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Determination of Cadmium Content in Pork by Graphite Furnace Atomic Absorption Spectrometry Combined with Matrix Matching Method and Its Health Risk Assessment

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Abstract

Objective: Optimization of the method of graphite furnace atomic absorption in the existing national standard method GB 5009.15-2014 to establish the method for quantitative detection of cadmium and analyze the health risks of cadmium in pork. **Methods:** The temperature program of the graphite furnace was optimized and was combined with the matrix matching method. The cadmium content and health risk of pork samples from seven producing areas from 2019 to 2020 were evaluated by the single factor pollution index method (Pi) and target hazard coefficient method (THQ) of non-carcinogenic pollutant risk. **Results:** The optimization method: The correlation coefficient of the standard curve was above 0.999, the recovery rate was 96.9% - 107.1%, and the coefficient of variation was 0.4% - 0.7%. The detection limit was 0.68 μg/Kg. The cadmium content in pork from 2019 to 2020: was 100% qualified, with an average value of 3.05 μg/kg; The range of Pi was 0.0050 - 0.189, the range of cadmium exposure was (0.0004 - 0.01700) μg/(kg·d), and the range of THQ was 0.0005 - 0.0204; The average of cadmium content, Pi, cadmium exposure, and THQ from 2019 to 2020 showed a downward trend, so as the maximum values of them; The cadmium content, Pi, cadmium exposure and THQ: The order of the average of them in the origin product was S5 > S3 > S4 > S1 > S2 > S7 > S6, so as the order of maximum of. Them. **Conclusion:** The Graphite furnace atomic absorption spectrometry combined with the matrix matching method for the detection of cadmium in pork has good accuracy, high precision and sensitivity, and low detection

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limit. The method was applied to the analysis of cadmium content in commercially available pork samples. The results showed that 100% of the samples were qualified, and the cadmium content showed a steady downward trend. Its cadmium pollution level is excellent, at a safe level, and there is no intake risk to human health.

Subject Areas

Analytical Chemistry

Keywords

Temperature Program, Health Risk, Nemerow Pollution Index Method, Cadmium Exposure, Target Hazard Coefficient Method

1. Introduction

With the improvement in living standards, the proportion of meat in people's diets has increased. Pork is rich in proteins, amino acids, fats, sugars and trace elements that regulate human metabolism and enhance immunity. Pork is one of the meats with high nutritional value and high consumption [1] [2]. With the development of industrialization and urbanization, the increase of heavy metal content in industrial wastes, the unscientific feeding of animals, and the unscientific processing, packaging and transportation of meat products have led to heavy metal pollution in meat, which poses a risk to human health. Enrichment of cadmium heavy metals in animal bodies can cause chronic poisoning of the liver and kidney by eating the human body, resulting in diabetes, amino acid urine, hypercalciuria, proteinuria, etc. Calcium loss causes osteoporosis [3] [4]. In recent years, the national government has had high requirements for food quality and safety. By eating pork containing cadmium and will cause the accumulation of heavy metals in the human body, it is difficult to eliminate. Cadmium pollution in pork will bring hidden dangers to human health [5]. The establishment of detection methods for cadmium content in pork is the basis for effective control of cadmium pollution in pork. There are many detection methods for heavy metal elements in food: inductively coupled plasma mass spectrometry (ICP-MS), colorimetry, atomic absorption spectrometry, atomic fluorescence spectrometry and high performance liquid chromatography [6] [7] [8]. In recent years, there have been reports on the detection of heavy metals in meat by graphite furnace atomic absorption spectrometry and risk assessment [9] [10] [11]. The existing graphite furnace atomic absorption spectrometry national standard method for the detection of cadmium, some conditions need to be optimized according to the specific laboratory equipment conditions and test sample conditions to achieve the purpose of accurate quantitative detection. This study was based on the determination of cadmium by graphite furnace atomic absorption spectrometry in GB 5009.15-2014 national food safety standard [12].

