



## Fluoride levels in different types and forms of tea drinks consumed in Taiwan and daily human exposure from tea drinks

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Received 2 November 2012, accepted 24 January 2013.

### Abstract

Tea is a major source of fluoride intake in humans. Adequate fluoride intake is helpful in preventing dental caries, but excessive intake may lead to adverse effects. In order to evaluate the safety of tea drinking in Taiwan, the fluoride concentrations of 89 leaf tea samples and 42 bagged tea samples in their 1% infusions and 78 ready-to-drink tea beverage samples were determined by a fluoride ion selective electrode, which were 0.14-2.31 mg/L, 0.23-3.60 mg/L and 0.43-2.51 mg/L, respectively. Taiwanese leaf teas of different fermentation degree or from different plantation areas did not differ significantly in the fluoride levels in their infusions, but Taiwanese leaf teas in semi-ball shape had a significantly lower fluoride level than those in stick shape. Moreover, the bagged teas with tea leaves from Taiwan or Sri Lanka had a significantly lower fluoride level than those with tea leaves from unknown or mixed sources. Assuming five cups of tea (approximately 1000 ml) or two bottles of 600 ml tea beverages were consumed per day, the daily fluoride intake from 1% infusions of leaf teas, 1% infusions of bagged teas and ready-to-drink tea beverages were 0.14-2.31 mg, 0.23-3.60 mg and 0.38-3.01 mg, respectively. As the Adequate Intake (AI) for fluoride is set at 0.05 mg/day/kg body weight, drinking tea infusions or ready-to-drink beverages result in a high risk of exceeding fluoride intake recommendations for children less than 45 kg. Children of 8 years or less are particularly concerned as the Tolerable Upper Intake Level (UL) is set at 0.10 mg/kg/day specifically for this age group. It is suggested that the determination of fluoride concentrations and the enactment of daily safety precautions are indicated for all types of tea products to prevent the intake of excessive fluoride.

**Key words:** Fluoride, dental caries, leaf tea, bagged tea, infusion, tea beverage, ion selective electrode, fermentation, adequate intake, tolerable upper intake level.

### Introduction

Tea is one of the most popular beverages in the world. It has been estimated that 4.12 million tons of tea was produced worldwide<sup>1</sup>, and more than three billion cups of tea were consumed daily<sup>2</sup>. The tea plant (*Camellia sinensis*) is known to absorb fluoride from the soil, and up to 98% of the fluoride absorbed accumulates in leaves<sup>3</sup>. The fluoride level in tea leaves increases with the maturation of the leaves<sup>3,4</sup>, usually from tens to hundreds of milligrams per gram (dry weight) in buds and new leaves and up to thousands of milligrams in old leaves<sup>4,6</sup>. The fluoride in tea leaves is readily released into beverages during infusion. Tea has been reported to be a major source of fluoride intake in humans<sup>7,8</sup>. Intake of a small amount of fluoride is beneficial to prevent dental cavities<sup>8,9</sup>. However, excessive intake for a long time may lead to adverse effects ranging from discoloration of teeth in children to severe osteoarthritis in adults<sup>7,9</sup>. The Adequate Intake (AI) for fluoride is set at 0.05 mg/day/kg body weight for all ages over 6 months, as this intake can provide a good protection against dental caries without causing unwanted side effects<sup>6,7</sup>.

Tea is a traditional and most popular drink in Taiwan and the consumption of tea has been increased in recent years. The average annual tea consumption rate per person in Taiwan was 0.34 kg in 1980, which increased to 1.70 kg in 2010<sup>10</sup>. Depending on the

