Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 5, No. 2, 2023

Heavy Metal Content and Health Risk Assessment of Some Commercial Foods in Jiaozuo City

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Abstract: In order to understand the pollution and health risks of heavy metals (HMs) such as Pb, Cd, Cr, As and Hg in the food of Jiaozuo city, samples of cereals, beans and vegetables were collected from local markets. Based on the determination of HMs contents, single factor pollution index and Nemerow comprehensive pollution index were used to evaluate the pollution levels, and then the THQ model was used to assess the health risks induced by HMs to local residents through ingestion of these foods. The results showed that rice and corn samples were heavily and slightly polluted, respectively, with Hg contributing the most to the pollution index. The soybean and peanut samples were at a slight pollution level and alert level respectively. Edible fungus samples were at a slight pollution level, while the contents of HMs in all the other vegetable samples were at a safe level. Health risk assessment indicated that rice and edible fungi posed relatively high risks after long-term consumption. As and Hg contributed the most to the risk induced by rice, while Cd, Cr and As contributed the most to the risk of edible fungi. Beans showed no health risk. The health risk of HMs in all foods was higher to children than to adults.

Keywords: Jiaozuo City, Food, Heavy metal, Pollution, Health Risks.

1. Introduction

Food safety is an important public health issue that affects social stability and economic development. With the development of China's economy and industrialization, various kinds of pollution emerge in endlessly in the environment [1]. Especially in recent years, heavy metal pollution in water and soil with prominent impact on agriculture [2]. Common heavy metal pollutants mainly include Pb, Cd, Cr, As, Hg, etc. Cd is a highly toxic heavy metal element. When it enters the human body, it will affect the absorption and metabolism of Ca, P and other elements, and then affect the formation of human bone cells, resulting in osteomalacia, deformation and pain, and induce canceration, resulting in visceral system disorder [3]. Pb can cause serious damage to the digestive system, nervous system and blood system of the human body [4]. As can induce cancer and has been recognized as a human carcinogen by the International Cancer Research Institute [5]. When Hg enters the human body, it invades human tissues through blood circulation, damages the central nervous system of the human body, and also enters the fetal body through the placenta, affecting human health [6]. The pollution of heavy metals in food has always been a hot issue of social concern.

Jiaozuo, known as "Shanyang" and "Huaizhou" in ancient times, is located on the north bank of the Yellow River and the south foot of the Taihang Mountains. Since ancient times, the environment has been suitable, farming has been developed, and the population has flourished. With the advancement of China's modern industrialization process and the mining of Jiaozuo coal mine, more people have poured into Jiaozuo, where they have taken root and multiplied. Today, Jiaozuo has developed into a regional central city with a population of more than 3.5 million. In order to understand the current situation of heavy metal pollution in foods sold in Jiaozuo and its health risks, this paper studied the content of heavy metals in some foods sold in Jiaozuo.

The Outline of China's Food and Nutrition Development (2014-2020) points out that in daily consumption, people's food intake mainly includes three categories: cereals, beans and vegetables. The sum of the per capita consumption of cereals and beans is about 148 kg/a, and the per capita consumption of vegetables is about 140 kg/a, which accounts for 62.75% of the total food consumption [7]. Therefore, this study took these three categories of food as the research object, and carried out sample collection, heavy metal content determination and health risk assessment. The research results can provide scientific basis for the food safety risk control work in Jiaozuo City.

2. Materials and Methods

2.1. Sample collection

Jiaozuo City is located at 35º10′-35º21N,113º4′-113º26′E, with a total area of 4072 km^2. By 2021, the city's annual resident population will reach 359714 million [8]. Jiaozuo City has five districts under its jurisdiction, namely, the Liberated Area, Shanyang District, Zhongzhan District, Machun District and the urban-rural integration demonstration area. The Liberated Area and Shanyang District are the main mixed commercial and residential areas in Jiaozuo City, with the most prosperous economy and the largest population density, accounting for 60% of the urban population of Jiaozuo. Zhongzhan District and Machun District are industrial administrative areas, and the urban-rural integration demonstration area is a complex functional area with urban-rural integration, industrial integration and overall development. In this study, Shanyang District and Liberated Areas with relatively concentrated population were selected as the study areas.

