Fluoride in Chilies from Southwestern China

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The purpose of this research is to investigate the fluoride contents in the chilies from southwest China and other countries in order to calculate the difference in fluoride levels in the fresh chilies. The standard method in China for analysis of fluoride in food (GB/T 5009.18-2003) was applied to determinate the fluoride content in chilies. By determining the fluoride content in 176 fresh chili samples from 77 counties in southwest China and 31 chili samples from other countries, the research not only aims to find the regularity of fluoride distribution in fresh chili, but also to determine the origin of fluoride in fresh chili in China compared with the foreign samples. The geometric mean of fluoride content in the fresh chili was 8.9 mg kg^{-1} (dry weight, 176 samples, confidence level: 95%). According to the study on the contents of fluoride in fresh chili, it seems that the fluoride content standard for vegetables in GB2762-2005 in China is inappropriate for chili, and 24.7 mg kg^{-1}(dry weight) and 5.2 mg kg^{-1} (fresh weight) in recommend as the fluoride contaminated discrimination values for fresh chili.

Key words: **chili; fluoride content; pollution discrimination**

Introduction

Fluoride is an essential trace element in humans, and fluoride insufficiency may cause dental problems. However, excessive fluoride may lead to fluorosis, manifested as dental fluorosis and skeletal fluorosis. According to the hygienic standard for total daily fluoride intake (WS/T87-1996), the safe fluoride daily intake for an adult is 3.5 mg, while WHO recommends 2.0 mg.[1,2]

Chili (*Capsicum*), which is native to Central and South America, was introduced into China in the late Ming dynasty. It has become an indispensable vegetable and condiment, and is also used as a drug plant.[3] Some studies show that the fluoride content in chili is related to the detection rate of moderate fluorosis.[4] Fluoride in chili may even be the main factor causing fluorosis in some regions.[5] There are many researchers determining the content of fluoride in some endemic areas, which ranges from 1.7 mg kg^{-1} to 195.0 mg kg^{-1}.[6–13] However, there is little research on the fluoride content of fresh chilies and the factors that influence its content. Therefore, there is no international hygienic standard for fluoride content in chili.

Southwest China is not only the region with the most serious fluorosis from coal-burning pollution,[1] but is also one of the best places for growing chili in China. By determining the fluoride content in 176 fresh chili samples from 77 counties in southwest China and 31 fresh chili samples from other countries, this research not only aims to determine the regularity of fluoride distribution in fresh chili, but also to determine the origin of fluoride in fresh chili compared with the foreign samples.

Methods

Sample Collection

Fresh chili and soil samples were collected from farmlands and markets of 77 counties

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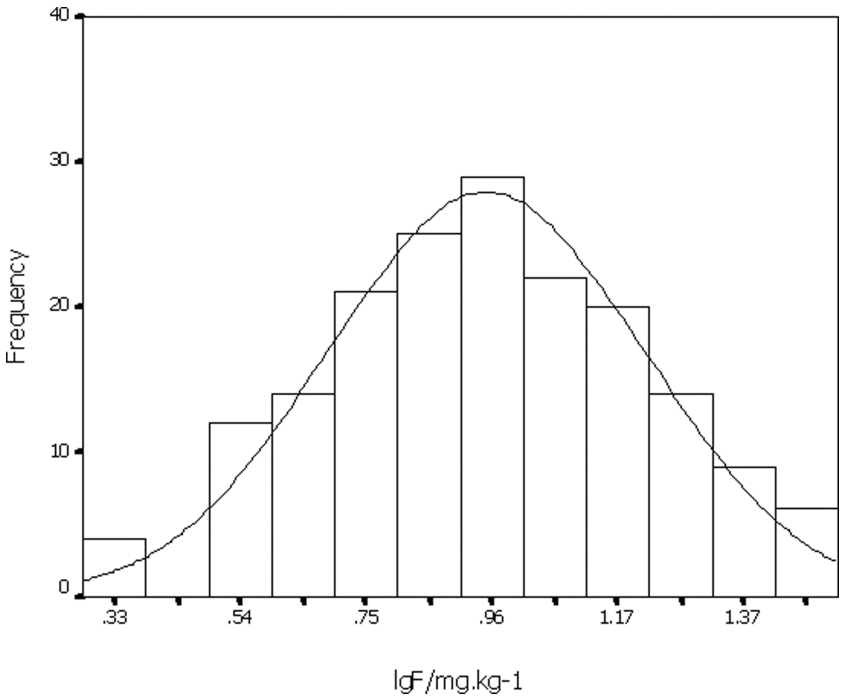

Figure 1. The distribution of fluoride content in fresh chilies.

in southwest China during the harvest season (August to December). In order to avoid fluoride contamination, the fresh chilies were sealed in plastic bags and washed before dehydration and crushing. The soil was dried naturally before removing debris and the sample ground to less than 100 mesh for analysis. The chili samples collected from the supermarkets and grocery stores from aboard were sealed in packages.