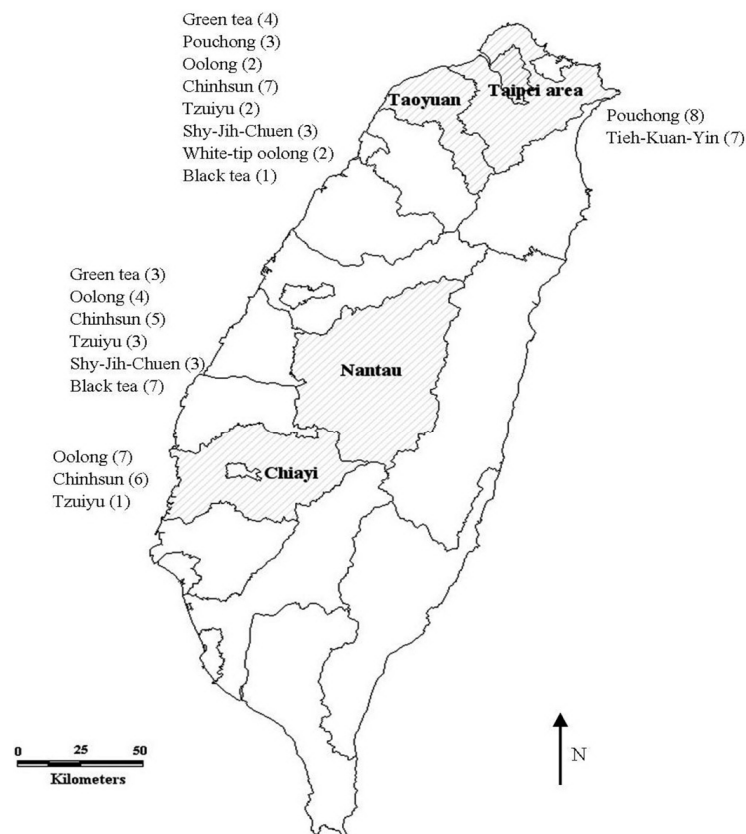
fermentation degree, tea is classified as non-fermented (or green tea), semi-fermented and fully fermented teas (or black tea), most Taiwanese people are accustomed to drinking teas brewed from semi-fermented teas. Many types of semi-fermented teas are produced in Taiwan, such as Pouchong, Oolong, Chihhusan and Tieh-Kuan-Yin. The fermentation degree of Taiwanese semi-fermented teas is 8-60%<sup>11</sup>. Some teas are specialty teas that are only produced in certain parts of Taiwan. For example, Pouchong and Tieh-Kuan-Yin are produced only in northern Taiwan. Taiwan also produces green and black teas, of which a large portion is used as a raw material for bagged teas and ready-to-drink tea beverages. There are four major tea plantation areas in Taiwan: the Taipei area and Taoyuan, Nantou and Chiayi Counties, with Nantou County being the major and most famous tea plantation area. Nantou County is also the main area for the production of Taiwanese black teas. All three types of tea (green, semi-fermented, and black) produced in Taiwan are for both local sales and for export. In 2010, a total of 2632 tons of tea were exported to at least 18 countries in Asia, North America, Australia and Europe<sup>12</sup>.

Fluoride concentrations of infusions prepared from teas on the Taiwanese market have been reported, including 1.12-3.17, 1.48-2.25, 1.68-2.85, 0.39-2.10, 1.34 and 1.97-8.64 mg/L<sup>5,6,13-16</sup>. As the

AI for fluoride is set at 0.05 mg/day/kg body weight, some of the tea infusions apparently have fluoride content so high that drinking them results in a high risk of taking in excess fluoride. Although the method of tea brewing has been shown to affect the fluoride content of tea infusions<sup>15</sup>, it is suspected that tea leaves harvested from specific plantation areas fermented to a certain degree or processed into specific types and forms may lead to a high fluoride content in their infusions. The objectives of this study were: (1) to compare the fluoride contents in different types and forms of tea drinks; and (2) to evaluate the safety of tea drinking in Taiwan.

### Materials and Methods

**Samples:** A total of 79 Taiwanese leaf tea samples were purchased from tea stores in the four major tea plantation areas in Taiwan: the Taoyuan, Nantou, and Chiayi Counties and the Taipei area (New Taipei and Taipei City), that sell local teas. Fig. 1 shows the locations of the four plantation areas in Taiwan and the numbers of green, semi-fermented (Pouchong, Oolong, Chinsun, Tzuiyu, Shy-Jih-Chuen, Tieh-Kuan-Yin and White-Tip Oolong) and black leaf teas purchased from tea stores in these four plantation areas. Additionally, 10 imported leaf tea samples, 24 bagged tea samples containing Taiwanese tea leaves, 18 bagged tea samples containing tea leaves from foreign countries or mixed or unknown sources, and 78 ready-to-drink tea beverages were purchased from supermarkets, convenience stores and stores that sell imported teas in Taiwan. The characteristics of the 89 leaf teas, 42 bagged teas and 78 ready-to-drink tea beverages are listed in Tables 1-3, respectively.



**Figure 1.** Number (in parenthesis) and type of Taiwanese leaf tea samples purchased from tea stores in the four major tea plantation areas in Taiwan.

**Preparation of tea infusions from leaf teas and bagged teas:** To prepare 1% tea infusions from leaf teas, 5 g of leaf teas were immersed in 500 mL boiling deionized water for 5 min, cooled to room temperature and filtered through a Millipore Stericup with 0.22- $\mu$ m GV PVDF membrane (Millipore, MA). To prepare 1% tea infusions from bagged teas, several tea bags from the same package were opened, the contents were mixed and the infusions were prepared in the same way that the 1% infusions from leaf teas were prepared.

