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Fluoride Concentration and pH of Iced Tea Products

Annekathrin Behrendt   Volker Oberste   Willi Eckhard Wetzel

Department of Pediatric Dentistry, Medical Center of Odontology, Justus Liebig University of Giessen, Germany

Key Words

Dental erosion · Dental fluorosis · Fluoride · Iced tea · PH

Abstract

The objective of this study was to determine the fluoride concentration and pH of 44 iced tea samples and hence to assess the possible role of these beverages as systemic fluoride source as well as their potential cariogenic and erosive character. Ten tea samples were available as a granular instant powder, and 34 as ready-to-drink liquid products. The iced teas contained different types of sugar alone or in combination with maltodextrin, glucose syrup and noncaloric sweeteners. In one product, only acesulfame and aspartame were established. All samples contained lemon juice or citric acid as an additive. The pH ranged from 4.04 to 2.63 and the titrated amount of base to pH 7.0 from 0.75 to 2.39 mmol NaOH/50 ml. The fluoride concentrations measured were <0.6 ppm in 14 products, 0.6–1.0 ppm in 10 products, 1.1–1.5 ppm in 16 products, 1.6–2.0 ppm in 2, and >2.0 ppm in another 2 products. In conclusion, most of the iced teas studied contained considerable fluoride concentrations. If infants ingest larger amounts of them because of their sweet taste, there is a risk of uncontrolled overdosing as a result of additional fluoride intake from other sources at the same time. Furthermore, the majority of the products revealed a highly cariogenic character and finally, all the iced teas appear to be acidic enough to cause dental erosion if these refreshments were excessively consumed from nursing bottles.

The successful use of systemic and topical fluoridation has been described and verified extensively in the last decades. Hefti [1986] published an informative review of fluoride metabolism. However, with the widespread availability of fluoride, especially of fluoride-containing oral health products, oral health professionals have become increasingly concerned with an increase in the prevalence of very mild and mild enamel fluorosis among children over the last years [Szpunar and Burt, 1987; Burt, 1992]. Therefore, continually updated scientific recommendations, according to the respective age-group, for the dosage of fluoride supplements and for the threshold range of the overall daily supply with fluoride have been made available in Germany [DGZMK Statement, 2000]. Here, changing eating habits with regard to the use of fluoride-containing mineral water or balanced infant diets were also considered in the last years. Green and black tea products, which, as is widely known, contain fluoride and caffeine, have not played a primary role in this process, as these drinks were presumably consumed by adults origi-

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Prof. Dr. W.E. Wetzel
Poliklinik für Kinderzahnheilkunde, Zentrum für ZMK
Schlangenzahl 14, D–35392 Giessen (Germany)
Tel. +49 641 9946241, Fax +49 641 9946239
E-Mail Willi-Eckhard.Wetzel@dentist.med.uni-giessen.de

nally. Now, case histories on nutrition taken within the framework of individual caries prophylaxis at the Clinic of Pediatric Dentistry in Giessen (Germany) have come up with evidence for increasing ingestion of iced tea products by infants as beverages from nursing bottles or vessels with bill-shaped extensions.

The objective of this study was therefore to assess the fluoride concentration of these modern refreshments and their possible influence as a systemic fluoride source and, in addition, to determine their cariogenic and erosive potential. First results on the fluoride concentrations of a smaller number of such products have recently been published in the German dental literature [Behrendt et al., 1999].

Materials and Methods

Investigated Products

Altogether 44 iced tea products were made available for our scientific purposes by 10 out of 19 firms we had contacted. From the packaging declarations a summary of the sweetening substances and the acidifiers contained in these drinks was drawn up.

Determination of Fluoride

The ionized fluoride was determined potentiometrically, using a fluoride-specific electrode (model 96-09-00, Orion Research Corp., Cambridge, Mass., USA) on the Orion Ionanalyzer 901. The Orion fluoride standard solution 94–09–06 was used to calibrate the measuring instrument.

According to the manufacturer's declaration about the fluoride concentrations of the products, the scope of the Ionanalyzer was adjusted to an interval from 0.20 to 3.00 mg/l. From a range of 5 original packets we randomly selected 3 of each product for analysis. In accordance with the manufacturer's information we first prepared standard solutions of the 10 granular instant powder tea samples using deionized distilled water. The 34 ready-to-drink products were investigated as delivered.

