# The Fluoride Content of Brewed and Microwave Brewed Black Teas

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## ABSTRACT

Fluoride (F) intake is recognized to be important to dental and bone health. Tea leaf is a known F accumulator and may contribute significantly to individual intake. The total F concentration in brewed tea also depends on the F in the brew water, which is highly variable across the US. The USDA's Nutrient Data Laboratory determined the fluoride content of brewed and microwaved teas, using geographically matched tap water samples, for inclusion in the USDA National Fluoride Database. Tap water samples were collected twice (over time) from 144 nationally representative residential locations in 72 counties, in 4 Census regions (2 residences per county). Thirty-six water composites were prepared by combining the samples from the 2 sites, from each time and from two counties, paired by closeness of location. Two brands of top-selling regular and one of decaffeinated teabags were purchased in one of the 4 locations corresponding to water sampling for each of the 36 composites. For brewed teas, each teabag was steeped for 4 minutes in 180 mL boiled water, in an acid-washed beaker. One regular brand was microwaved (tea bag and water together) for 1 minute in a 1200-watt microwave, and steeped for another 30 seconds. Over all samples, the water brew temperature was 93.4 2.52 °C (89.0 to 100 °C). The F content was determined by direct read using an ion-selective electrode method at University of Iowa. The mean F content for regular brewed tea was 373 49 mcg/100 g (n=63) and for decaffeinated tea was 270 46 mcg/100 g (n=34). The F content of regular brewed tea varied by region from 355 mcg/100g in the South to 393 mcg/100 g in the Midwest; decaffeinated varied from 247 mcg/100 g in the West to 293 mcg/100 g in the Midwest. The overall mean for F in microwaved regular tea, lower than regular brew, was 322 30 mcg/100 g (n=36). No significant regional differences were shown; values ranged from 309 mcg/100 g in the Northeast to 319 mcg/100 g in the Midwest. In all cases, prepared tea using water from the Midwest had the highest F values. The mean F content of the brewed teas was 4-5 times higher than the national mean of the tap water, analyzed separately (71 33 mcg/100g). These data are the first nationally representative fluoride values for brewed teas, and will provide valuable information to the dental and medical research community in assessment of fluoride intake and impact on the health of bones and teeth.

## BACKGROUND

Fluoride (F) intake is recognized to be important to dental (e.g., dental caries and fluorosis) and bone health. The NAS Dietary Reference Intake (Adequate Intake) for F in adult males is 4 mg/day and for adult females, 3 mg/day.

Tea is a naturally rich source of F; it absorbs F (passive diffusion) from the soil in which it grows (Ruan & Wong, 2001). Because it is a F accumulator, tea consumption may contribute significantly to individual F intake. Historically, tea was grown in natural soil; however, many tea growers now use F-containing fertilizers which may further increase the F content of the tea. The average North American consumes one cup of tea per day (NHANES, 2001) and tea consumption appears to be rising. The total F concentration in brewed tea depends to a certain extent on the F of the water in which it is brewed. The F content of US municipal water supplies is highly variable due to variability in fluoridation practices as well as the existence of geographic areas with naturally-occurring F and home water filtration systems that remove F in the household water. This study examined F from the brew water, the tea leaves, brand differences, the influence of the type of brew, and whether or not caffeine played a role. Resulting data are included in the USDA National Fluoride Database: www.nal.usda.gov/fnic/foodcomp/.