**Determination of fluoride concentration using ion-selective electrode:** Fluoride content in tea infusions and the ready-to-drink beverages were determined by the fluoride ion-selective electrode (Orion-96-09, Thermo Electron Corp., MA) coupled with an ion analyzer (Mettler Delta 350, Mettler-Toledo, Zurich, Switzerland) according to the method described previously<sup>15</sup>. First, five NaF standard solutions ranging from 0.1 to 2.0 mg/L were prepared, and 25 mL of each was mixed with an equal volume of TISAB (total ionic strength adjustment buffer: 58.5 g/L NaCl, 15 mL/L glacial acetic acid, 102 g/L sodium acetate trihydrate, and 30 g/L sodium citrate dehydrate, pH 5.30  $\pm$  0.02). The electrode was immersed in the mixture, and the electrical potential of the solution was recorded. A linear regression equation of the electrical potential vs. fluoride concentration was established. Next, 25 mL of a tea infusion or a ready-to-drink tea beverage was mixed with an equal volume of TISAB, the electrode was immersed in the infusion, and the electrical potential was recorded. The fluoride concentration was determined according to the regression equation. All of the determinations were performed three times with triplicate samples. The results of the determinations are presented as the mean  $\pm$  SD.

**Statistical analysis:** Statistical comparison of the various tea drink groups were performed using Student's t-test, ANOVA and multiple comparison test using STATISTICA 7.1 software (StatSoft Inc., Tulsa, Oklahoma) with  $p < 0.05$  indicating as a statistically significant difference. Data that did not meet the normality and homoscedasticity assumptions were transformed to square root values prior to analysis.

### Results and Discussion

The fluoride concentrations were determined in infusions of 89 leaf tea samples, including 8 green, 65 semi-fermented and 16 black leaf tea samples, after 5 min of brewing. A higher number of the semi-fermented tea samples were tested because most Taiwanese people are accustomed to drinking tea infusions brewed with semi-fermented leaf teas and more market share of semi-fermented leaf teas in Taiwan. As shown in Table 1, the fluoride concentrations in 1% infusion of green, semi-fermented and black leaf teas ranged from 0.37 to 1.05, from 0.14 to 1.72 and from 0.17 to 2.31 mg/L, respectively. Since only one green, one semi-fermented and eight black imported leaf tea samples were tested, statistical analyses were performed only on the results of the 79 Taiwanese leaf tea samples. No significant differences were found in the fluoride levels among the infusions of Taiwanese leaf teas of the three fermentation types ( $F_{(2,76,0.05)} = 0.6653, p = 0.5171$ ), nor among the infusions of Taiwanese leaf teas from the four tea plantation areas ( $F_{(3,75,0.05)} = 0.4156, p = 0.7423$ ).

However, the Taiwanese leaf teas that were semi-ball shape had a significantly lower fluoride content in their infusions ( $0.55 \pm 0.23$  mg/L;  $n = 53$ ) than did the Taiwanese leaf teas that were stick shape ( $0.70 \pm 0.35$  mg/L;  $n = 26$ ) ( $t_{(77,0.05)} = 2.2733, p = 0.0258$ ). The leaves of the semi-ball shape teas were likely unfolded less

efficiently than the leaves of the stick shape teas and therefore released less fluoride into the infusion during the 5-min brewing.

The fluoride contents of the 1% infusions in the 42 bagged tea samples on the Taiwanese market were also determined. As shown in Table 2, the fluoride contents in the infusions of green, semi-fermented and black bagged tea samples ranged from 0.80 to 3.60, from 0.78 to 2.21 and from 0.23 to 3.13 mg/L, respectively. No significant difference was found in the fluoride levels among the infusions of the bagged teas of the three fermentation types ( $F_{(2,39,0.05)} = 0.2675, p = 0.4193$ ), nor between the infusions of the bagged teas with Taiwanese whole leaves and those with Taiwanese small-and-broken leaf pieces ( $t_{(19,0.05)} = 0.2304, p = 0.8202$ ; Table 2).