To assess the risk of cadmium intake in pork, the necessary method optimization was carried out on demand, combined with the matrix matching method, so as to quickly establish a graphite furnace atomic absorption method for accurate detection of cadmium in pork. After the method was confirmed, it was applied to analyze the cadmium content characteristics and health risks of commercially available pork from 2019 to 2020, so as to provide reliable data support and risk warning for relevant regulatory authorities, and provide reference for consumers.

2. Materials and Methods

2.1. Reagents and Instruments

Nitric acid (electronic grade, Deshan Pharmaceutical Industry, South Korea); argon (purity more than 99.99%, Beijing Hepu North Gas Industry); the water used in the laboratory is pure water prepared by ultrapure water meter. GBW (E) 080119 cadmium single element standard solution 100 μg/mL (16111 batches, National Institute of Metrology, China); cFAPA-QC442B rice flour unit quality control samples (Dalian Zhongshi National Testing Technology Co., Ltd.). The glassware and digestion tubes used were soaked in nitric acid (20%) for more than 24 h, and finally washed with pure water to dry.

Tissue mashing machine (Buqi, Switzerland, B-400), atomic absorption spectrophotometer (Shimadzu, AA6880), high density graphite tube (Shimadzu, 206-50587-85); microwave digestion instrument (CEM, MARS6); electronic balance (Mettler, MS204S), ultrapure water meter (MILLI-Q, Bright-D24UV).

2.2. Pork Samples

According to 10/unit sampling, a total of 70 samples were collected from 5 units in 2019 and 2 units in 2020 in the market pork. The sampling method referred to NY/T 763-2004 [13], and the 7 units were marked as S1 to S7 according to the sampling time sequence. Pork samples were prepared in the laboratory according to GB/T 20756-2006 [14] and frozen in the refrigerator.

2.3. Test Method

2.3.1. Instrument Working Conditions

Atomic absorption spectrometer instrument parameter conditionsReference instrument recommendation: lamp current 8 mA, wavelength 228.8 nm; the slit was 0.7 nm, no matrix modifier, injection volume 20 μL, deuterium lamp background; the drying stage of the graphite furnace heating program is uniform heating to 120˚C in 20 S, and the purification stage rapidly heats up to 1600˚C and maintains 3 S. The graphite furnace heating program was set after ashing and atomization optimization.

2.3.2. Sample Pretreatment

Pork samples were pre-digested at room temperature, 0.400 g was weighed in the digestion tube, and 5.00 mL of nitric acid was added. Microwave digestion of lead was carried out after optimization of microwave digestion temperature program [15]. The acid was removed to about 1 mL at 150˚C. The cold cut was added with 2 mL of pure water at room temperature. The acid was removed at 140˚C to a small drop, and the volume was fixed to 25 mL. At the same time, the reagent blank was made. This test solution can be used for graphite furnace-atomic absorption method to detect cadmium. The rice flour CFAPA-QC442B was used as the standard quality control product, and the test was repeated three times after the same pretreatment.

2.3.3. Matrix Standard Method

The cadmium standard solution was prepared by the solution obtained from the blank pork sample after pretreatment, and the working standard solution was prepared by gradually diluting each reserve standard solution, and the cadmium was 2 ng/mL; the blank pork sample was pre-treated to obtain a solution as a solvent to automatically match the working standard solution and put on the machine.

2.3.4. Three-Level Standard Addition Test

Three levels of low, medium and high concentrations of cadmium heavy metal elements were added to pork samples. The three addition levels were 30 μg/kg, 60 μg/kg and 100 μg/kg, respectively. Digestion, acid removal, constant volume, and on-line detection were performed according to the 1.3.2 sample pretreatment method, and each level concentration was repeated 6 times. After removing the difference, the mean value is taken to reflect the result. During the determination, the deuterium lamp deducts the background interference.

