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Risk Evaluation of Pesticide Residue in Strawberries

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Abstract: In order to identify the types of pesticide residues and the maximum residue limit (MRLs) values in strawberries, the national estimated daily intake and short-term intake were used to assess the risk of pesticide residues in different populations, respectively. Meanwhile, the existing pesticide MRLs standard was used to evaluate the consumer protection level, and the risk ranking matrix was used to rank the risk of detected pesticides.The results showed that a total of 14 pesticides in all strawberries were detected with a detection rate of 4.5%~72.7%; of these, 1 exceeded their MRLs, which was found in 2.3% of the samples. However, there are pesticides that are not registered in Strawberries production but are used.In different age groups, the risk of chronic and acute dietary intake of Strawberries pesticide residues is less than 100%, and the risk is acceptable. The consumer protection level for chronic dietary risk (CPLc) of the existing pesticide MRLs for different age groups was 6.2~7254.4. It is greater than 1, so the risk protection has reached an acceptable level. The consumer protection level for acute dietary risk (CPLa) of the existing pesticide MRLs for different age groups was 0.3~1290.0. However, the risk is unacceptable. The CPLa of procymidone is less than 1 among children aged 2~4 years, women aged 18~30 years and 60~70 years. Moreover, the CPLa of pyraclostrobine ether ester is less than 1 among children aged 2~4 years. It is suggested that the MRL of procymidone and pyraclostrobine ether ester in Strawberries should be revised to 3.5 mg / kg and 1 mg / kg. According to the results of risk assessment, more attention should be focus on the pesticide residues of procymidone, acetamiprid, boscalid, pyraclostrobine, bifenazate, carbendazim, Imidacloprid, difenoconazole, triadimefon and chlorothalonil in Strawberries.

1. Introduction

China is the country with the largest distribution of strawberry species in the world, and also the country with the largest cultivated area and highest yield. In 2017, the planting area is about 403,000 hectares worldwide, and the annual output is about 8.783 million tons; among which, the planting area in China is about 141,300 hectares, with an annual output of about 3.753 million tons, accounting for about 42.7% of the global total output, and the output value exceeds 50 billion yuan [1]. Strawberry has become a favorite kind of fruit for people. However, the strawberry will be affected by gray mold, powdery mildew, leaf spot, aphid, red spider and other diseases and pests in the growing process [2,3]. If it is not controlled, the quality and yield of strawberry will be seriously

affected. At present, the most effective control method is chemical pesticide. If the use of a large amount of chemical pesticides is not properly managed, there will lead to food safety risks. With the increase of the consumption of fresh strawberries, the potential health risks have been paid more and more attention. Therefore, a comprehensive investigation and analysis of pesticide residues in strawberries is of great significance for understanding the dietary risk of strawberries, the safe use of drugs and supervision.

The species and concentration of pesticide residues in strawberries not only affect the quality and safety level of strawberries, but also are the main factors restricting the quality of strawberries. Through risk analysis, we can understand the use of strawberry pesticide, find out the pesticide with the most risk in strawberry, and then focus on its supervision, which can improve the supervision efficiency to a great extent. There are also some differences in residual pesticides in strawberry production areas. So far, there is no report on pesticide residue and risk assessment of strawberry in a city.

In this paper, through the detection and evaluation of strawberry samples, we understand the main pesticide residues in strawberry and the pesticides that need to be paid attention to, so as to provide certain reference and basis for the safe production, consumption and quality safety supervision of strawberry.

2. Materials and Methods

2.1. Source of Sample

In the mature period of strawberry market in 2020, 44 batches of fresh strawberries were collected according to NY/T 789-2004 Guideline on Sampling for Pesticide Residue Analysis [4]. The pesticide residues commonly used in strawberries were tested, and 18 kinds of pesticides were detected this time.

2.2. Instruments and Reagents

Agilent 7890B-7000C gas chromatography-mass spectrometer and Agilent 1290-G6460 ultra-high pressure liquid chromatography-mass spectrometry (Agilent Technologies Co., Ltd.); BS210S electronic balance (Sartorius Company, Germany); AS10200B ultrasonic cleaner (Tianjin Automatic Science Instrument Co., Ltd.); Milli-Q ultrapure water preparation system (Millipore (China) Co., Ltd.); WX-80A vortex mixer (Haimen KYlin-Bell Lab Instruments Co., Ltd.); JHD-12E nitrogen blower (Shanghai Jiheng Industrial Co., Ltd.); SIGM-3-18K High Speed Refrigeration Centrifuge (SIGMA-ALDRICH (SHANGHAI) Trading Co., Ltd.).