There are 14 large supermarkets, 9 farmers' markets and 2 wholesale markets in the Liberated Areas and Shanyang District. In this study, 6 major supermarkets, 6 farmers' markets and 1 wholesale market are selected as the sampling points. The collected samples include 78 grains (rice, corn, flour), 52 beans (soybeans, mung beans, peanuts) and 117 vegetables (leaves, solanaceous fruits, rhizomes, edible fungi, cabbage), with a total of 247 samples. The distribution of sampling points and sample types can basically represent the current situation of the corresponding market food in Jiaozuo City.

2.2. Sample handling

(1) Sample pretreatment: the weight of each sample in each type of food shall not be less than 300g, which shall be packed in plastic bags and transported back to the laboratory. For rice, corn and beans samples, wash with deionized water for 3-4 times, then dry them, put them in an oven at 70 ℃ to dry to constant weight, cool them at room temperature, grind them to powder and pass through a 100-mesh sieve, classify them, number them, dry and seal them, and save flour samples without cleaning. For vegetable samples, after removing the withered leaves and other inedible parts, wash the remaining parts with deionized water for three times, absorb the surface water with filter paper, cut them with stainless steel knife, put them into a 100 ℃ oven for 30 minutes, and then dry them to constant weight at 65 ℃, grind them into powder with a grinder, classify and number them into sealed bags for cold storage. In this paper, the content of heavy metals in cereal and legume samples is calculated by dry weight, and the content of heavy metals in vegetable samples is expressed by fresh weight.

(2) Sample digestion [9]: For grain and bean samples, weigh 0.25g (accurate to 0.001g) into a polytetrafluoroethylene (PTFE) digestion tank, add 6mL nitric acid (MOS grade), cover and place for 1h, and then put it into a graphite digester for digestion; For vegetable samples, weigh 0.1g (accurate to 0.001g) of solid samples into a PTFE digestion tank, add 6mL of nitric acid (MOS grade) and 1.5mL of hydrofluoric acid (EP grade), pre-digest at 100 ℃ for one hour on the graphite digester, and then cover to continue digestion. The digestion temperature procedure is as follows: 120 ℃ digestion for 0.5h, 150 ℃ digestion for 10min, 180 ℃ digestion for 0.5h, after digestion to clear, set the temperature to 140 ℃, drive the acid to about 1 mL of colorless or light yellow clear liquid, stop, transfer the digestion solution to a 25ml centrifuge tube (PP material), wash the digestion tank with deionized water 2-3 times, and the washed liquid is also transferred into the centrifuge tube, and finally use deionized water to volume, use 0.45 μm PTFE needle filter is filtered, and then tested on the machine.

2.3. 2.3 Determination of heavy metal content

(1) Hg content

The content of mercury in food samples was determined by the direct injection mercury method in the National Standard for Food Safety - Determination of Total Mercury and Organic Mercury in Food (GB5009.17-2021). The instrument used was DMA-80 direct mercury meter (Italy Milestone, detection limit is 0.001 ng).

(2) Pb, Cd, Cr, As content

The contents of heavy metal elements Pb, Cd, Cr and As in the digestion solution of each sample were determined by inductively coupled plasma mass spectrometer (Varian810-MS, Analytik Jena AG, Germany).

2.4. 2.4 Quality control

In order to ensure the accuracy of the experimental process and results, two parallel samples, one blank sample and one reference material sample (Hunan Rice Reference Material (GBW10045a)) were set for each batch of 24 samples for quality control. The response values of blank samples are lower than the detection limit, and the relative standard deviation of parallel samples is within ± 20%. The measured values of Pb, Cd, Cr, As and Hg are within the given error range.

2.5. Assessment method of heavy metal pollution

The contents of Pb, Cd, As, Cr and Hg in these three categories of food were evaluated according to the Maximum Levels of Pollutants in Food (GB 2762-2017) [10].

Single-factor pollution index method [11]: Single-factor pollution index is a dimensionless index to evaluate the degree of pollution, which can reflect the degree of pollution of pollutants. The calculation formula (1) is as follows:

$$Pi = Ci /Si \qquad (1)$$

In formula (1): i is the number of pollutant; Pi is the single pollution index of the pollutant in the sample; Ci is the measured value of pollutant i in the sample, mg/kg; Si is the evaluation standard of pollutant i, mg/kg. When Pi ≤ 1, it indicates that the sample is not contaminated; When Pi>1, it indicates that the sample has been contaminated. With the increase of Pi value, it indicates that the sample is polluted more. GB 2762-2017 does not specify the limit value of total mercury content in legumes, so the pollution index of Hg in legumes will not be analyzed.

