41	0.08	1.40	0.08	1.51	0.54
Sugar	0.08	4.02	129.31	9.30	4.03	1.21	7.27	19.44	11.28	14.43	0.08	1.06	19.62	4.02	9.24	3.34	7.45	61.24	7.20	9.30	7.27	8.71	5.17	6.23	14.60
Water and beverages	0.08	2.66	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1.65	6.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.50
Alcohol beverages	0.08	0.08	0.08	1.13	1.73	0.08	6.29	8.10	0.08	0.08	0.08	1.36	0.08	4.88	0.08	0.08	5.88	0.08	0.08	0.08	6.29	0.08	0.08	0.08	1.54

Abbreviations: HL=Heilongjiang; LN=Liaoning; HE=Hebei; BJ=Beijing; JL=Jilin; SX=Shanxi; SN=Shaanxi; HA=Henan; NX=Ningxia; NM=Inner Mongolia; QH=Qinghai; GS=Gansu; SH=Shanghai; FJ=Fujian; JX=Jiangxi; JS=Jiangsu; ZJ=Zhejiang; SD=Shandong; HB=Hubei; SC=Sichuan; GX=Guangxi; HN=Hunan; GD=Guangdong; GZ=Guizhou.

* Results lower than LOD were assigned 1/2 LOD in calculations.

TABLE 2. Estimated dietary intake of acrylamide (ng/kg body weight per day) from the Sixth Chinese Total Diet Study, 2016–2019 (n=288).

Food composites	HL	LN	HE	BJ	JL	SX	SN	HA	NX	NM	QH	GS	SH	FJ	JX	JS	ZJ	SD	HB	SC	GX	HN	GD	GZ	Mean
Cereals	49.534	18.904	38.530	35.095	59.296	35.194	36.363	36.991	26.951	84.811	31.417	1.477	16.243	17.780	77.592	27.915	1.071	49.742	15.037	34.590	33.861	24.197	13.182	26.459	33.010
Legumes	2.242	20.557	6.630	5.003	2.917	7.144	4.102	10.259	2.546	2.427	0.194	9.290	12.202	5.225	7.458	37.068	7.702	9.627	14.572	10.561	1.902	11.618	0.775	5.660	8.237
Potatoes	2.502	6.130	3.408	15.317	64.571	5.474	12.423	51.261	16.517	58.639	12.466	33.194	3.464	5.601	90.303	1.990	11.038	7.691	7.240	2.413	1.479	4.743	0.033	3.632	17.564
Meat	2.704	0.105	2.264	2.526	1.661	5.854	0.049	1.829	2.394	4.349	5.462	1.878	5.038	3.969	3.588	0.118	6.201	0.133	12.667	10.039	0.192	8.931	0.167	6.984	3.713
Eggs	0.052	0.068	1.269	0.745	0.059	0.036	0.649	0.865	0.604	1.567	0.834	0.438	1.018	0.596	1.369	1.153	0.771	1.647	2.868	0.585	0.398	1.636	0.413	0.529	0.840
Aquatic foods	1.952	0.030	0.245	0.284	0.547	0.301	0.332	0.166	0.003	0.464	0.490	0.200	1.426	1.196	1.561	0.051	2.274	1.294	2.085	0.518	0.124	4.123	1.268	0.135	0.878
Diary products	0.743	0.056	1.385	1.737	0.759	0.960	0.025	0.330	0.534	0.044	1.386	0.018	2.288	0.046	0.904	0.694	1.871	0.443	0.130	0.273	0.023	0.428	1.284	0.844	0.717
Vegetables	109.745	58.522	94.417	43.580	210.912	24.088	15.105	155.119	72.678	47.589	50.715	21.895	28.835	40.181	72.121	12.547	77.428	101.180	27.798	60.173	18.383	31.233	82.820	1002.636	102.487
Fruits	1.291	1.375	0.048	2.303	0.112	0.809	0.051	0.031	0.125	0.145	0.020	0.042	0.093	1.101	0.072	0.035	0.085	0.069	0.305	0.335	0.082	1.406	0.037	0.503	0.436
Sugar	0.003	0.047	1.006	0.291	0.061	0.021	4.378	0.120	0.143	0.238	0.001	0.007	2.364	0.019	0.141	0.014	0.125	0.476	0.021	0.060	0.054	0.069	0.019	0.029	0.404
Water and beverages	1.552	20.827	0.985	1.407	1.653	0.947	0.439	1.514	0.657	3.270	0.785	1.500	18.414	83.638	1.500	1.281	0.999	2.287	0.362	0.399	1.654	1.349	1.515	1.590	6.272
Alcohol beverages	0.028	0.043	0.014	0.490	0.263	0.000	0.166	0.407	0.001	0.026	0.006	0.071	0.029	1.104	0.027	0.048	5.858	0.144	0.018	0.007	3.196	0.021	0.002	0.003	0.499
Total	172.348	126.664	150.200	108.778	342.811	80.827	74.080	258.893	123.152	203.569	103.777	70.010	91.413	160.457	256.637	82.913	115.424	174.733	83.103	119.954	61.348	89.755	101.514	1049.005	175.057