Pesticide standard, Environmental Quality Supervision, Inspection and Testing Center of Ministry of Agriculture (Tianjin); acetonitrile (chromatographically pure), acetone (chromatographically pure), Thermo Fisher Scientific Co., Ltd.; other reagents, Chengdu Kelong Chemical Reagent Factory. Test water was prepared from Milli-Q ultrapure water purifier.

2.3. Experimental Method

2.3.1. Risk Assessment Method

(1) Risk Assessment Methods for Chronic Dietary Intake [5]

$$\text{NEDI} = \frac{STMR \times F}{m} \quad (1)$$

In the formula, NEDI is national estimated daily intake, μg/kg m_b, STMR is the median residue

of strawberry in standard experiment, mg/kg, taking the average residue value of this experiment; F is strawberry consumption (g/d); m is standard body weight of different populations, kg.

The risk of chronic dietary intake is expressed by the risk quotient RQ_{ADI} and is calculated as follows.

$$RQ_{ADI} = \frac{NEDI}{ADI} \times 100\% \quad (2)$$

When $RQ_{ADI} \leq 100\%$, indicates that the chronic health risk is acceptable. The smaller the RQ_{ADI}, the smaller the risk; otherwise, the higher the risk.

(2) Acute dietary intake risk assessment methods [6]

$$NESTI = \frac{Lp \times HR}{m} \quad (3)$$

In the formula, NESTI is the national estimated short-term intake, HR is the maximum residual amount of pesticide kinds detected in strawberry samples, mg/kg; Lp is the daily consumption of large meals of strawberry, calculated with the daily large intake of fruit, kg/d.

The risk of acute dietary intake is represented by the risk quotient RQ_{ARfD} [7] and the safety margin (SM, mg/kg) for each residual pesticide is calculated as follows.

$$RQ_{ARfD} = \frac{NESTI}{ARfD} \times 100\% \quad (4)$$

$$SM = \frac{ARfD \times m}{Ue \times v + Lp - Ue} \quad (5)$$

In the formula, Ue is the single mass of the product calculated as the edible part, and the single mass of strawberry is about 15-50 g, which values 30 g; ARfD is the acute reference dose, mg/kg mb; v is the variation factor, generally valued as 3.

When $RQ_{ARfD} \leq 100\%$, indicates that the acute risk is acceptable. The smaller the RQ_{ARfD}, the smaller the risk; otherwise, the higher the risk. When pesticide residues in the product are within the safety margin, the acute risk is acceptable; otherwise, there is an unacceptable acute risk [8].

2.3.2. Assessment of Consumer Protection by Existing MRL Standards

(1) Assessment of consumer protection for chronic risks of long-term intake [9]

The theoretical maximum daily intake (TMDI, μg/kg m_b) is calculated by Equation (6). The chronic risk protection level (CPLc) of the existing MRL standard for consumers is expressed as the quotient of ADI and TMDI of the risk factor. The calculation formula is as follows.

$$TMDI = \frac{MRL \times F}{m} \quad (6)$$

$$CPLc = \frac{ADI}{TMDI} \quad (7)$$

In the formula, MRL is the maximum residue limit of pesticide, mg/kg.

When $CPLc \geq 1$, it indicates that the current MRL standard has an acceptable level of protection for consumers in terms of chronic intake risk. The larger the CPLc, the higher the protection level; conversely, the smaller the CPLc, the lower the protection level [10].

(2) Assessment of consumer protection level for acute risk of short-term intake

The theoretical maximum short-term intake (TMSTI, μg/kg m_b) and the acute risk protection level (CPLa) for the consumer were calculated using the following formula when the individual mass of the product was greater than 25 g but less than the large meal.

$$TMSTI = \frac{MRL \times Ue \times v + (Lp - Ue) \times MRL}{m} \quad (8)$$

$$\mathrm{CPLa} = \frac{ARfD}{TMSTI} \tag{9}$$

When CPLa≥1, it indicates that the current MRL standard has an acceptable level of protection for consumers in terms of acute intake risk. The larger the CPLa, the higher the protection level; conversely, the smaller the CPLa, the lower the protection level.