Nemerow comprehensive index method is one of the commonly used methods to evaluate the comprehensive pollution degree of various pollutants, and the formula is as follows [12]:

$$P_N = [(P_{ave}{}^2 + P_{max}{}^2)/2]^{1/2} \qquad (2)$$

In formula (2), PN is the comprehensive pollution index of a measured sample, Pmax is the single pollution index with the largest value in the pollutants, and Pave is the average value of each pollution index. The Nemerow composite index is divided into five levels: PN ≤ 0.7, safety level; 0.7<PN ≤ 1.0, warning level; 1.0<PN ≤ 2.0, slightly polluted; 2.0<PN ≤ 3.0, moderately polluted; PN>3.0, serious pollution [13].

2.6. 2.6 Health risk assessment method

Target hazard factors (THQ) is a method established by the United States Environmental Protection Agency (USEPA) in 2000 to assess the health risks caused by heavy metals ingested by human beings through food [14]. The risk quotient (THQ) is used to assess the health risks caused by the consumption of a single heavy metal in food. When THQ is less than 1, pollutants will not harm human health. The calculation formula is:

$$THQ=(c\times IR\times E_D\times E_F)/(R_{FD}\times BW\times ATn) \qquad (3)$$

In formula (3), c is the content of heavy metal in food [mg · kg^{-1}]; IR is the daily intake per capita [kg · (d · person)

$^{-1}$]; E_D is the exposure duration (a); E_F is the exposure frequency (d/a); R_{FD} is the oral reference dose of heavy metals [mg · (kg · d) - 1], BW is the average body weight of the evaluated population (kg); Average exposure time of ATn (d, E_D × 365d/a). See Table 1 for parameter values.

The impact of heavy metals on human health is generally the result of the joint action of multiple elements. THQs is used to evaluate the risk of multiple heavy metals exposure of the same food on human health, and the calculation formula is:

$$THQs=\Sigma THQ \quad (4)$$

If THQs ≤ 1.0, it indicates that long-term consumption of this food has no significant negative impact on human health; THQs>1.0 indicates that long-term consumption of this food may have a negative impact on health, and the higher the value, the greater the negative impact.

Table 1. Parameter values of health risk assessment [15,16]

index	parameter	unit	children	adult
Basic parameters	c	mg/kg		
	ED	a	7	30
	BW	kg	32.7	60
Exposure behavior parameters	EF	d/a	365	365
	ATn	d	2555	10950
Direct intake	$IR_{vegetable}$	kg/d	0.218	0.329
	IR_{grain}		0.25	0.3247
	IR_{beans}		0.005	0.016
Reference dose of heavy metals	Rfd Pb	mg/(kg·d)	3.50×10^{-3}	
	Rfd Cr		3.00×10^{-3}	
	Rfd Cd		1.00×10^{-3}	
	Rfd As		3.0×10^{-4}	
	Rfd Hg		3.00×10^{-4}	

2.7. Data processing and analysis

SPSS software and Excel software are used to sort out the measured data and carry out corresponding analysis and calculation.

3. Results and Discussion

3.1. Content of heavy metals in foods and their compliance

Table 2 shows the mean value, range, coefficient of variation of heavy metals in various foods as well as the standard of heavy metals.

The content of heavy metals in different cereal foods varies. The Pb content in corn is the highest, followed by rice and flour. This result is consistent with the research conclusion of Dong Fengguang et al. [17] on the pollution status of grain and its products sold in Yantai. The average value of Cd and Cr content from high to low is flour>rice>corn, the average value of As content from high to low is rice>flour>corn, and the average value of Hg content from high to low is rice>corn>flour.

In terms of the rate of reaching the standard, the content of As and Cd elements in all grain samples sampled this time can meet the national standard, while Cr in flour, Pb and Hg in rice and corn have different proportions of exceeding the standard, especially the rate of reaching the standard of Hg in rice and corn is low, 25.71% and 45.45% respectively, indicating that there is a relatively common pollution phenomenon, which should be paid attention to.

In the bean samples, the average value of Pb content from high to low is soybean>mung bean>peanut, the average value of Cd and As content from high to low is peanut>soybean>mung bean, the average value of Cr content from high to low is soybean>peanut>mung bean, and the average value of Hg content from high to low is mung bean>soybean>peanut.