**Table 1.** Fluoride concentrations in the infusions of 89 leaf tea samples. (Part 1).

Tea Type/No.	Leaf Shape	Origin/brand	Fluoride concentration in infusion (mg/L)
<b>Green tea (n=8)</b>			
1	Stick	Taiwan, Taouyan County	0.76 ± 0.02
2	Stick	Taiwan, Taouyan County	0.37 ± 0.02
3	Stick	Taiwan, Taouyan County	0.82 ± 0.03
4	Stick	Taiwan, Taouyan County	0.94 ± 0.03
5	Stick	Taiwan, Nantou County	0.55 ± 0.02
6	Stick	Taiwan, Nantou County	0.43 ± 0.01
7	Stick	Taiwan, Nantou County	1.05 ± 0.07
8	Stick	India, Darjeeling/ Andees	0.94 ± 0.04
<b>Semi-fermented tea (n= 65)</b>			
<b>Pouchong</b>			
1	Stick	Taiwan, Taipei area	0.70 ± 0.03
2	Stick	Taiwan, Taipei area	1.72 ± 0.03
3	Stick	Taiwan, Taipei area	0.75 ± 0.01
4	Stick	Taiwan, Taipei area	0.61 ± 0.00
5	Stick	Taiwan, Taipei area	0.49 ± 0.02
6	Stick	Taiwan, Taipei area	0.28 ± 0.03
7	Stick	Taiwan, Taipei area	0.34 ± 0.02
8	Stick	Taiwan, Taipei area	0.43 ± 0.02
9	Stick	Taiwan, Taouyan County	0.66 ± 0.03
10	Stick	Taiwan, Taouyan County	1.51 ± 0.03
11	Stick	Taiwan, Taouyan County	0.92 ± 0.05
<b>Oolong</b>			
1	Semi-ball	Taiwan, Taouyan County	0.68 ± 0.02
2	Semi-ball	Taiwan, Taouyan County	1.08 ± 0.01
3	Semi-ball	Taiwan, Nantou County	0.32 ± 0.01
4	Semi-ball	Taiwan, Nantou County	0.69 ± 0.03
5	Semi-ball	Taiwan, Nantou County	0.54 ± 0.03
6	Semi-ball	Taiwan, Nantou County	0.22 ± 0.02
7	Semi-ball	Taiwan, Chiayi County	1.05 ± 0.04
8	Semi-ball	Taiwan, Chiayi County	0.44 ± 0.02
9	Semi-ball	Taiwan, Chiayi County	0.67 ± 0.04
10	Semi-ball	Taiwan, Chiayi County	0.38 ± 0.01
11	Semi-ball	Taiwan, Chiayi County	0.14 ± 0.01
12	Semi-ball	Taiwan, Chiayi County	0.63 ± 0.02
13	Semi-ball	Taiwan, Chiayi County	0.49 ± 0.02
14	Semi-ball	NA <sup>a</sup> / Whittard	1.12 ± 0.06
<b>Chinhsuan</b>			
1	Semi-ball	Taiwan, Taouyan County	0.38 ± 0.01
2	Semi-ball	Taiwan, Taouyan County	0.35 ± 0.00
3	Semi-ball	Taiwan, Taouyan County	0.38 ± 0.01
4	Semi-ball	Taiwan, Taouyan County	0.43 ± 0.02
5	Semi-ball	Taiwan, Taouyan County	0.56 ± 0.02
6	Semi-ball	Taiwan, Taouyan County	0.61 ± 0.03
7	Semi-ball	Taiwan, Taouyan County	0.82 ± 0.03
8	Semi-ball	Taiwan, Nantou County	0.63 ± 0.05
9	Semi-ball	Taiwan, Nantou County	0.37 ± 0.02
10	Semi-ball	Taiwan, Nantou County	0.62 ± 0.02
11	Semi-ball	Taiwan, Nantou County	0.59 ± 0.02
12	Semi-ball	Taiwan, Nantou County	0.63 ± 0.04
13	Semi-ball	Taiwan, Chiayi County	0.77 ± 0.01
14	Semi-ball	Taiwan, Chiayi County	0.77 ± 0.03
15	Semi-ball	Taiwan, Chiayi County	0.39 ± 0.02
16	Semi-ball	Taiwan, Chiayi County	1.25 ± 0.02
17	Semi-ball	Taiwan, Chiayi County	0.41 ± 0.02
18	Semi-ball	Taiwan, Chiayi County	0.43 ± 0.03
19	Semi-ball	Taiwan, Chiayi County	0.68 ± 0.01
<b>Tzuiyu</b>			
1	Semi-ball	Taiwan, Taouyan County	0.45 ± 0.02
2	Semi-ball	Taiwan, Taouyan County	0.69 ± 0.02

<sup>a</sup>NA: not available.

Of the 21 black bagged tea samples, eight, two, six and five samples contained tea leaves from Taiwan, India, Sri Lanka and mixed or unknown sources (Table 2). The eight samples with tea leaves from Taiwan did not differ significantly from the six samples with tea leaves from Sri Lanka in the fluoride levels in their infusions ( $t_{(12,0.05)} = 0.5491, p = 0.5930$ ). However, each of these two sample groups had a significantly lower fluoride content than did the five samples with tea leaves from mixed or unknown sources ( $t_{(11,0.05)} = 5.7410, p = 0.0001$  for samples with tea leaves from Taiwan;  $t_{(9,0.05)} = 6.6403, p = 0.0001$  for samples with tea leaves from Sri Lanka). It appears that the source, instead of the shape, of the tea leaf raw materials in the tea bag plays an important role in the fluoride content of bagged tea infusions. The bagged teas with tea leaves from mixed or unknown sources were likely made from low-quality tea leaves, such as old leaves or fallen leaves.