2.3.3. Risk Ranking Method

The risk ranking of pesticide residues in strawberries is conducted according to the risk ranking matrix and carries out according to the risk ranking index assignment standard [11]. The pesticide use frequency (FOD) and the residual risk score (S) of each pesticide in the sample are calculated according to the following formula. The residual risk score of each pesticide is calculated as the average value of the residual risk score of the pesticide in all samples. The higher the value is, the greater the residual risk is [12].

$$\mathrm{FOD}(\%) = \frac{T}{P} \times 100\% \tag{10}$$

$$\mathrm{S} = (A + B) \times (C + D + E + F) \tag{11}$$

$$\mathrm{RI} = \sum_{i=1}^{n} S_i - TS_0 \tag{12}$$

In the formula, T refers to the number of times of pesticide use in fruit growth period; P refers to fruit growth period/d; A refers to toxicity (half refers to lethal dose) score; B refers to toxicity (ADI) score; C refers to dietary proportion (percentage of food in total diet of residents); D refers to pesticide use frequency score; E refers to score of high exposed population; F refers to residual level score. n is the pesticide detected, the unit is species; TS0 is the sum of the residual risk scores of the samples for which n pesticides are not detected. The residual risk scores of each of the n pesticides are calculated by Formula (7) and summed up.

3. Results and Discussion

3.1. General Condition of Pesticide Detection in Strawberry

Pesticide residues were detected in 43 of 44 strawberry samples, accounting for 97.7% of the total samples. Carbendazim residue in 1 sample exceeded the standard, accounting for 2.3% (see Table 1). Strawberry is easy to suffer from downy mildew, gray mold, spot blight, powdery mildew, anthracnose, leaf mold, verticillium wilt, root rot, aphid, red spider, and other diseases and insect pests in the growth process of strawberry. In order to reduce the loss, many types and large amounts of pesticides are used in the process of growth and development, which may lead to potential safety risks.

Table 1: Detection of Strawberry Samples

samples/piece	checked out/piece	exceeding standard/piece	Detection rate/%	Exceeding rate/%
44	43	1	97.7%	2.3%

The detection results of strawberry pesticide residues in a city are shown in Table 2, and 18 pesticide parameters are detected in 44 samples, of which 14 pesticides are detected. The detection rate of each pesticide in strawberry ranged from 4.5% to 72.7%, and the detection rate of procymidone was the highest (72.7%).

Only 34 kinds of pesticides have been registered and allowed to be used in strawberry production in China, and 174 kinds of pesticides with maximum residue limit (MRL) of pesticides have been established (GB 2763-2021) [13]. According to the detection results, 10 pesticides out of 18

pesticides have not been registered on strawberries, including the most detected procymidone and carbendazim [14].

It can be seen from Figure 1 that the samples with multiple pesticide residues (more than 2 pesticide residues detected) account for 81.8% of the total samples; the proportion of samples with 2 pesticide residues detected in the same sample is the highest (27.3%) and the proportion of 8 pesticide residues detected in the same sample is the lowest with 2.3% (only one sample). According to GB 2763-2021, the qualified rate of strawberry sample is 97.7%. The pesticide exceeding the standard is carbendazim, and the exceeding rate is 2.3%.

Table 2: Results of Pesticide Residues in Strawberry Samples

Detect out pesticide	Toxicity	Samples detected (pcs.)	Maximum residue limit (mg/kg)	Max. test value (mg/kg)	Detection Median (mg/kg)	Average value of test (mg/kg)	Detection rate (%)	Out-of-specification rate (%)
Procymidone	Low	32	10	1.18	0.19	0.29	72.7	0
Pyrimethanil	Low	21	7	0.80	0.09	0.18	47.7	0
Boscalid	Low	18	3	0.90	0.11	0.23	40.9	0
Pyraclostrobin	Low	15	2	1.04	0.14	0.26	34.1	0
Bifenazate	Low	13	2	0.40	0.10	0.12	29.5	0
Azoxystrobin	Low	5	10	0.23	0.04	0.09	11.4	0
Difenoconazole	Low	4	1	0.044	0.024	0.027	9.1	0
Triazolone	High	3	0.7	0.043	0.037	0.034	6.8	0
Kresoxim-methyl	Low	3	2	0.61	0.51	0.44	6.8	0
Dimethomorph	Low	3	0.05	0.010	0.009	0.009	6.8	0
Carbendazim	Low	3	0.5	1.32	0.17	0.32	6.8	2.3
Chlorothalonil	Low toxicity	2	5	0.018	0.014	0.014	4.5	0
Acetamiprid	Poisoning	2	2	0.065	0.056	0.044	4.5	0
Imidacloprid	Low	2	0.5	0.173	0.046	0.072	4.5	0