Determination

In this research, the standard method for analysis of fluoride in food (GB/T 5009.18-2003) and the standard method for analysis of fluoride in coal and soil (WS/T88-1996) were applied to determinate the fluoride content in chili and soil, respectively. The quality-control results were all in accord with the accuracy required in the experiments. The results from duplicate samples were within 10% of the mean to ensure precision.

Results

Fluoride Content in Fresh Chili of China

In order to investigate the fluoride content and the distribution of fluoride levels in fresh chili from China, 176 fresh samples were collected and analyzed. Figure 1 represents the logarithmic normal distribution of fluorine content in fresh chili. This normal distribution suggests that the geometric mean is appropriate for appraising of fluoride level. The fluoride content in fresh chilies ranges from 1.9 mg kg^{-1} to 32.0 mg kg^{-1}, with an arithmetic mean of 10.6 mg kg^{-1} and a geometric mean of 8.9 mg kg^{-1}.

Fluoride Content in Fresh Chili in China and Abroad

Table 1 shows the distributed sectors of fluoride content in fresh chili from China and abroad. The geometrical mean of fluorine content in fresh chili in China is 8.9 mg kg^{-1},

TABLE 1. The Distributed Sectors of Fluoride Content in Fresh Chilies in China and Abroad[a]

	Scope/mg kg^{-1} (dry weight)								
	1.0∼2.0	2.0∼5.0 (%)	5.0∼10.0 (%)	10.0∼20.0 (%)	20.0∼30.0 (%)	>30.0 (%)	Arithmetic mean	Geometric mean	Sample No.
China	0.57	18.18	38.64	32.95	7.95	1.70	10.6	8.9	176
Foreign		48.00	52.00				5.1	4.8	31

[a]The fluorine content was measured in mg kg^{-1} (dry weight).

TABLE 2. Fluoride Content in the Fresh Chili of Different Varieties[a]

Variety	Scope	Arithmetic mean	Geometric mean	Sample number
Cherry pepper	7.1∼28.0	12.6	11.3	8
Corn pepper	3.6∼30.1	10.0	8.8	17
Long pepper	1.9∼32.0	10.6	8.8	118
Cluster pepper	2.1∼28.8	10.2	8.6	32
Pimiento		10.5		1

[a]The fluorine content was measured in mg kg^{-1} (dry weight).

which is about 1.8 times that of foreign samples (4.8 mg kg^{-1}). Whether from domestic or foreign sources, a large number of chili samples had a fluoride content between 5.0 mg kg^{-1} and 10.0 mg kg^{-1}. This was the case for 38.64% of the Chinese samples and 52.00% of the foreign samples.

Fluoride Content in Fresh Chili in Different Varieties

According to the classification criteria of chilies by Bailey, chili can be divided into five varieties, the cherry pepper (*Cerasiforme* var.), corn pepper (*Conoides* var.), long pepper (*Longum* var.), cluster pepper (*Fasciculatum* var.), and pimiento (*Grossum* var.).[14]

The differences in fluoride content in different varieties of fresh chilies are shown in Table 2. The arithmetic mean of fluorine content in cherry peppers (*Cerasiforme* var.) was 12.6 mg kg^{-1}, the arithmetic means of the other four varieties were within 10.0 mg kg^{-1}∼10.6 mg kg^{-1}.

TABLE 3. Fluorine Content in Different Parts of Chilies[a]

Number	Fluoride content in chili peel	Fluoride content in chili seed	Seed/peel
1	9.4	10.7	1.14
2	8.7	11.6	1.33
3	11.0	11.6	1.06
4	9.8	11.1	1.14

[a]The fluorine content was measured in mg kg^{-1} (dry weight).

Fluoride Content in Different Edible Parts of Fresh Chili

Four fresh chili samples of different varieties were chosen in order to determine the fluoride content in peel and seed, respectively. Table 3 shows that the fluoride content in seeds is 1.17 times higher than that in the peel.

Relationship of Fluoride Content Between Fresh Chili and Soil

Mature fresh chilies and plowed layer soil samples were collected in different regions.

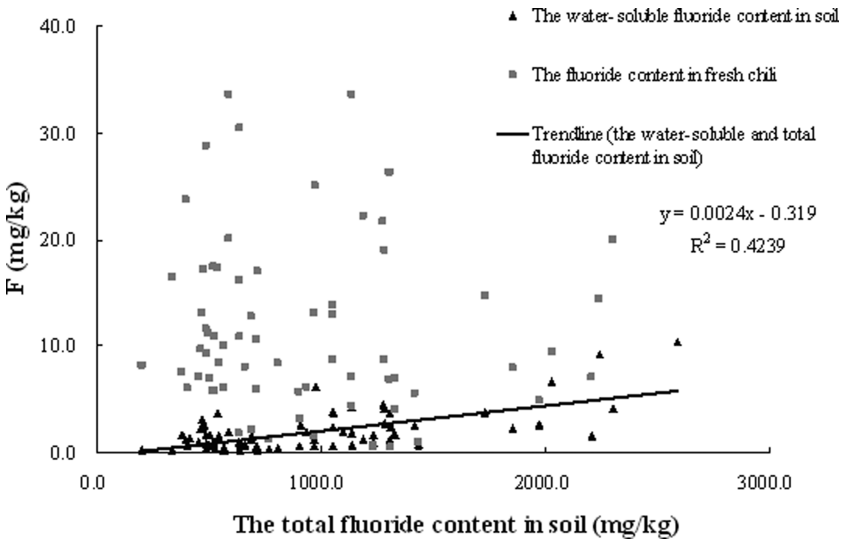

Figure 2. Relationship of fluoride content between fresh chili and soil.