2.4. Statistical Methods

Cadmium content: The cadmium content in pork was calculated according to Formula (1). The undetected cadmium content was calculated according to half of the detection limit [16] [17] [18]. The detection limit was 1 μg/kg according to the national standard GB5009.15-2014 [12]. Below the detection limit is regarded as half of the detection limit of 0.5 μg/kg; the detection rate refers to the percentage of the number of detection results greater than or equal to the detection limit in the total number of test samples; the over-standard rate refers to the percentage of the number of detection results greater than or equal to the detection limit pollution limit value in the total number of detection samples; the limit of cadmium pollution was 100 μg/kg according to GB2762-2022 meat (except livestock and poultry viscera) [19].

Estimated daily intake (EDI): In 2019, the annual consumption of pork per capita was 20.3 kg [20], and the consumption time of pork was 365 days per year. It can be seen that the daily consumption of pork per capita in 2019 was 55.6 g/d, which is assumed to be the daily intake of pork per capita F_{IR}; according to the report on nutrition and chronic diseases of Chinese residents in 2015, the average weight of Chinese residents was 61.8 kg [21], and the dietary exposure (EDI) of cadmium and heavy metals in pork was calculated according to Formula (4).

Health risk analysis uses the Target Hazard Ouotient (THO) method: The THO method is a method established by the National Environmental Protection Agency in 2000 to evaluate the risk of non-carcinogenic pollutants [22] [23] [24]. THO method was used to evaluate the health risk of single heavy metal to exposed population. If the value is less than 1, it indicates that there is no obvious health risk in the exposed population, otherwise, there is a health risk [25]. The greater the value, the greater the health risk. The risk of single heavy metal is calculated according to Formula (5) [26].

The detection limit DL of the optimized method was calculated by the following Formula (2) [27]; the Nemerow index method (P_i) is a single factor pollution index method, and its evaluation model is such as Formula (3) [28] [29]. According to the Nemero single factor pollution index method, the pollution level is determined as **Table 1** [30]; JECFA 2010 set R_{FD} as the reference dose of 0.025 mg/(kg·month) [31], calculated by 30 days per month, and the converted reference value R_{FD} was 0.83 μg/(kg·d).

$$X = \left(C - C_0\right) \times V/W \tag{1}$$

$$\mathrm{DL} = 3 \times \mathrm{SD}/K \tag{2}$$

$$P_i = X/S_i \tag{3}$$

$$\mathrm{EDI}\left(\mu\mathrm{g}/\left(\mathrm{kg}\cdot\mathrm{d}\right)\right) = \frac{X \times F_{IR}}{1000 \times M} \tag{4}$$

$$\mathrm{THQ} = \frac{\mathrm{EDI}}{R_{FD}} \tag{5}$$

In Formulas (1) - (5): X: result / (μg/kg); C_0: blank concentration/(ng/mL); C: direct reading concentration/(ng/mL); V: constant volume/mL; W: sampling amount/g; the standard deviation of continuous measurement of 20 absorbance values of standard blank solution is SD, and the slope of standard working curve is K; P_i is the single factor pollution index of a metal element, and S_i is the evaluation standard value of heavy metal elements/(μg/kg). F_{IR} is the average dietary intake/(g/d); R_{FD} was the reference dose/(μg/(kg·d)). M is the average body weight/kg.

Table 1. Criteria for classification of heavy metal pollution.

Grade	Single factor pollution index classification standard	
	Pollution index	Pollution level
1	Pi ≤ 0.7	Excellent
2	0.7 ≤ Pi ≤ 1	Safety
3	1 ≤ Pi ≤ 2	Light pollution
4	2 ≤ Pi ≤ 3	Medium pollution
5	Pi ≥ 3	Heavy pollution

3. Results and Analysis

3.1. Microwave oven Digestion Program

In order to avoid violent reaction and better complete digestion, the whole digestion process is slowed down. The optimized microwave digestion temperature program is: climb to 120˚C in 12 min, keep 5 min; up to 160˚C in 7 min, keep 10 min; climb to 180˚C in 7 min and for 10 min.