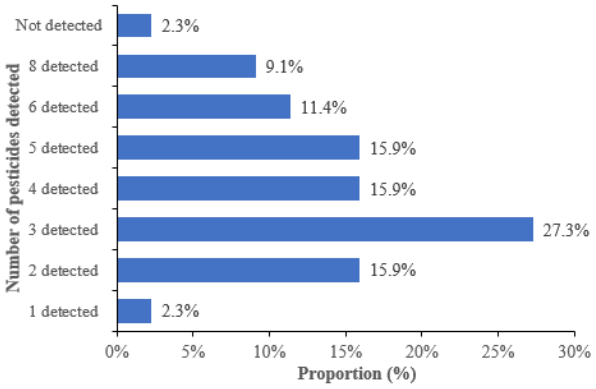

Figure 1: Detection of pesticide species in the same strawberry sample

3.2. Risk Analysis of Strawberry Chronic Dietary Intake

As can be seen from Figure 2, the RQ_{ADI} of chronic dietary risk quotient of all exposed groups in strawberry was lower than 100%, indicating that the risk of chronic dietary intake of 18 pesticide residues in strawberry was acceptable. Among the different exposure assessment populations, the risk of female was higher than that of male, and the dietary risk decreased with the increase of age. The risk of 2-4 years old population was about 4 times higher than that of other assessment populations, which was related to the difference of dietary proportion structure at different age stages and different genders [15].

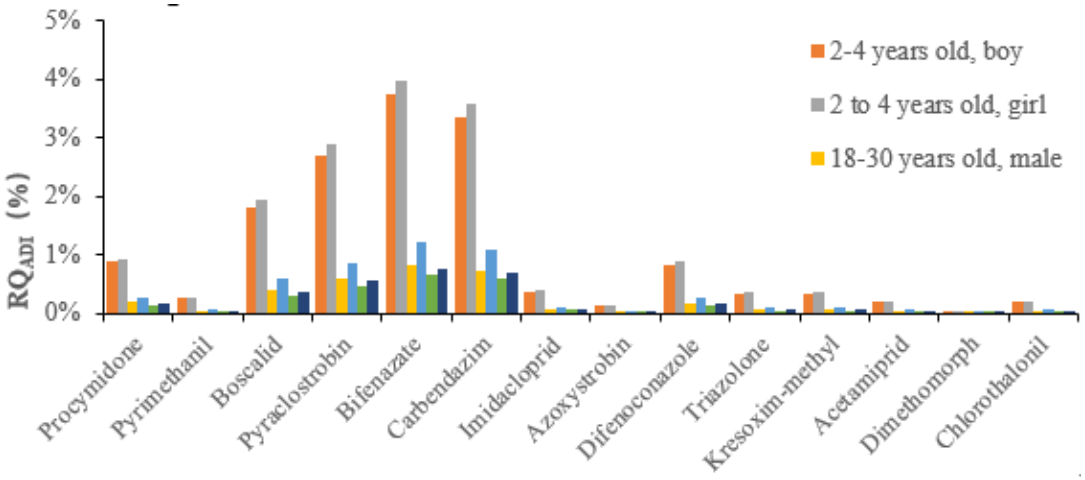

Figure 2: Chronic Dietary Risk of Different Pesticides in Strawberry by Exposure Assessment Population

3.3. Risk Analysis of Acute Dietary Intake of Strawberry

Of the 14 detected pesticides, ARfD values were not required for 5 pesticides, and only 9 pesticides with ARfD values were assessed for acute dietary risk [16]. As can be seen from Figure 3, the acute dietary risk quotient RQ_{ARfD} in strawberries was below 100% for all exposure assessment populations, indicating an acceptable risk of acute dietary intake of 18 pesticide residues in strawberries. Among the different exposure assessment populations, the risk of female is higher than that of male, and the risk of 2-4 years old population is about 3 times higher than that of other assessment populations. The risk quotient RQ_{ARfD} of 18~30 years old and 60~70 years old is basically similar, which is related to the difference of dietary proportion structure in different age stages and different genders [17].

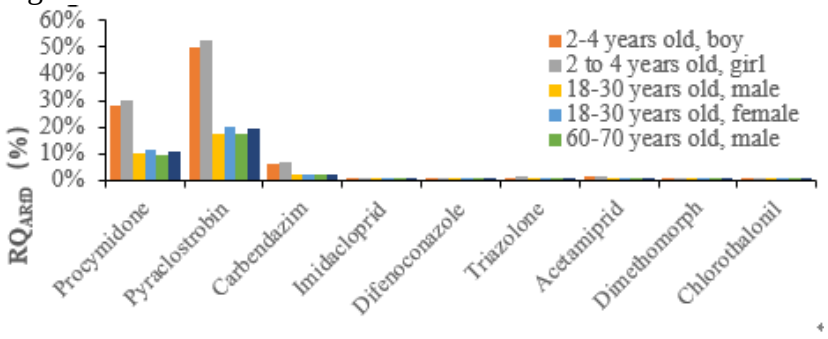

Figure 3: Acute Dietary Risk for Different Pesticides in Strawberry by Exposure Assessment Population