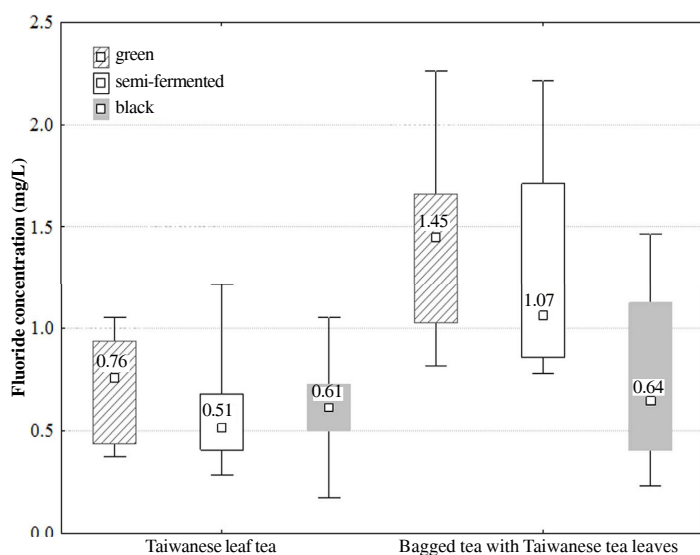
Fig. 2 shows that the fluoride content in the infusions of Taiwanese green leaf teas was significantly lower than that in the bagged teas with Taiwanese green tea leaves ( $t_{(12,0.05)} = 3.6339, p = 0.0003$ ). The same was true for the Taiwanese semi-fermented leaf teas vs. the bagged teas with Taiwanese semi-fermented leaves ( $t_{(71,0.05)} = 5.9001, p < 0.0001$ ), but not for the Taiwanese black leaf teas vs. the bagged teas with Taiwanese black tea leaves ( $t_{(14,0.05)} = 0.7961, p = 0.4393$ ). Because all three types of Taiwanese leaf teas did not differ significantly in the fluoride contents in their infusions and they are produced from buds and young leaves, which accumulate less fluoride than old leaves<sup>3, 4, 17</sup>, our results suggest that bagged teas with Taiwanese green and semi-fermented tea leaves are likely made from older tea leaves, whereas bagged teas with Taiwanese black tea leaves are likely made from buds and young leaves. Bagged teas with Sri Lankan black tea leaves may be made from buds and new leaves as well because the 6 bagged teas with Sri Lankan black tea leaves had fluoride levels in their infusions (0.58-0.76 mg/L; no. 9-14 in Table 2) similar to those of the Sri Lankan black leaf teas in this study (0.77 mg/L; Table 1) and in the study of Chandrajith *et al.*<sup>18</sup> (0.32-1.69 mg/L).

Table 3 lists the fluoride concentrations of 78 ready-to-drink tea beverages from the Taiwanese market. The fluoride levels of green, semi-fermented, and black tea beverages ranged from 0.45 to 2.51, from 0.75 to 2.22 and from 0.32 to 1.94 mg/L, respectively. No significant difference was