3.2. Graphite Furnace Heating Process

The optimization of graphite furnace heating temperature program of cadmium is ashing stage and atomization stage. According to the temperature program of the drying stage and the purification stage recommended by the instrument, the atomization stage is set to 1500˚C, and the optimization of the ashing stage is optimized from 250˚C to 500˚C, increasing at 50˚C. The optimization results of the ashing stage are shown in **Figure 1**, and the temperature of the ashing stage is 250˚C. The optimization of the atomization stage is to set the heating program according to the recommended drying and purification stage. The ashing stage is optimized according to the optimized setting. The optimization of the atomization stage is optimized from the range of 1000˚C to 1700˚C, increasing at 50˚C. The optimization results of atomization stage are shown in **Figure 2**, and the optimum temperature of atomization is 1150˚C.

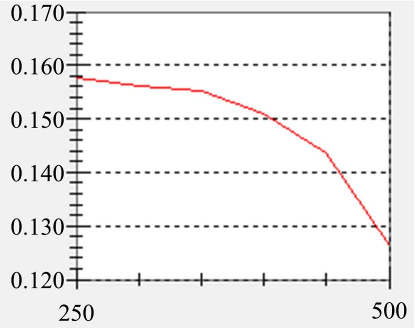

Figure 1. Optimization of the ashing stage (Note: horizontal and vertical is the temperature of heating, the unit is ˚C; the longitudinal axis represents the absorbance value).

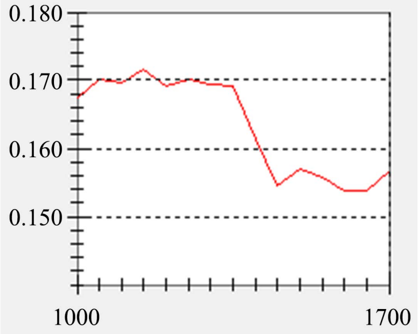

Figure 2. Optimization of the atomization stage (Note: horizontal and vertical is the temperature of heating, the unit is ˚C; the longitudinal axis represents the absorbance value).

The four-stage heating program of graphite furnace; drying is uniform heating to 120˚C in 20 S; ashing is uniform heating to 250˚C in 20 S and constant temperature for 13 S; atomization is rapid heating to 1150˚C and constant temperature for 3 s; purification is rapid heating to 1600˚C and constant temperature for 3 s.

3.3. Three Levels of Standard Addition Results and Quality Control Results

The results of three levels of standard addition are shown in **Table 2**. It can be seen from **Table 2** that the correlation coefficient of the standard curve is above 0.999, and the recovery rate is 96.9% - 107.1%. The coefficient of variation is 0.4% - 0.7%, which meets the requirements of the relevant standard GB/T 27404-2008 [27]; the detection limit is 0.68 μg/Kg, which is less than the national standard of 1 μg/Kg [12]. The standard value of cadmium was (248 - 286) μg/Kg, and the detection result was (268 ± 31.6) μg/Kg, with an average value of 268 μg/Kg, which was within the standard value range.

3.4. Characteristics of Cadmium Content in Pork

The cadmium content in pork is shown in **Table 3**. It can be seen from **Table 3** that the cadmium content in pork in 7 sampling sites from 2019 to 2020 ranged from (0.50 - 18.90) μg/kg, with an average of 3.05 μg/kg. The cadmium content of pork in these 7 places did not exceed the standard, 100% qualified; the detection rate ranged from 0.0% to 100%, and the order was: S5 > (S3 = S4) > S1 > S2 > S7 > S6.

According to the statistical analysis of the origin, the average and maximum values of cadmium content were ranked as follows:S5 > S3 > S4 > S1 > S2 > S7 > S6;the average content of cadmium: S6 minimum 0.5 μg/kg, S5 maximum 15.3 μg/kg; the maximum cadmium content: S6 minimum 0.5 μg/kg, S5 maximum 18.90 μg/kg; according to the minimum value of cadmium content, the order is S5 > (S3 = S4 = S1 = S2 = S7 = S6). Except that the highest value of S5 is 11.85 μg/kg, the other six regions are all 0.5 μg/kg. This is because these six regions are not detected, and it is calculated to be 0.5 μg/kg according to half of the detection limit. The maximum cadmium content of S5 pork was 18.90 μg/kg, which was far less than its pollution limit of 100 μg/kg [19]. Therefore, it can be inferred that the cadmium content of pork in these seven producing areas was 100% qualified.