It can be seen from Figure 4 that the risk factor RQ_{ARfD} of the two-to-four-year-old population is about three times lower than that of other assessment populations in different exposure assessment populations, and the risk quotient RQARfD is basically similar in the period of 18 to 30 years and 60 to 70 years, which is related to the difference of dietary proportion structure and tolerance in different age stages and genders. The safety limit SM of procymidone, pyraclostrobin, triadimefon and acetamiprid in strawberry is far lower than that of the other 5 pesticides, which requires long-term attention in daily monitoring [18, 19]. Although the safety margin SM of carbendazim is high, the risk of chronic diet and acute diet is also high, which may be related to the exceeding standard of carbendazim in this test.

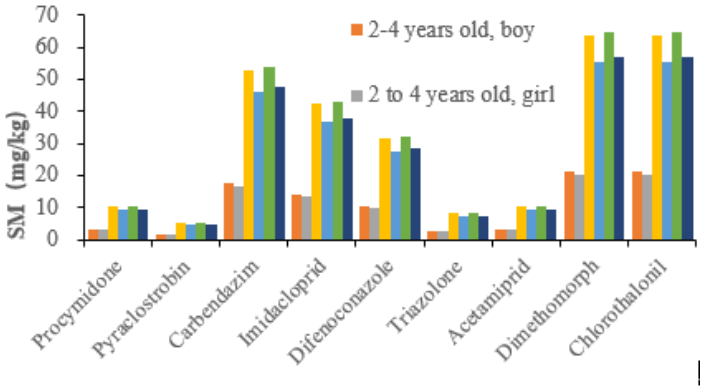

Figure 4: Safety Limits SM for Different Pesticides in Strawberry by Exposure Assessment Population

3.4. Risk Ranking of Pesticide Residues in Strawberry and Analysis of Sample Risk Index

The ADI is derived from GB 2763-2021 and assigned according to the assignment criteria. The intake of strawberry was replaced by the intake of fruits and consumption, accounting for 2.5%～20% of the total diet of residents. The score of diet was 1. The pesticide use frequency is assigned to 1. This risk ranking takes into account the difference of the exposure population, and the score is 2. The risk ranking of 14 pesticides detected in strawberries was carried out with reference to the risk ranking formula proposed by the British Veterinary Association [20].

The risk ranking scores of 14 pesticides in strawberry are shown in Figure 5. The 14 pesticides in this evaluation are divided into 2 categories, including 10 high-risk pesticides and 4 medium-risk pesticides. Acetamiprid has the highest risk ranking, which is related to its moderate toxicity. Although the rest of the pesticides are all low toxicity, the risk ranking is high due to the prevalence of use and high residues. Therefore, it is necessary to strengthen the daily supervision and follow-up of strawberry drugs to ensure that the quality and safety risks of strawberries are controlled [21].

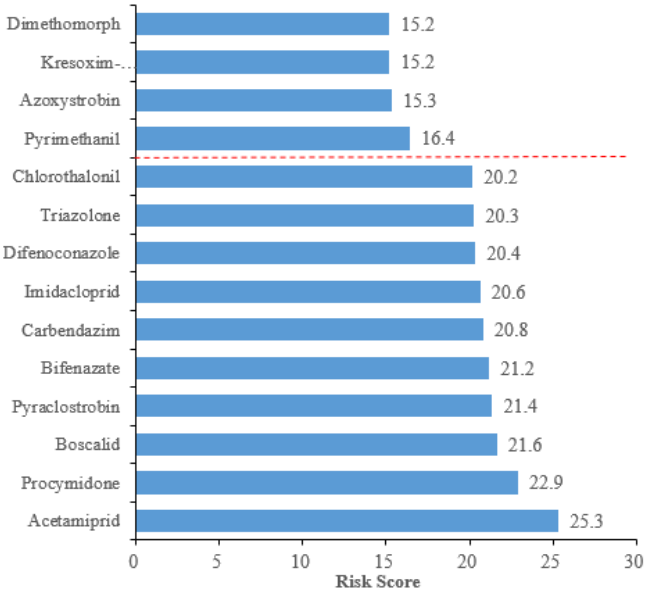

Figure 5: Residual risk ranking of 14 detected pesticides in strawberries

Calculate the respective pesticide residue risk index (RI) for each strawberry sample using

Equation (11). Taking 5 as RI difference, strawberry samples can be divided into 4 categories, the first category is high risk samples, RI≥15, the second category is medium risk samples, RI<15-10, the third category is low risk samples, RI<10-5, the fourth category is very low risk samples, RI<5. It can be seen from Figure 6 that the low risk accounts for 61.3%, the high risk is 38.6%, and the pesticide residue risk is high. It is necessary to strengthen the daily supervision and follow-up of strawberry usage of pesticide.