**Table 1.** Fluoride concentrations in the infusions of 89 leaf tea samples. (Part 2).

Tea Type/No.	Leaf Shape	Origin/brand	Fluoride concentration in infusion (mg/L)
3	Semi-ball	Taiwan, Nantou County	0.50 ± 0.02
4	Semi-ball	Taiwan, Nantou County	0.52 ± 0.02
5	Semi-ball	Taiwan, Nantou County	0.52 ± 0.01
6	Semi-ball	Taiwan, Chiayi County	0.51 ± 0.02
Shy-Jih-Chuen			
1	Semi-ball	Taiwan, Taoyuan County	0.53 ± 0.02
2	Semi-ball	Taiwan, Taoyuan County	1.22 ± 0.06
3	Semi-ball	Taiwan, Taoyuan County	0.45 ± 0.00
4	Semi-ball	Taiwan, Nantou County	0.32 ± 0.02
5	Semi-ball	Taiwan, Nantou County	0.38 ± 0.02
6	Semi-ball	Taiwan, Nantou County	0.92 ± 0.04
Tieh-Kuan-Yin			
1	Semi-ball	Taiwan, Taipei area	0.43 ± 0.00
2	Semi-ball	Taiwan, Taipei area	0.41 ± 0.01
3	Semi-ball	Taiwan, Taipei area	0.45 ± 0.02
4	Semi-ball	Taiwan, Taipei area	0.24 ± 0.01
5	Semi-ball	Taiwan, Taipei area	0.46 ± 0.01
6	Semi-ball	Taiwan, Taipei area	0.43 ± 0.02
7	Semi-ball	Taiwan, Taipei area	0.59 ± 0.04
White-Tip Oolong			
1	Semi-ball	Taiwan, Taoyuan County	0.44 ± 0.01
2	Semi-ball	Taiwan, Taoyuan County	0.37 ± 0.01
Black tea (n=16)			
1	Stick	Taiwan, Taoyuan County	0.17 ± 0.00
2	Stick	Taiwan, Nantou County	0.53 ± 0.02
3	Stick	Taiwan, Nantou County	1.05 ± 0.02
4	Stick	Taiwan, Nantou County	0.75 ± 0.03
5	Stick	Taiwan, Nantou County	0.70 ± 0.03
6	Stick	Taiwan, Nantou County	0.65 ± 0.01
7	Stick	Taiwan, Nantou County	0.46 ± 0.01
8	Stick	Taiwan, Nantou County	0.57 ± 0.01
9	Stick	India, Darjeeling/ Deliket	0.90 ± 0.01
10	Stick	India, Assam/ Lepcha	1.11 ± 0.04
11	Granulated	Sri Lanka/ Whittard (Ceylon)	0.77 ± 0.03
12	Granulated	Kenya/ Whittard	2.31 ± 0.07
13	Granulated	NA/ Whittard (English breakfast tea)	0.75 ± 0.02
14	Granulated	NA/ Whittard (Originat)	1.05 ± 0.06
15	Granulated	NA/Twinings (English breakfast tea)	1.15 ± 0.08
16	Granulated	NA/Ahmad (English breakfast tea)	0.93 ± 0.04

<sup>a</sup>NA: not available.



**Figure 2.** Comparison of fluoride contents in 1% infusions of green, semi-fermented and black Taiwanese leaf tea samples with those of green, semi-fermented and black bagged tea samples with Taiwanese tea leaves. Numbers, boxes and whiskers in each group indicate median, 25-75% and 5-95% of the individual samples, respectively.

found among the three types of beverages ( $F_{(3, 75, 0.05)} = 0.053, p = 0.9505$ ). The four Japanese green tea beverages had fluoride contents ranging from 0.51 to 0.76 mg/L, which are similar to the level previously reported for Japanese green tea beverages (0.53-0.90 mg/L)<sup>4</sup>.

The adequate intake (AI) for fluoride is set at 0.05 mg/day/kg body weight for all ages over 6 months. The Tolerable Upper Intake Level (UL) was set at 10 mg/day for adults and children over 8 years of age, and 0.10 mg/kg/day for children of 8 years or less<sup>7</sup>. Assuming an average of five cups (approximately 1000 mL) of tea infusions or two bottles of 600 mL ready-to-drink tea beverages were consumed per person per day, the daily intake of fluoride from 1% infusions of leaf teas, bagged teas with Taiwanese tea leaves and bagged teas with tea leaves from foreign countries or from mixed or unknown sources can be calculated to be from 0.14 to 2.31 mg, 0.23 to 2.26 mg and 0.56 to 3.60 mg, respectively, and the daily intake of fluoride from tea beverages from 0.38 to 3.01 mg. It appears that the daily fluoride intake from drinking infusions prepared from bagged teas with tea leaves from foreign countries or from mixed or unknown sources or drinking tea beverages yields some risk of taking in excess fluoride for adults and children less than 60 kg but over 45 kg. For children less than 45 kg, however, drinking all types of these tea drinks places them at high risk of exceeding the recommended intake of fluoride. Children of 8 years or less are

particularly concerned as the UL for this age group is 0.10 mg/kg/day<sup>7</sup>. In recent years, the consumption of the ready-to-drink tea beverages by children has been increasing dramatically in Taiwan. It is suggested that the determination of fluoride concentrations and the enactment of daily safety precautions are indicated for all types of tea products to prevent the intake of excessive fluoride.

Our measurements of the fluoride levels in the infusions of 89 leaf tea samples and in 78 ready-to-drink beverages are comparable to the fluoride levels in the infusions of leaf teas on the Taiwanese market reported by Cao. *et al.*<sup>5</sup>, Malinowska *et al.*<sup>14</sup>, Shyu *et al.*<sup>15</sup> and Kolbar *et al.*<sup>6</sup> and the fluoride level of a ready-to-drink beverage from a Taiwanese market reported by Cao *et al.*<sup>19</sup>. Our results, however, are much lower than the results of Lung *et al.*<sup>16</sup>, in which the fluoride content of infusions (2.5 min brewing of 2.5 g tea leaves in 4 rounds of 150 mL boiling water) of leaf teas on the Taiwan market were from 1.97 to 8.64 mg/L. It is suspected that the differences are likely due to the different methods used for brewing and/or for fluoride determination; ionic chromatography was used by Lung *et al.*<sup>16</sup> and fluoride ion-selective electrodes were used by others and in this study.