In terms of the rate of reaching the standard, Hg in beans is not specified in the food standard, so it is not calculated to meet the standard, and it is defaulted that all of them meet the standard. As element can meet the national standard, while Pb and Cd in soybeans and mung beans, and Cr in soybeans have different over-standard phenomena, especially the standard rate of Cr in soybeans is low, 57.15%, indicating that there is a certain pollution phenomenon, which needs to be paid attention to.

In vegetable foods, the average Pb content from high to low is leafy vegetables>edible fungi>eggplant fruit>rhizome>cabbage; The average value of Cd content from high to low is edible fungi>leafy vegetables>rhizome=cabbage>eggplant fruit; The average value of Cr content from high to low is edible fungi>leafy vegetables>eggplant fruit>rhizome>cabbage; The average value of As content from high to low is edible fungus>leafy vegetables>rhizome>cabbage>eggplant fruit; The average value of Hg content from high to low is leafy vegetables>edible fungi=cabbage>rhizome=eggplant fruit.

Table 2. Heavy metal content in food samples (mg/kg) and compliance rate (%)

Food category		project	Pb	Cd	Cr	As	Hg
Cereal	Rice	**mean value**	**0.11**	**0.01**	**0.23**	**0.13**	**0.1**
		Range	ND~1.80	ND~0.03	0.04~0.88	0.09~0.17	ND~0.38
		Coefficient of variation	0.85	1.18	0.89	0.18	1.15
		Compliance rate	89.74	100	100	100	25.71
	Flour	**mean value**	**0.05**	**0.02**	**0.32**	**0.002**	**0.005**
		Range	ND~0.18	0.01~0.04	ND~0.62	ND~0.01	ND~0.015
		Coefficient of variation	0.78	0.26	0.76	1.99	0.45
		Compliance rate	100	100	88.89	100	100
	Corn	**mean value**	**0.21**	**—**	**0.12**	**—**	**0.03**
		Range	0.05~1.15	—	ND~0.30	—	ND~0.06
		Coefficient of variation	1.4	—	0.74	—	0.92
		Compliance rate	83.33	100	100	100	45.45
beans	Soybean	**mean value**	**0.44**	**0.02**	**1.17**	**0.01**	**0.01**
		Range	0.03~0.94	ND~0.05	0.59~2.60	ND~0.02	ND~0.018
		Coefficient of variation	1.39	0.66	0.46	0.49	0.86
		Compliance rate	95.24	95.24	57.14	100	100
	peanut	**mean value**	**0.05**	**0.23**	**0.74**	**0.02**	**0.007**
		Range	0.02~0.16	0.07~0.43	0.53~0.92	ND~0.03	ND~0.01
		Coefficient of variation	0.71	0.52	0.13	0.44	0.98
		Compliance rate	100	100	100	100	100
	Mung bean	**mean value**	**0.11**	**0.002**	**0.27**	**0.003**	**0.013**
		Range	0.01~0.38	ND~0.01	0.07~0.66	ND~0.01	ND~0.03
		Coefficient of variation	1.03	2.11	0.79	1.61	0.9
		Compliance rate	80	80	100	100	100
Vegetables	Leafy vegetable	**mean value**	**0.22**	**0.07**	**0.2**	**0.08**	**0.006**
		Range	ND~0.49	0.005~0.25	ND~0.60	0.01~0.93	ND~0.01
		Coefficient of variation	0.68	0.78	0.84	1.88	0.37
		Compliance rate	71.43	97.14	94.29	97.14	94.12
	Rhizome vegetables	**mean value**	**0.04**	**0.02**	**0.08**	**0.03**	**0.002**
		Range	ND~0.24	ND~0.14	ND~0.33	0.001~0.07	ND~0..004
		Coefficient of variation	1.37	1.43	0.96	0.69	0.57
		Compliance rate	95.24	95.24	100	100	100
	edible fungi	**mean value**	**0.13**	**0.21**	**0.92**	**0.1**	**0.004**
		Range	ND~0.83	0.01~0.64	0.02~2.39	ND~0.33	ND~0.006
		Coefficient of variation	1.56	1.03	0.69	0.84	0.53
		Compliance rate	100	66.67	23.81	100	100
	Eggplant fruit	**mean value**	**0.07**	**0.03**	**0.1**	**0.011**	**0.002**
		Range	ND~0.27	ND~0.10	ND~0.26	0.002~0.04	ND~0.005
		Coefficient of variation	1.04	0.76	0.7	0.79	0.67
		Compliance rate	81.82	95.83	100	100	100
	Cabbage	**mean value**	**0.005**	**0.02**	**0.07**	**0.02**	**0.004**
		Range	ND~0.009	ND~0.04	0.01~0.21	0.005~0.04	ND~0.008
		Coefficient of variation	0.69	0.52	0.82	0.65	0.59
		Compliance rate	100	100	100	100	100