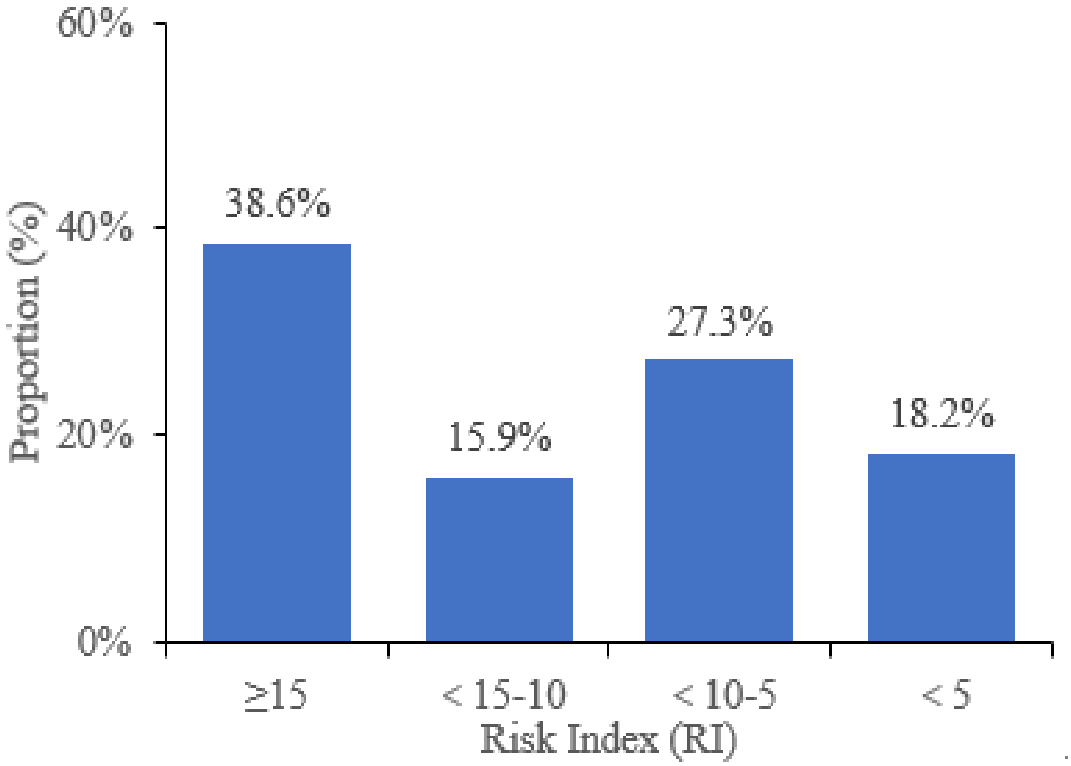

Figure 6: Distribution of pesticide residue risk index of strawberry samples

3.5. Assessment of Consumer Protection Level by Existing MRLs Values

The MRLs value of GB 2763-2021 was used to assess the protection level (CPLc) of the risk of dietary exposure to consumers.

3.5.1. Assessment of Chronic Exposure Risk on Consumer Protection Level

As can be seen from Table 3 that among the 18 pesticides tested in strawberry samples in China, the TMDI range is 0.06~33.13 μg/kg mb and the CPLc is 1.2~1290.6 in the population aged 2-4 years in China; the TMDI range is 0.01~10.06 μg/kg mb and the CPLc is 4.0~5789.5 in the population aged 18~30 years; the TMDI range is 0.01-6.41 μg/kg mb and the CPLc is 6.2~7254.4 in the population aged 60-70 years; the CPLc value of all exposure assessment populations is >1. Indicating that the MRL value of the pesticide in strawberries provides an acceptable level of protection for consumers with regard to the risk of chronic ingestion. There are age and gender differences in the level of protection. The level of protection for males is higher than that for females; with the increase of age, the value of CPLc increased and the protection level increased. This may be related to individual differences in age, sex, dietary ratio and tolerance [22].