**Table 2.** Fluoride concentrations in the infusions of 42 bagged tea samples.

Tea type/ No.	Leaf shape	Source of tea leaves / brand	Fluoride concentration in infusion (mg/L)
Green tea (n=12)			
1	Whole leaf	Taiwan/Ten Ren	1.03 ± 0.07
2	Whole leaf	Taiwan/Lipton, Jasmine green tea	0.82 ± 0.01
3	Whole leaf	NA <sup>a</sup> /Lipton	1.98 ± 0.07
4	Whole leaf	NA/Chung Yi	1.45 ± 0.07
5	Small or broken pieces	Taiwan/Ten Ren	1.66 ± 0.09
6	Small or broken pieces	Taiwan/Ten Ren, Jasmine green tea	1.56 ± 0.03
7	Small or broken pieces	Taiwan/Tradition	2.26 ± 0.10
8	Small or broken pieces	Taiwan/Kin Ping	1.29 ± 0.02
9	Small or broken pieces	Sri Lanka/Stassen	0.80 ± 0.04
10	Small or broken pieces	NA/Ahmad	0.95 ± 0.04
11	Small or broken pieces with powders	Japan/Tokyo	1.38 ± 0.06
12	Small or broken pieces with powders	Japan/Chugoku	3.60 ± 0.09
Semi-fermented tea (n=9)			
Pouchong			
1	Small or broken pieces	Taiwan/Yung Fa	1.32 ± 0.07
2	Small or broken pieces	Taiwan/Ten Ren	1.76 ± 0.10
Oolong			
1	Whole leaf	Taiwan/Ten Ren	1.07 ± 0.08
2	Whole leaf	Taiwan/Lipton	0.88 ± 0.04
3	Small or broken pieces	Taiwan/Tradition	1.71 ± 0.02
4	Small or broken pieces	Taiwan/Ten Ren	0.78 ± 0.06
5	Small or broken pieces	Taiwan/Yung Fa	2.21 ± 0.04
Tieh-Kuan-Yin			
1	Small or broken pieces	Taiwan/Ten Ren	0.86 ± 0.03
White-Tip Oolong			
1	Whole leaf	Taiwan/Ten Ren	0.83 ± 0.06
Black tea (n=21)			
1	Whole leaf	Taiwan NT/Awas, TTES No.8	1.18 ± 0.02
2	Whole leaf	Taiwan NT/Awas, TTES No.18	0.70 ± 0.02
3	Small or broken pieces	Taiwan NT/Liao Mayor black tea, TTES No.18	0.39 ± 0.02
4	Small or broken pieces	Taiwan NT/Old-farmer, TTES No.18	1.47 ± 0.07
5	Small or broken pieces	Taiwan NT/Yuchi Farmers Association, TTES No.8	1.07 ± 0.09
6	Small or broken pieces	Taiwan NT/ Yuchi Farmers Association, TTES No.8	0.23 ± 0.01
7	Small or broken pieces	Taiwan NT/Lin-Sun Moon Lake, TTES No.8	0.59 ± 0.01
8	Small or broken pieces	Taiwan NT/Chien-yen, TTES No.8	0.42 ± 0.01
9	Tiny bits and pieces	Sri Lanka/ Tradition, Ceylon black tea	0.62 ± 0.05
10	Tiny bits and pieces	Sri Lanka/Ahmad, Ceylon tea	0.56 ± 0.01
11	Tiny bits and pieces	Sri Lanka/Twinings, Ceylon Orange pekoe tea	0.76 ± 0.02
12	Tiny bits and pieces	Sri Lanka/Stassen, Ceylon tea	0.72 ± 0.01
13	Tiny bits and pieces	Sri Lanka /Dilmah, English breakfast tea	0.58 ± 0.01
14	Tiny bits and pieces	Sri Lanka /Twea Tang, Ceylon tea	0.69 ± 0.00
15	Tiny bits and pieces	India/Ahmad, Assam tea	1.13 ± 0.03
16	Tiny bits and pieces	India/Twinings , Darjeeling tea	1.06 ± 0.03
17	Tiny bits and pieces	Assam, Ceylon, Kenya/PG Tips	3.13 ± 0.11
18	Tiny bits and pieces	NA/Ahmad, English Tea No.1	1.33 ± 0.05
19	Tiny bits and pieces	NA/Twinings, English breakfast tea	2.79 ± 0.03
20	Tiny bits and pieces	NA/Lipton, Yellow label tea	2.73 ± 0.03
21	Tiny bits and pieces	NA/Pikwick, Earl Grey	2.76 ± 0.07

<sup>a</sup>NA: not available.