In terms of the rate of reaching the standard, we can see that the rate of reaching the standard for Pb in leafy vegetables is relatively low, only 71.43%, and the rate of reaching the standard for Cd, Cr, As and Hg in leafy vegetables is about 95%; The standard rate of Pb and Cd in rhizomes is 95%, and other elements are up to standard; Edible fungi have a low standard rate of 66.67% on Cd and 23.81% on Cr, and all other elements have reached the standard; The rate of reaching the standard for Pb and Cd in solanaceous fruits is 81.82% and 95% respectively, and other elements are up to the standard; All kinds of heavy metal elements in cabbage are 100% up to the standard. From the perspective of reaching the standard, Pb, Cd and Cr are the main pollution elements in the study of vegetable samples, which is consistent with the relevant research results of Zhou Jianli et al. [18]. According to Fang Fengman [19]'s research on the characteristics of heavy metal pollution in vegetables, leafy vegetables are mainly polluted by Pb in atmospheric dust, affecting the situation of reaching the standard. In addition, the rate of reaching the standard of edible fungi is far lower than that of other types of vegetables, and related research also has a similar conclusion, that is, edible fungi show greater heavy metal absorption capacity than common green plants [18]. The excessive content of Cr in edible mushroom vegetables should be paid attention to. Therefore, during the planting of various vegetables, the water and soil environment in the planting area should be strictly controlled, and the possible pollutants should be prevented and controlled. In particular, relevant departments should strengthen the investigation and research on the pollution sources of edible fungi, the supervision and the influence of cultivation mode on them.

3.2. Assessment of heavy metal pollution in food

The pollution index of heavy metals in the sample is shown in Table 3.

Table 3. Heavy metal pollution assessment of various foods

Food category		Single pollution index (Pi)					Comprehensive pollution index (P_N)	class of pollution
		Pb	Cd	Cr	As	Hg		
cereal	Rice	0.55	0.1	0.23	0.26	5.0	3.64	**Severe pollution**
	Flour	0.25	0.2	0.24	0.004	0.25	0.22	Security
	Corn	1.05	—	0.12	—	1.5	1.13	Mild pollution
beans	Soybean	2.2	0.1	1.17	0.02	—	1.63	Mild pollution
	Peanut	0.25	1.15	0.74	0.04	—	0.87	Alert level
	Mung bean	0.2	0.01	0.27	0.006	—	0.20	Security
vegetable	Leafy vegetable	0.73	0.35	0.4	0.16	0.6	0.61	Security
	Rhizome vegetables	0.4	0.2	0.16	0.06	0.2	0.32	Security
	edible fungi	0.13	1.05	1.84	0.2	0.04	1.38	Mild pollution
	Eggplant fruit	0.7	0.6	0.2	0.02	0.2	0.55	Security
	Cabbage	0.02	0.4	0.14	0.04	0.4	0.32	Security

In cereal samples, the single-factor pollution index of rice Hg reached 5.0, which was relatively serious. The single-factor pollution index of other heavy metals was less than 1, which was at the non-polluting level; The comprehensive pollution index of rice is 3.68, which belongs to heavy pollution, which should be attributed to the high degree of Hg pollution of rice. The single factor pollution index of flour is less than 1, which is at the non-pollution level, and the comprehensive pollution index is also at the safety level. The single-factor pollution index of Pb and Hg in maize exceeded 1.0, indicating that maize was polluted by these two elements; The comprehensive pollution index of corn is 1.13, belonging to the light pollution level, which should be attributed to the Pb and Hg elements in corn, which have a large contribution to the comprehensive pollution index.