According to the statistical analysis of the year, the average and maximum values of cadmium content were 2019 > 2020, and the average values of cadmium content in 2019 and 2020 were 4.06 μg/kg and 0.54 μg/kg respectively. The maximum cadmium content in 2019 and 2020 was 18.90 μg/kg and 1.30 μg/kg, respectively. The minimum value of cadmium content was 0.50 μg/kg in 2019 or 2020, which was not detected. It can be seen that the cadmium content of pork decreased from 2019 to 2020.

Table 2. Results of three-level mark-adding test (n = 6).

Standard addition concentration (μg/kg)	Background value (μg/kg)	Mean (μg/kg)	Recovery rate (%)	Coefficient of variation (%)	GB/T27404-2008 [27] (%)		Linear equation	Correlation r	Detection limit (μg/kg)
					Recovery rate	Coefficient of variation			
30	0	32.1	107.1	0.4	60 - 120	15 - 21	$Y = 0.36021X + 0.018416$	0.9991	0.684
60		61.3	102.2	0.7		15 - 21			
100		97.2	96.9	0.7		15 - 21			

Table 3. Characteristics of cadmium content in pork.

Origin/year	Number of samples	Cadmium content (μg/kg)			SD	Detection rate/%	Over standard rate/%
		Average value	Maximum value	Minimum value			
S1	10	1.20	2.35	0.50	0.71	60.0	0.0
S2	10	0.77	1.52	0.50	0.44	30.0	0.0
S3	10	1.75	5.19	0.50	1.38	70.0	0.0
S4	10	1.32	3.22	0.50	0.87	70.0	0.0
S5	10	15.25	18.90	11.85	2.10	100.0	0.0
S6	10	0.50	0.50	0.50	0.00	0.0	0.0
S7	10	0.58	1.30	0.50	0.25	10.0	0.0
2019	50	4.06	18.90	0.50	5.79	66.0	0.0
2020	20	0.54	1.30	0.50	0.18	5.0	0.0
2019-2020	70	3.05	18.90	0.50	5.13	48.6	0.0

3.5. Cadmium Exposure in Pork (EDI)

The cadmium exposure in pork is shown in Table 4. The average or maximum values of cadmium exposure in pork were S5 > S3 > S4 > S1 > S2 > S7 > S6. The average value of cadmium exposure: the highest S5 was 0.0137 μg/(kg·d); the lowest S6 was 0.0004 μg/(kg·d). The maximum value of cadmium exposure: the highest S5 was 0.0170 μg/(kg·d); the lowest S6 was 0.0004 μg/(kg·d). The order of the minimum value of cadmium exposure was S5 > (S3 = S4 = S1 = S2 = S7 = S6). Except that the maximum value of S5 was 0.0107 μg/(kg·d), the other six regions were 0.0004 μg/(kg·d). According to the statistical analysis of years, the average or maximum values of cadmium exposure in pork were ranked as 2019 > 2020. The average values of cadmium exposure in 2019 and 2020 were 0.0037 μg/(kg·d) and 0.0005 μg/(kg·d) respectively. The maximum values of cadmium exposure in 2019 and 2020 were 0.0170 μg/(kg·d) and 0.0012 μg/(kg·d) respectively. The minimum value of cadmium exposure was 0.0004 μg/(kg·d) in 2019 or 2020. It can be seen that the exposure of cadmium in pork is decreasing from 2019 to 2020.

Table 4. Cadmium exposure of pork.