Table 3: Theoretical maximum daily intake of different pesticides in strawberries (TMDI (ug/kg)) and chronic risk protection level (CPLc)

Detect out pesticide	2-4 years old, boy		2 to 4 years old, girl		18-30 years old, male		18-30 years old, female		60-70 years old, male		60-70 years old, female	
	TMDI	CPLc	TMDI	CPLc	TMDI	CPLc	TMD	CPLc	TMDI	CPLc	TMDI	CPLc
Chlorothalonil	15.50	1.3	16.57	1.2	3.45	5.8	5.03	4.0	2.76	7.3	3.20	6.2
Bifenazate	6.20	1.6	6.63	1.5	1.38	7.2	2.01	5.0	1.10	9.1	1.28	7.8
Difenoconazole	3.10	3.2	3.31	3.0	0.69	14.5	1.01	9.9	0.55	18.1	0.64	15.6
Bifenthrin	3.10	3.2	3.31	3.0	0.69	14.5	1.01	9.9	0.55	18.1	0.64	15.6
Procymidone	30.99	3.2	33.13	3.0	6.91	14.5	10.06	9.9	5.51	18.1	6.41	15.6
Boscalid	9.30	4.3	9.94	4.0	2.07	19.3	3.02	13.3	1.65	24.2	1.92	20.8
Pyraclostrobin	6.20	4.8	6.63	4.5	1.38	21.7	2.01	14.9	1.10	27.2	1.28	23.4
Omethoate	0.06	4.8	0.07	4.5	0.01	21.7	0.02	14.9	0.01	27.2	0.01	23.4
Azoxystrobin	30.99	6.5	33.13	6.0	6.91	28.9	10.06	19.9	5.51	36.3	6.41	31.2
Pyrimethanil	21.70	9.2	23.19	8.6	4.84	41.4	7.04	28.4	3.86	51.8	4.49	44.6
Acetamiprid	6.20	11.3	6.63	10.6	1.38	50.7	2.01	34.8	1.10	63.5	1.28	54.6
Triazolone	2.17	13.8	2.32	12.9	0.48	62.0	0.70	42.6	0.39	77.7	0.45	66.9
Carbofuran	0.06	16.1	0.07	15.1	0.01	72.4	0.02	49.7	0.01	90.7	0.01	78.0
Carbendazim	1.55	19.4	1.66	18.1	0.35	86.8	0.50	59.7	0.28	108.8	0.32	93.6
Avermectin	0.06	32.3	0.07	30.2	0.01	144.7	0.02	99.4	0.01	181.4	0.01	156.0
Imidacloprid	1.55	38.7	1.66	36.2	0.35	173.7	0.50	119.3	0.28	217.6	0.32	187.2
Kresoxim-methyl	6.20	64.5	6.63	60.4	1.38	289.5	2.01	198.9	1.10	362.7	1.28	312.1
Dimethomorph	0.15	1290.6	0.17	1207.2	0.03	5789.5	0.05	3977.3	0.03	7254.4	0.03	6241.4

3.5.2. Assessment of Consumer Protection Level of Acute Exposure Risk

Table 4: Theoretical Maximum Short-term Intake of Different Pesticides in Strawberry (TMSTI (ug/kg)) and Consumer Protection Level for Acute Dietary Risk (CPLa)