Among the bean samples, the single factor pollution index of Pb and Cr in soybeans reached 2.2 and 1.17 respectively. The single factor pollution index of these two elements exceeded 1, indicating that soybeans were polluted by these two elements; The comprehensive pollution index of soybeans is 1.63, belonging to the light pollution level, which is attributed to the pollution of Pb and Cr elements in soybeans. The single factor pollution index of Cd in peanut is 1.15, indicating that peanut is polluted by this element. The single factor pollution index of other heavy metals is less than 1, which is at the non-polluting level; The comprehensive pollution index of peanut is 0.87, belonging to the alert level, mainly due to Cd pollution. The single-factor pollution index of all heavy metals in mungbean is less than 1, which is at the non-polluting level; The comprehensive pollution index of mungbean is 0.20, which belongs to the safety level. This research result is consistent with the research result of Xu Menghuai [20] on the pollution status of beans sold in Guizhou. It is suggested to pay special attention to the pollution of heavy metals Cr and Pb in soybeans and Cd in peanuts, and take preventive and control measures for heavy metal pollution.

In the vegetable samples, the single factor pollution index of each heavy metal in leafy vegetables, roots, eggplants, and cabbage is less than 1, which is at the non-pollution level, and their comprehensive pollution index is also at the safety level. The single factor pollution index of Cd and Cr in edible fungi is greater than 1, indicating that they are polluted by these two heavy metals; The comprehensive pollution index of edible fungi is 1.38, belonging to the light pollution level, mainly due to the contribution of Cd and Cr. This result is consistent with Cui Huijin [21] and other studies on heavy metals in vegetables in Taiyuan. In general, the heavy metal pollution in the vegetables sold in Jiaozuo this time is good and generally at the safe level. Only fungus vegetables need attention.

3.3. Food health risk assessment

The health risk index of heavy metals ingested through food is shown in Table 4.

Table 4. Health Risk Index of Heavy Metals in Different Kinds of Food in Adults and Children

Food category		THQ (Adults)					THQs
		Pb	Cd	Cr	As	Hg	
cereal	Rice	0.159	0.051	0.389	2.198	1.691	4.489
	Flour	0.072	0.101	0.541	0.034	0.085	0.833
	Corn	0.304	—	0.203	—	0.507	1.015
beans	Soybean	0.031	0.005	0.098	0.008	0.008	0.151
	Peanut	0.004	0.058	0.062	0.017	0.006	0.145
	Mung bean	0.008	0.001	0.023	0.003	0.011	0.044
vegetable	Leafy vegetable	0.323	0.360	0.343	1.371	0.103	2.499
	Rhizome vegetables	0.059	0.103	0.137	0.514	0.034	0.847
	edible fungi	0.191	1.080	1.576	1.714	0.069	4.629
	Eggplant fruit	0.103	0.154	0.171	0.188	0.034	0.651
	Cabbage	0.007	0.103	0.120	0.343	0.069	0.641
Food category		THQ (Children)					THQs
		Pb	Cd	Cr	As	Hg	
cereal	Rice	0.240	0.076	0.586	3.313	2.548	6.764
	Flour	0.109	0.153	0.815	0.051	0.127	1.256
	Corn	0.459	—	0.306	—	0.765	1.529
beans	Soybean	0.019	0.003	0.060	0.005	0.005	0.092
	Peanut	0.000	0.035	0.038	0.010	0.004	0.087
	Mung bean	0.000	0.000	0.014	0.002	0.007	0.023
vegetable	Leafy vegetable	0.419	0.467	0.444	1.778	0.133	3.241
	Rhizome vegetables	0.076	0.133	0.178	0.667	0.044	1.098
	edible fungi	0.248	1.400	2.044	2.222	0.089	6.003
	Eggplant fruit	0.133	0.200	0.222	0.244	0.044	0.844
	Cabbage	0.010	0.133	0.156	0.444	0.089	0.832

From the single heavy metal risk index (THQ) of cereals, in rice, the THQ of As and Hg in adults and children is more than 1, and the THQ value of children is higher than that of adults, which indicates that when eating rice, As and Hg may bring potential health risks, and the health risks to children are higher than that of adults. The single heavy metal risk index THQ value of various heavy metal elements in flour and corn is less than 1, indicating that the contents of heavy metals in flour and corn are in a safe state and will not bring health risks to people.