Abbreviations: HL=Heilongjiang; LN=Liaoning; HE=Hebei; BJ=Beijing; JL=Jilin; SX=Shanxi; SN=Shaanxi; HA=Henan; NX=Ningxia; NM=Inner Mongolia; QH=Qinghai; GS=Gansu; SH=Shanghai; FJ=Fujian; JX=Jiangxi; JS=Jiangsu; ZJ=Zhejiang; SD=Shandong; HB=Hubei; SC=Sichuan; GX=Guangxi; HN=Hunan; GD=Guangdong; GZ=Guizhou.

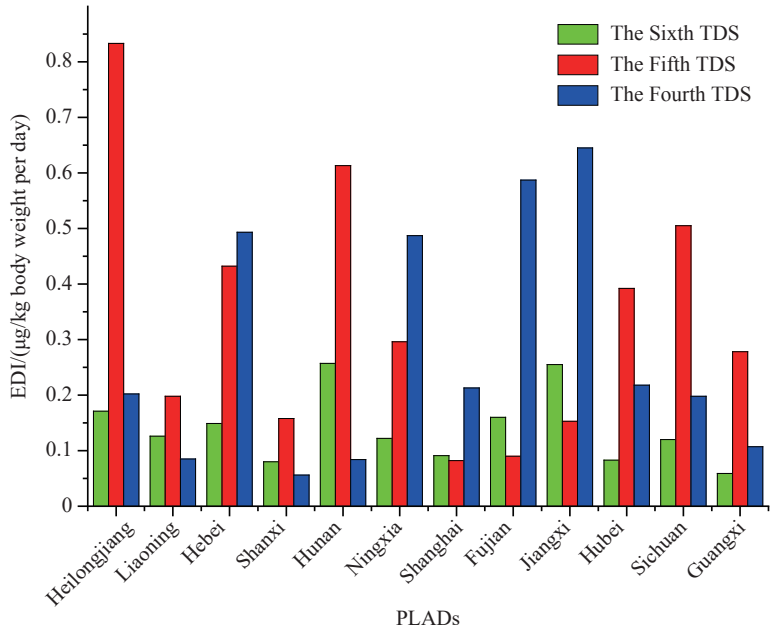

FIGURE 2. Comparative estimated daily intakes of acrylamide from the Fourth, Fifth, and Sixth TDS in various PLADs in China.
Abbreviations: TDS=Total Diet Study; PLADs=provincial-level administrative divisions; EDI=estimated dietary intakes.

(temperature, time, etc.), uncertainties of consumption data, accuracy of detection method, and no assessment for different ages.

In the Sixth TDS, the mean EDI of AA for the Chinese population was 0.175 μg/kg body weight per day, which was lower than the values of the three previous TDSs and other international studies, indicating that measures implemented to reduce AA were effective from 2016 to 2019. However, the calculated MOE value was relatively low, still implying potential human health concerns. Vegetables, cereals, and potatoes were the 3 top predominant sources and accounted for 88% dietary exposure to AA. It is necessary to monitor continuously the AA exposure risk in the Chinese population. In the future, food processing methods and daily diet should be altered to reduce dietary exposure to acrylamide.

Conflicts of interest: No conflicts of interest.

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