Five samples of 5 ml each were taken from each solution and each of them was mixed by means of a magnetic mixing system while slowly adding an equal volume of TISAB-II buffer, to adjust pH to 5.5 and to standardize ionic strength. Measurements were made after submersion of the electrode in the stirred samples for 10 min at room temperature. The mean readings were then compared with the manufacturer's information if available.

Determination of pH and Buffering Capacity

Measurements were carried out using a WTW microprocessor pH meter 537 (Scientific-Technical Workshops GmbH, Weilheim, Germany), with a combination electrode incorporating a temperature sensor. The precision for pH measurements was ±0.01 units and for temperature ±0.2°C. WTW standard buffers, pH 7.0 and pH 4.0, were used for calibration. The measurements took place under the same conditions and, consequently, also at the same room temperature. Five measurements of pH were taken for each product. The buffering capacity was determined for altogether 9 iced tea samples (5 liquid products contained 'green', 'black' and 'fruit' tea and 5 granular products 'black' tea). To determine the amount of base needed to raise the pH to 7.0 (= 'buffer capacity') 50 ml of each beverage was titrated with 1 *N* NaOH.

Statistical Analysis

Student's t test was used to test the differences between the fluoride concentration and pH of the liquid and the granular instant powder products.

Results

From the manufacturer's information, the iced tea samples contained non-decaffeinated 'black tea' in 28 products (64%), 'tea' without any further specification in 8 products (18%), 'fruit tea' in 5 products (11%), and 'green tea' in 3 products (7%, table 1).

The sweetening substances are summarized in table 2. Twenty-three products included solely sugar (sucrose), whereas the remaining samples showed combinations of sugar with noncaloric sweeteners, glucose syrup and/or maltodextrin. There was only 1 product with only acesulfame and aspartame ('Liptonice light', Lipton Ltd.). In 24 products the percentage of sugar and carbohydrate was declared on the packaging and varied from 0.2 to 9.0 g% w/v. All iced tea samples contained lemon juice or citric acid as an additive.

Table 1 shows the fluoride concentrations in the 44 iced tea products in ascending order. The range was 0.03–3.35 ppm (median 1.01). The majority of the products (36.3%) ranged from 1.1 to 1.5 ppm (fig. 1). The fluoride concentrations for the granular instant powder products ranged from 0.49 to 3.35 ppm (n = 10, mean = 1.48 ppm). The liquid products ranged from 0.03 to 1.79 ppm, mean 0.78 ppm (n = 34) (table 1, fig. 1). The fluoride concentration of the powder products was significantly higher than that of the liquid products ($p = 0.02$).

For none of the iced tea products from the study was the fluoride concentration directly indicated on the packaging, but in 25 products it could be derived from additional company information we had received. In 9 cases (36%) the differences between these figures and our measurements were less than 0.1 ppm, in 16 cases (64%) they exceeded 0.1 ppm. In extreme cases our fluoride concentrations were 0.90 ppm lower or 2.21 ppm higher than the stated concentrations (table 1).

Table 1 also shows the mean pH measurements with standard deviations of all iced tea products. The mean pH values ranged from 4.04 to 2.63 with a mean of 3.1, while half of all the products had a pH value between 2.6 and

Table 1. Fluoride concentration, pH and buffering capacity in brewed iced teas (means ± SD)