From the perspective of multiple heavy metal compound risk indexes (THQs) of cereals, for adults, the THQs values of rice and corn both exceed 1, which means that adults will have potential health risks in long-term consumption of rice and corn foods, and the health risk of rice is higher than that of corn; For children, the THQs of rice, flour and corn are more than 1, indicating that children have potential health risks when eating these grains for a long time. Because children are growing up and have low immunity, children are more likely to be contaminated by heavy metals in grains than adults after eating them, resulting in potential risks [22]. Therefore, more attention should be paid to the health risks of heavy metals exposed to children's grain intake, and the dietary management of residents in Jiaozuo should be strengthened to optimize the proportion of grain intake.

According to the single heavy metal risk index (THQ) of beans, the THQ value of each heavy metal element in all kinds of beans is not more than 1, indicating that adults and children are in a safe state during long-term consumption of beans. From the perspective of multiple heavy metal compound risk indexes (THQs) of beans, the THQs values of these three beans are less than 1 for both adults and children, which means that long-term consumption of beans will not cause health risks and is a safe range. From the perspective of dietary balance and food safety, both adults and children can appropriately increase the intake of soy food.

From the single heavy metal risk index (THQ) of vegetables, the THQ value of As element in leafy vegetables for adults and children is greater than 1, which indicates that the As element in leafy vegetables may have a potential impact on human health after long-term consumption. In edible fungus food, the THQ value of Cd, Cr and As is greater than 1, which indicates that long-term consumption of edible fungus food may have potential impact on human health. Both of the above foods are children with higher THQ values than adults, which indicates that children will suffer higher health risks than adults. For adults and children, the THQ value of each element in rhizomes, solanaceae and cabbage is less than 1, which indicates that heavy metal elements will not harm human health when adults and children eat these vegetables.

From the perspective of multiple heavy metal compound risk indexes (THQs) of vegetables, for adults, the THQs of leafy vegetables and edible fungi reached 2.499 and 4.629, both of which were greater than 1, indicating that long-term consumption of these two vegetables by adults would have potential health risks, and the risk of edible fungi was greater than that of leafy vegetables; The THQs values of rhizomes, eggplant fruits and cabbage are all less than 1, which indicates that it is safe for adults to eat these vegetable foods for a long time. For children, in addition to leafy vegetables and edible fungi, the THQs value of rhizomes is also greater than 1, which indicates that children will have potential health risks during long-term consumption of these three vegetables; The THQs of solanaceous fruits and cabbage are less than 1, which indicates that it is safe for children to eat these vegetables and vegetables for a long time. Compared with adults and children, children have higher THQs values of the above three vegetables than adults, which indicates that children will suffer higher health risks than adults. In addition, no matter the risk of single heavy metal or the compound risk of multiple metals, the health risk of edible fungi vegetables consumed by adults and children is much higher than that of other vegetables, which is consistent with the conclusion of Fu Jie et al. [23] on the health risk assessment of heavy metals in edible fungi on the market. In general, it is suggested that residents of Jiaozuo should try to choose cabbage, eggplant fruit and rhizome vegetables when choosing vegetables, and reduce the consumption of edible fungi and leafy vegetables, which can effectively reduce the potential health risks.

4. Conclusion

(1) In terms of the standard rate of heavy metals in the food sold in Jiaozuo City, the Hg element of rice and corn in the grain food showed a low standard rate of only 25% and 45.45%, and other elements in the grain basically reached the standard; In legumes, all kinds of heavy metal elements are up to the standard, except for the low rate of Cr in soybeans, which is 57.14%, and the rate of Pd and Cd in mung beans, which are 80%; Among vegetables and vegetables, the Pb standard rate in leafy vegetables is 71.43%, the Cd and Cr in edible fungi are 66.67% and 23.81%, and the Pb in solanaceous fruits is 81.82%. Other heavy metal elements are in the standard state in vegetables.

(2) In terms of comprehensive pollution degree, rice is heavily polluted and corn is slightly polluted in cereal foods, with the largest contribution of Hg; Soybeans and peanuts are in the light pollution and warning level respectively in the bean food; Only fungi in vegetables are at the level of slight pollution, and other foods are at the level of safety.

(3) In terms of health risk, the health risk of rice in cereal food is higher, and the health risk of edible fungi in vegetable food is higher. Among them, As and Hg in rice play a major role; In bean food, all kinds of food and heavy metal elements are at the level of no health risk; In vegetable food, there are health risks in the long-term consumption of leafy vegetables and edible fungi. As elements in leafy vegetables and Cd, Cr and As in edible fungi play a very high role. The overall health risk of children is greater than that of adults, which needs to be paid attention to by relevant departments.

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