Origin/year	Number of samples	EDI μg/(kg·d)		
		Average value	Maximum value	Minimum value
S1	10	0.0011	0.0021	0.0004
S2	10	0.0007	0.0014	0.0004
S3	10	0.0016	0.0047	0.0004
S4	10	0.0012	0.0029	0.0004
S5	10	0.0137	0.0170	0.0107
S6	10	0.0004	0.0004	0.0004
S7	10	0.0005	0.0012	0.0004
2019	50	0.0037	0.0170	0.0004
2020	20	0.0005	0.0012	0.0004
2019-2020	70	0.0027	0.0170	0.0004

3.6. Pollution Level of Cadmium in Pork and Its Intake Risk Assessment (THQ)

The pollution level and intake risk of cadmium in pork are shown in Table 5. It can be seen from Table 5 that the range of cadmium Nemerow index of pork in 7 sampling sites from 2019 to 2020 was 0.0050 - 0.1890. The intake risk THQ ranged from 0.0005 to 0.0204.

According to the statistical analysis of producing areas, the average or maximum values of Nemerow index and THQ value were ranked as follows: S5 > S3 > S4 > S1 > S2 > S7 > S6; the average value of Nemerow index: S6 lowest 0.0050, S5 highest 0.1525; the average THQ of intake risk: S6 minimum 0.0005, S5 maximum 0.0165; the maximum Nemerow index: S6 lowest 0.0050, S5 highest 0.1890; the maximum intake risk THQ: S6 minimum 0.0005, S5 maximum 0.0204. The order of the minimum values of the Nemerow index or the THQ value is S5 > (S3 = S4 = S1 = S2 = S7 = S6); the minimum value of Nemerow index is 0.1185 in S5 and 0.0050 in other regions. The minimum value of intake risk THQ: S5 is 0.0128, 0.0005 in other 6 areas. In summary, the maximum value of Nemerow index of cadmium pollution in S1 - S7 pork is S5, the highest is 0.1890, and its value is far less than 0.7. It can be seen that the cadmium pollution level of pork in these 7 areas is excellent. The highest THQ health risk S5 is 0.0204, and its value is far less than 1. It can be seen that there is no obvious intake risk of pork in these 7 places.

According to the statistical analysis of the year, the average and maximum values of the Nemerow index, the average and maximum values of THQ value are 2019 > 2020, and the average values of the Nemerow index in 2019 and 2020 are 0.0406 and 0.0054 respectively. The maximum values of the Nemerow index in 2019 and 2020 are 0.1890 and 0.0130 respectively; the minimum value of the Nemero index is 0.0050 in 2019 or in 2020. The average values of THQ in 2019

Table 5. Levels of cadmium contamination in pork and its health risks.

Origin/year	Pi				THQ			
	Average value	Maximum value	Minimum value	Pollution level	Average value	Maximum value	Minimum value	Health risks
S1	0.0120	0.0235	0.0050	Excellent	0.0013	0.0025	0.0005	no
S2	0.0077	0.0152	0.0050	Excellent	0.0008	0.0016	0.0005	no
S3	0.0175	0.0519	0.0050	Excellent	0.0019	0.0056	0.0005	no
S4	0.0132	0.0322	0.0050	Excellent	0.0014	0.0035	0.0005	no
S5	0.1525	0.1890	0.1185	Excellent	0.0165	0.0204	0.0128	no
S6	0.0050	0.0050	0.0050	Excellent	0.0005	0.0005	0.0005	no
S7	0.0058	0.0130	0.0050	Excellent	0.0006	0.0014	0.0005	no
2019	0.0406	0.1890	0.0050	Excellent	0.0044	0.0204	0.0005	no
2020	0.0054	0.0130	0.0050	Excellent	0.0006	0.0014	0.0005	no
2019 - 2020	0.0305	0.1890	0.0050	Excellent	0.0033	0.0204	0.0005	no

and 2020 were 0.0044 and 0.0006, respectively. The maximum values of THQ in 2019 and 2020 are 0.0204 and 0.0014, respectively. The minimum value of THQ is 0.0005 in 2019 or in 2020. It can be seen that the cadmium Nemerow index and THQ value of pork also showed a downward trend from 2019 to 2020. This shows that the cadmium content in pork has decreased steadily.