## METHODS AND MATERIALS

*Step 1. Prepared Sampling Frame Data*
- County and state code, name and 2000 Population Census
- Code, name, population of Census consolidated metropolitan statistical area (CMSA)
- Counties not in CMSA assigned county values and called generalized CMSA (gCMSA)
- Local urbanicity indices applied within CMSA

*Step 2. Sampling Design Development*
- US population ordered by county and divided into 72 equal zones
- 1 county selected from each zone with probability minimum replacement (PMR)
- 2 locations (residential, retail outlets) selected in each sampled county (Figure 1)

*Step 3. Census State Ordering (Figure 1)*
- Sort by Census regions, division, state; sort counties serpentinely by gCMSA size
- Within gCMSA, sort serpentinely by urbanicity
- gCMSA in odd numbered states decrease in size; those in even numbered states increase in size
- Similar pattern for urbanicity within gCMSA

*Step 4. Study approval*
- Federal Register announcement and approval by Office of Management and Budget of process, survey and incentives

*Step 5. Subject Recruitment*
- Phone call recruitment (neighborhood clusters)
- Substitution list used to replace refusals in water collection
- Followup letters confirming collection date
- USDA vehicle emergency packs – first collection incentive

*Step 6. Water sample (2 pickups) and tea purchase*
- Contracted agents pick up samples, issue surveys
- First residential tap water pickup – February-March, 2003
- Second residential tap water pickup – April-June, 2003
- Top tea brands picked up in one location in paired counties
- Sample size and design based on pilot study (Miller-Ihli, 2003)
- Tap water included municipal and well water

*Step 7. Composite water samples*
- Water combined from 2 sites, both times, within counties
- Counties paired by geographic proximity (exception (MD-KS), included in the Midwest region)

*Step 8. Brew teas*
- Water brew temperature averaged 93.4 2.52 °C (89.0 to 100 °C).

- ***Traditional brew***:
  - 36 samples of one regular brand, 36 samples of second regular brand, and 36 samples of one decaffeinated brand
  - Each teabag steeped for 4 minutes in 180 mL boiled water, in an acid-washed beaker.
  - Brew time consistent with manufacturer's recommendations.
- ***Microwave brew***:
  - 36 samples of one regular brand microwaved (tea bag and water together) for 1 minute in a 1200-watt microwave, then steeped for another 30 seconds.
  - Brew time consistent with manufacturer's recommendations.

*Step 9. Analyze samples*
- Ion Selective Electrode, direct read method
- QC: Calgary 93 Drinking Water (LGC Promochem) blind duplicates, high and low level F in-house materials

*Step 10. Data Analysis*

**FIGURE 1. FLUORIDE SAMPLING BY REGIONS AND COUNTIES**

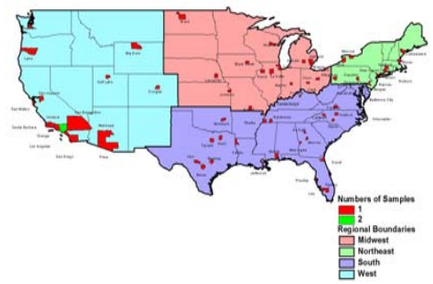


TABLE 1. FLUORIDE IN BREWED BLACK TEAS

| Tea (national) | n[1] | Total F[2] (mcg/100g) |
|---|---|---|
| Traditional brew[3] | 97 | 337 ± 69 |
| Microwave brew[4] | 36 | 322 ± 30 |
| With caffeine[5] | 99 | 354 ± 50 |
| With caffeine, traditional brew[6] | 63 | 373 ± 49 |
| Decaffeinated[4] | 34 | 270 ± 46 |

[1] Across all regions; less than 36 indicates tea not found in some locations.
[2] Mean ± sd.
[3] Two brands; one brand includes regular and decaffeinated types.
[4] One brand.
[5] Two brands; one brand includes traditional and microwave brewed.
[6] Two brands; traditional brew only.