Detect out pesticide	2-4 years old, boy		2 to 4 years old, girl		18-30 years old, male		18-30 years old, female		60-70 years old, male		60-70 years old, female	
	TMSTI	CPLa	TMSTI	CPLa	TMSTI	CPLa	TMSTI	CPLa	TMSTI	CPLa	TMSTI	CPLa
Procymidone	283.26	0.4	298.06	0.3	94.25	1.1	108.41	0.9	93.02	1.1	105.01	0.95
Pyraclostrobin	56.65	0.9	59.61	0.8	18.85	2.7	21.68	2.3	18.60	2.7	21.00	2.4
Carbofuran	0.57	1.8	0.60	1.7	0.19	5.3	0.22	4.6	0.19	5.4	0.21	4.8
Acetamiprid	56.65	1.8	59.61	1.7	18.85	5.3	21.68	4.6	18.60	5.4	21.00	4.8
Triazolone	19.83	4.0	20.86	3.8	6.60	12.1	7.59	10.5	6.51	12.3	7.35	10.9
Chlorothalonil	141.63	4.2	149.03	4.0	47.13	12.7	54.20	11.1	46.51	12.9	52.51	11.4
Avermectin	0.57	5.3	0.60	5.0	0.19	15.9	0.22	13.8	0.19	16.1	0.21	14.3
Difenoconazol	28.33	10.6	29.81	10.1	9.43	31.8	10.84	27.7	9.30	32.3	10.50	28.6
Imidacloprid	14.16	28.2	14.90	26.8	4.71	84.9	5.42	73.8	4.65	86.0	5.25	76.2
Carbendazim	14.16	35.3	14.90	33.6	4.71	106.1	5.42	92.2	4.65	107.5	5.25	95.2
Dimethomorph	1.42	423.6	1.49	402.6	0.47	1273.2	0.54	1106.9	0.47	1290.0	0.53	1142.7
Bifenthrin	28.33	/	29.81	/	9.43	/	10.84	/	9.30	/	10.50	/
Omethoate	0.57	/	0.60	/	0.19	/	0.22	/	0.19	/	0.21	/
Pyrimethanil	198.28	/	208.64	/	65.98	/	75.89	/	65.12	/	73.51	/
Boscalid	84.98	/	89.42	/	28.28	/	32.52	/	27.91	/	31.50	/
Bifenazate	56.65	/	59.61	/	18.85	/	21.68	/	18.60	/	21.00	/
Azoxystrobin	283.26	/	298.06	/	94.25	/	108.41	/	93.02	/	105.01	/
Kresoxim-methy	56.65	/	59.61	/	18.85	/	21.68	/	18.60	/	21.00	/

Note: *ARfD value is not established for this pesticide, **ARfD value of this pesticide is not required; neither has CPLa.

As can be seen from Table 4 that among the 18 pesticides tested in strawberry samples, 2

pesticides have no ARfD value and 5 pesticides are not required for ARfD value. In China, the TMSTI ranges from 0.57 to 298.06 μg/kg mb and CPLa ranges from 0.3 to 423.6 in the population aged 2 to 4; the TMST ranges from 0.19 to 108.4 μg/kg mb and the CPLa ranges from 0.9 to 1273.2 in the population aged from 18 to 30 years old; the TMSTI ranges from 0.19 to 105.01 μg/kg mb and the CPLa ranges from 1.0 to 1290.0 in the population aged from 60 to 70 years; the CPLa values of the rest pesticide exposure assessment populations are >1, except for procymidone and pyraclostrobin. Indicating that the MRL value of the pesticide in strawberries provides an acceptable level of protection for consumers with respect to the risk of acute ingestion. There are age and gender differences in the level of protection. The level of protection for males is higher than that for females; With the increase of age, the CPLa value increased and the protection level increased, but the difference of CPLa value between 18~30 years old and 60~70 years old was not significant. This may be related to individual differences in age and gender, dietary proportion, tolerance, but the risk of acute intake tends to be consistent with age to some extent [23]. In our country, CPLa values of male and female aged 2~4 years were less than 1, and CPLa values of procymidone and pyraclostrobin were less than 1 for women aged 18~30 and 60~70 years. Therefore, long-term attention should be paid to procymidone and pyraclostrobin in daily monitoring. It is suggested that the current MRL standard of procymidone and pyraclostrobin in strawberries should be adjusted to 3.5 mg/kg and 1 mg/kg. The MRL value can achieve an acceptable level of protection of acute intake risk for consumers of all ages.

4. Conclusion

(1) Status of pesticide residues in strawberries. The qualified rate of 18 pesticide residues in strawberry samples was 97.7%. Only one sample of carbendazim exceeded the standard. The detection rate of pesticides was 97.7%, in which 81.8% of the samples were multi-residue samples. The detection rate of pesticide residues of different varieties was 4.5%~72.7%. Among the pesticides with high detection rate, pythium chloride, pyrimethanil, boscalid, pyraclostrobin, bifenazate and azoxystrobin were all low toxicity pesticides, and the residues were also low.

(2) Risk assessment of pesticide residues in strawberries. RQ_{ADI} and RQ_{ARfD} were below 100% for all exposure assessment populations in strawberries. However, in different exposure assessment populations, there is a relationship between female and male risk, the risk of female was higher than that of male. The risk of 2-4 years old was higher than that of other assessment populations, which was related to the difference of dietary proportion structure in different age groups and different genders.

(3) The protection level of current MRL for consumers should consider the adaptability to different age group. The existing MRL standard of procymidone and pyraclostrobin at 10 mg/kg and 2 mg/kg can be adjusted to 3.5 mg/kg and 1 mg/kg.

(4) According to the results of risk ranking and risk index, the overall risk level of pesticide residue in strawberry is good, but it needs to strengthen the monitoring and regulation, and rational and standardized use of pesticides to ensure that the risk is controllable.

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