4. Discussions

4.1. Method Optimization

Optimization of inorganic pretreatment: In case of fat and protein in the pork, easy to violent reaction. Firstly, pre-digestion at room temperature was carried out, and then the microwave digestion procedure of lead in GB5009.12-2017 [15] was optimized to ensure that the microwave digestion was safe and complete. Secondary remove acid in order to obtain a clear and transparent digestion solution, reduce matrix interference.

The ashing stage and atomization stage are the most critical in the heating program of graphite furnace. In this study, the temperature search function of the instrument itself is used to optimize by the absorption value as the main reference. Due to the inevitable introduction of new impurities with the addition of matrix modifier, the matrix environment is more complex [32]. The preferred detection method in this study is the detection method without matrix modifier. The deuterium lamp background method is generally used in the wavelength range of 185 nm - 430 nm. The characteristic wavelength of cadmium is 228.8 nm, so the deuterium lamp background is selected.

4.2. The Characteristics of Cadmium Content in Pork and Its Health Risk

According to the test results of pork samples sold from 2019 to 2020, the cadmium content in pork is 100% qualified, the cadmium pollution level is excellent, and there is no health risk of cadmium intake in pork.

From the perspective of assessment methods: THQ is only a method of health risk assessment, and there are many other methods. According to the needs, a variety of assessment methods can be used to conduct a comprehensive and systematic assessment of its health risks to determine its potential health risks. Starting from the health risk of heavy metals in pork: the detection methods of other heavy metals in pork need to be established in order to comprehensively analyze the health risk of heavy metals ingestion. Similar studies have reported the comprehensive health risk of six heavy metals in strawberry [30]. From the perspective of people: the daily intake of a variety of foods, including staple foods, vegetables, fruits and meat, etc., requires a comprehensive analysis of the health risks of heavy metals in all food intakes in order to more comprehensively and objectively assess their health risks to the human body, similar to the study reported by Wei Junxiao [26].

5. Conclusion

5.1. The Optimized Graphite Furnace-Atomic Absorption Method Combined with Matrix Matching Method Can Achieve Accurate Detection of Cadmium in Pork

Optimize the graphite tube heating program: drying is uniform heating to 120˚C in 20 s; the ashing stage is divided into two parts, uniform heating to 250˚C in 20 s and constant temperature for 13 s; atomization is rapid heating to 1150˚C and constant temperature for 3 s; purification is rapid heating to 1600˚C and constant temperature for 3 s.

The optimized method: the detection limit is 0.684 μg/kg, and the detection limit of this method in the national standard GB5009.15-2014 [12] is 1 μg/kg, which meets the requirements and its detection limit is lower than the corresponding national standard. The recovery rate of the three levels was between 96% and 108%, and the accuracy was good. The coefficient of variation is 0.4% - 0.7%, and the precision is very good, which meets the requirements of GB/T 27404-2008 [27]. The optimized graphite furnace atomic absorption method realizes the accurate detection of cadmium in pork without a matrix modifier and deuterium lamp background.

5.2. From 2019 to 2020, the Cadmium Content in Pork Was 100% Qualified, the Pollution Index Was Rated as Excellent, It Was at a Safe Level, and There Was No Health Risk of Intake

The cadmium content in pork ranged from (0.5 - 18.9) μg/kg, which was less than the pollution limit of 100 μg/kg [19], 100% qualified; Pi is 0.0050 - 0.189, which is far less than 0.7, and the pollution level is excellent; the range of cadmium exposure in pork was (0.0004 - 0.0170) μg/(kg·d). The THQ value ranged from 0.0005 to 0.0204, and the THQ value was far less than 1, so there was no health risk of intake. The average or maximum values of cadmium content, Nemero pollution index, cadmium exposure and THQ were S5 > S3 > S4 > S1 > S2 > S7 > S6. In general, there was no health risk of cadmium intake in commercially available pork from 2019 to 2020.

Conflicts of Interest

The authors declare no conflicts of interest.

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