TABLE 2. FLUORIDE IN BREWED BLACK TEAS: SOURCES OF VARIABILITY[1]

| Variable | No. of sites | Total F (mcg/100g) | F in water (mcg/100g) | F from tea (mcg/100g)[2] |
|---|---|---|---|---|
| Region (all teas) | | | | |
| Midwest | 8 | 345 ± 65 | 87 ± 26 | 258 ± 59 (75%) |
| Northeast | 7 | 326 ± 56 | 69 ± 46 | 256 ± 45 (78%) |
| South | 13 | 342 ± 57 | 78 ± 24 | 264 ± 58 (77%) |
| West | 8 | 313 ± 65 | 48 ± 26 | 265 ± 67 (85%) |
| Brand[3] | | | | |
| Brand A | 27 | 385 ± 59 | 73 ± 33 | 312 ± 31 (81%) |
| Brand B | 27 | 367 ± 43 | 73 ± 33 | 294 ± 31 (80%) |
| Brew[3] | | | | |
| Traditional | 36 | 364 ± 40 | 71 ± 33 | 293 ± 28 (80%) |
| Microwave | 36 | 322 ± 30 | 71 ± 33 | 251 ± 31 (78%) |
| Caffeine[3] | | | | |
| Decaffeinated | 34 | 270 ± 44 | 71 ± 34 | 199 ± 35 (74%) |
| Regular | 34 | 364 ± 40 | 71 ± 34 | 294 ± 28 (81%) |

[1] Mean ± SD. Slight differences from mean and variability data in the USDA National Fluoride Database may be attributed to the combining of composite data for this research. [2] F contributed by tea in parentheses. [3] Matched by location. [4] Significant differences.

| Fixed Effect | DF | P | Predictive model (E = expected value) |
|---|---|---|---|
| Brew | 1 | <.0001[4] | E = 317.36 + 0.6556 x (ave F in water) + 0 standard *or* -42.19 microwave |
| Brand | 1 | 0.1659 | E = 335.36 + 0.6735 x (ave F in water) + 0 Brand A *or* -17.89 Brand B |
| Caffeine | 1 | <.0001[4] | E = 303.86 + 0.9014 x (ave F in water) + 0 regular *or* -94.26 decaf |

## RESULTS AND DISCUSSION

The effect of brewing method, brand of tea, the caffeine level and region of tap water/tea collection on the F content of the brewed black tea was determined. The F content was determined several ways:

- Regular brewed tea (national mean) was 373 ± 49 mcg/100g (Table 1);
- Decaffeinated tea (one brand, national mean) was 270 ± 46 mcg/100g; and
- Microwaved tea (one brand, national mean) was 322 ± 30 mcg/100 g.

In addition:

- No significant regional differences were shown across all tea brands, brews and caffeine level. In all cases, tea from the Midwest had the highest F values, consistent with the F content of the water.
- F in traditional brew tea was higher than microwaved tea: subtracting out the F from the water, F coming from traditional brew tea ranged from 29-58 mcg/100g (South - Midwest) more than from microwaved tea.
- F from traditional brew regular tea was higher than from decaffeinated tea; the range in differences was 47-88 mcg/100g with the largest difference between teas in the Midwest and the lowest in the west.
- The F content of the Brand B tea, excluding F from water, either showed no difference or was slightly higher in F than Brand A tea: 0-33 mcg/100g F, with the largest difference in the south and no difference in the northwest and west samples.
- In all cases, most of the F was contributed by the tea leaves (range 74-85%, Table 2a).
- For matched pairs (matched by location, excluding missing values, Table 2a), F variability was significantly affected by brew type (traditional 364 ± 40 vs. microwave 322 ± 30 mcg/100g, p<.0001) and caffeine level (regular 270 ± 44 vs. decaf. 364 ± 40 mcg/100g, p <.0001).
- For matched pairs, no significant differences were observed for effect of region (p = 0.3288-0.7499) and brand of tea (p = .1659, Table 2b). For the latter, the average amount of F coming from the water contributes most to the variability of F in the brewed tea.

Missing values for the Brand A is a limitation of these results. Predictive models (Table 2b) based on these data were generated for assessing intakes of F from brewed black tea. A cup of brewed tea weighs 178 (6 oz) to 237 (8 oz), doubling the F amounts presented here; therefore, the F provided by tea may contribute significantly to daily F intake, and quality of dental and bone health.

## REFERENCES:

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