Seventy-two soil samples were taken to measure total fluoride and water-soluble fluoride content. This research aimed to find the relationship between the total fluoride content, water-soluble fluoride content in soil, and the fluoride content in fresh chili that have not been contaminated by fluoride during storing and processing. As in Figure 2, in the check list of related factors we find that there is a significant positive correlation between the water-soluble fluoride content and the total fluoride content of soil. The trend line equation is $y = 0.0024x - 0.3190$ ($R^2 = 0.4239$). The fluoride background content of fresh chili and the total fluoride content of soil show no significant correlation (the related coefficient is -0.0821). The related coefficient mean of fluoride background content in fresh chili and the water-soluble fluoride content in soil is 0.2717; thus, it presents a weak positive correlation. As for the accurate related correlation, we need further research for confirmation.

Discussion

This was the first time that the fluoride content in fresh chili was systematically researched. The results show that the fluoride contents in fresh chilies shows a logarithmic normal distribution, with an arithmetic mean of 10.6 mg kg^{-1} and a geometric mean of 8.9 mg kg^{-1}.

The geometric mean of fluoride content in fresh chilies in China is 8.9 mg kg^{-1}, which is 1.8 times higher than the foreign samples. Compared with the widely centralized chili cultivation abroad, in China most planting is done near the house for convenience. The fluoride contamination caused by coal-burning in southwestern China is very serious, so the chilies may be contaminated by gaseous fluoride.

According to our research, the fluoride content in cherry pepper was a little higher than that in other varieties. This may be related to the chili's smooth surface. There was no significant difference among the corn pepper, long pepper, and cluster pepper. As a result, we conclude that the fluoride content in fresh chili is not significantly correlated with its species.

The fluoride content in seeds is a bit higher than that in peel in fresh chili, which is contrary to the trend of fluoride content in corn.[15] However, because of the limited number of samples, this observation needs to be replicated.

It is found that there is no significant correlation of fluoride content between fresh chili and

soil. There was, however, a weak but positive correlation between fluoride content in fresh chili and water-soluble fluoride content in soil.

Fluoride standard values for fresh chili should be established. Endemic fluorosis is quite severe in China. Different species of plants vary in their ability to concentrate fluoride. Tea is one of the plants that most concentrates fluoride. The allowable content of fluoride in tea is up to 200.0 mg kg^{-1} according to the standard for residue limits for chromium, cadmium, mercury, arsenic, and fluoride in tea (NY659-2003). To date, there is no standard for fluoride content in chili and little data or systematic research on fluoride content in chili. According to the fluoride content standard for vegetables in GB2762-2005,[16] the fluoride content in vegetables should not surpass 1.0 mg kg^{-1}. From our study on the content of fluoride in fresh chili, it seems the present standard is greatly exceeded for chili. Even in fresh chili, the fluoride background content has reached to 8.9 mg kg^{-1} (dry weight). According to the statistics of 114 fresh chilies, the average water content in fresh chili is about 78.80%. Converted into fresh weight, the background content is also up to 1.9 mg kg^{-1}. Although it is unclear whether the standard is based on dry weight or fresh weight, the level cannot be less than 1.0 mg kg^{-1} according to fresh weight results obtained in this research. Therefore the GB2762-2005 standard is inappropriate for chili.

We can calculate the probability in other intervals by the formula $|u| = |x - \mu|/\sigma$.[17] The fluoride content in fresh chili shows a log-normal distribution. Accordingly, $\mu = 0.95$, $\sigma = 0.26$, $u = 1.7$, the area is 0.4554, so $x = 1.392$. The right-side probability in the whole curve is 1/2, so the probability that the fluoride content logarithm mean is higher than 1.392 is 0.5000–0.4554 = 0.0446, and the probability that the fluoride content logarithm mean is lower than 1.392 is 1–0.0446 = 0.9554. After conversion, the fluoride content of 95.54% of the fresh chilies is less than 24.7 mg kg^{-1} (dry weight). We recommend 24.7 mg kg^{-1} (dry weight) and 5.2 mg kg^{-1} (fresh weight) as the fluoride contaminated discrimination values for fresh chili (Contaminated discrimination value = Geometric mean × Geometrical deviation$^{1.7}$).

In order to establish a more scientific, reasonable, and feasible standard for the permissible content of fluoride in fresh chili, we must do more comprehensive studies. Such studies must include research on the fluoride background content, dietary pattern, fluoride content in the atmosphere, tolerable limit to fluoride with regard to human health, and even the degree of hotness of the chili. However the standard must consider the average fluoride content in fresh chili.

Acknowledgments

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Conflicts of Interest

The authors declare no conflicts of interest.

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