### Conclusions

The fluoride concentrations of 89 leaf tea samples and 42 bagged tea samples in their 1% infusions and 78 ready-to-drink tea beverage samples were 0.14-2.31, 0.23-3.60 and 0.43-2.51 mg/L, respectively. Taiwanese leaf teas in semi-ball shape had a significantly lower fluoride level in their infusions than those in stick shape. The bagged teas with tea leaves from Taiwan or Sri Lanka had a significantly lower fluoride level than those with tea leaves from unknown or mixed sources. The adequate intake (AI) for fluoride is set at 0.05 mg/day/kg body weight. Assuming an average of five cups (approximately 1000 mL) of tea infusions or two bottles of 600 mL ready-to-drink beverages were consumed per person per day, drinking tea infusions or ready-to-drink beverages result in a high risk of exceeding fluoride intake

recommendations for children less than 45 kg. It is suggested that the determination of fluoride concentrations and the enactment of daily safety precautions are indicated for all types of tea products to prevent the intake of excessive fluoride. .

### Acknowledgements

This study was supported by the Council of Agriculture, Executive Yuan, Taiwan (R.O.C.).

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**Table 3.** Fluoride concentrations of 79 Ready-to-drink tea beverages.

Tea Type	Source of tea leaves /Product manufacturer	Fluoride concentration
		Mean ± SD (Min-Max) (mg/L)
Green tea (n=36)		
	NA <sup>a</sup> /A.G. V. Food, 2 products	1.44 ± 0.34 (1.20 - 1.68)
	NA / Chen Kou Wei, 2 products	1.23 ± 0.07 (1.18 - 1.28)
	Japan / ITO EN, 4 products	0.60 ± 0.11 (0.51 - 0.76)
	NA / Kingcar, 3 products	1.28 ± 0.12 (1.19 - 1.42)
	Taiwan (1) <sup>b</sup> and NA (3) / Kuangchuan, 4 products	0.99 ± 0.23 (0.66 - 1.16)
	Taiwan (1) and NA (1) / Tait, 2 products	1.31 ± 0.52 (0.94 - 1.68)
	NA/ Sunkey, 1 product	0.80
	Japan(1); NA (5) / Uni-President, 6 products	1.29 ± 0.45 (0.58 - 1.80)
	Japan / Vedan, 2 products	1.35 ± 0.23 (1.19 - 1.51)
	NA/Vitalon, 5 products	1.41 ± 0.64 (0.89 - 2.51)
	Japan / Weichuan, 1 product	1.26
	Taiwan (1) ; NA (3) / Young Energy Source, 4 products	0.81 ± 0.27 (0.45 - 1.11)
Semi-fermented tea (n=29)		
Oolong tea (n=29)		
	Taiwan (2) and NA (1) / Hetsong, 3 products	0.86 ± 0.03 (0.83 - 0.88)
	Japan / ITO EN, 1 product	2.22
	NA / Kuangchuan, 2 products	1.02 ± 0.38 (0.75 - 1.29)
	Taiwan / Nestle, 1 product	0.98
	Taiwan (2) and NA (1) / Tait, 3 products	0.79 ± 0.03 (0.79 - 0.94)
	Taiwan (4) / Uni-President, 4 products	1.37 ± 0.33 (0.94 - 1.73)
	Taiwan (3) and NA (4) /Vitalon, 7 products	1.11 ± 0.21 (0.91 - 1.49)
	Taiwan (3) and NA (3) / Weichuan, 6 products	1.11 ± 0.23 (0.77 - 1.37)
	NA / Young Energy Source, 2 products	0.94 ± 0.12 (0.85 - 1.02)
Black tea (n=13)		
	Sri Lanka / Kingcar, 1 product	0.43
	Sri Lanka (1) and NA (1) / Lipton, 2 products	0.99 ± 0.94 (0.32-1.66)
	NA / Nestle, 1 product	1.94
	NA / Sunkey, 2 products	0.80 ± 0.16 (0.69 - 0.91)
	NA / Taisun, 2 products	1.07 ± 1.03 (0.34 - 1.79)
	NA / Tait, 1 product	1.30
	Sri Lanka (1) and NA (3) / Uni-President, 4 products	1.36 ± 0.41 ( 0.95 - 1.76 )

<sup>a</sup>NA: not available. <sup>b</sup>Numbers in the parentheses: Number of the product tested.