Product No.	Tea extract	Original state	Fluoride concentration ppm	Manufacturer ppm	Difference ppm	pH	Buffer capacity[a] mmol NaOH/50 ml
1	fruit tea	liquid	0.03 ± 0.01	n.s.	–	2.68 ± 0.01	1.93 ± 0.02
2	fruit tea	liquid	0.04 ± 0.01	n.s.	–	2.80 ± 0.02	–
3	fruit tea	liquid	0.04 ± 0.01	n.s.	–	2.92 ± 0.17	1.50 ± 0.02
4	fruit tea	liquid	0.08 ± 0.02	n.s.	–	3.31 ± 0.02	–
5	fruit tea	liquid	0.09 ± 0.01	n.s.	–	2.84 ± 0.04	–
6	black tea	liquid	0.25 ± 0.00	0.33	–0.08	3.65 ± 0.02	–
7	black tea	liquid	0.28 ± 0.01	0.31	–0.03	3.53 ± 0.08	–
8	tea	liquid	0.35 ± 0.01	1.50[b]	–1.15	3.00 ± 0.02	–
9	black tea	liquid	0.39 ± 0.02	n.s.	–	2.75 ± 0.04	–
10	green tea	liquid	0.46 ± 0.01	n.s.	–	2.75 ± 0.07	1.93 ± 0.02
11	tea	liquid	0.48 ± 0.01	1.50[b]	–1.02	3.09 ± 0.02	–
12	black tea	granular	0.49 ± 0.03	2.70	–2.21	2.66 ± 0.06	–
13	tea	liquid	0.52 ± 0.01	0.77	–0.25	3.45 ± 0.02	–
14	tea	liquid	0.53 ± 0.02	0.77	–0.24	3.26 ± 0.03	–
15	tea	liquid	0.58 ± 0.07	0.62	–0.04	2.95 ± 0.04	–
16	black tea	liquid	0.62 ± 0.01	n.s.	–	2.77 ± 0.08	–
17	black tea	liquid	0.63 ± 0.01	0.15[b]	+0.48	3.78 ± 0.02	2.39 ± 0.04
18	black tea	liquid	0.65 ± 0.01	0.15[b]	+0.50	3.73 ± 0.02	–
19	tea	liquid	0.66 ± 0.01	0.62	+0.04	3.45 ± 0.08	–
20	tea	liquid	0.66 ± 0.06	0.62	+0.04	3.10 ± 0.02	–
21	tea	liquid	0.83 ± 0.06	0.62	+0.21	2.63 ± 0.04	–
22	black tea	granular	0.98 ± 0.00	n.s.	–	2.79 ± 0.02	0.75 ± 0.01
23	black tea	granular	1.01 ± 0.05	n.s.	–	2.72 ± 0.02	2.33 ± 0.05
24	black tea	liquid	1.03 ± 0.02	0.15[b]	+0.88	3.78 ± 0.05	–
25	black tea	liquid	1.05 ± 0.01	0.15[b]	+0.90	3.76 ± 0.05	–
26	black tea	granular	1.15 ± 0.10	n.s.	–	2.82 ± 0.03	–
27	black tea	granular	1.17 ± 0.02	n.s.	–	2.69 ± 0.00	–
28	black tea	granular	1.20 ± 0.06	n.s.	–	2.77 ± 0.06	2.08 ± 0.02
29	black tea	liquid	1.22 ± 0.01	n.s.	–	3.19 ± 0.02	1.67 ± 0.04
30	black tea	liquid	1.22 ± 0.02	n.s.	–	2.80 ± 0.02	–
31	black tea	liquid	1.23 ± 0.02	n.s.	–	2.95 ± 0.06	–
32	black tea	liquid	1.24 ± 0.02	1.30	–0.06	3.40 ± 0.01	–
33	black tea	liquid	1.24 ± 0.04	1.30	–0.06	3.25 ± 0.04	–
34	black tea	liquid	1.27 ± 0.00	1.30	–0.03	3.53 ± 0.02	–
35	black tea	liquid	1.28 ± 0.03	1.30	–0.02	3.51 ± 0.01	–
36	black tea	granular	1.31 ± 0.05	n.s.	–	2.74 ± 0.02	1.24 ± 0.02
37	black tea	liquid	1.33 ± 0.01	n.s.	–	2.96 ± 0.04	–
38	black tea	liquid	1.33 ± 0.01	n.s.	–	3.41 ± 0.01	–
39	black tea	liquid	1.34 ± 0.03	1.50[b]	–0.16	3.19 ± 0.01	–
40	black tea	liquid	1.38 ± 0.03	1.50[b]	–0.12	4.04 ± 0.04	–
41	black tea	liquid	1.79 ± 0.01	1.50[b]	+0.29	3.86 ± 0.03	–
42	green Tea	granular	1.99 ± 0.06	4.20	–2.21	2.69 ± 0.06	–
43	green Tea	granular	2.16 ± 0.04	4.20	–2.04	2.73 ± 0.03	–
44	black tea	granular	3.35 ± 0.02	3.00	+0.35	3.05 ± 0.04	–

n.s. = No statement.
[a] Amount of NaOH required to titrate 50 ml tea from initial pH to pH 7.0.
[b] Mean value.

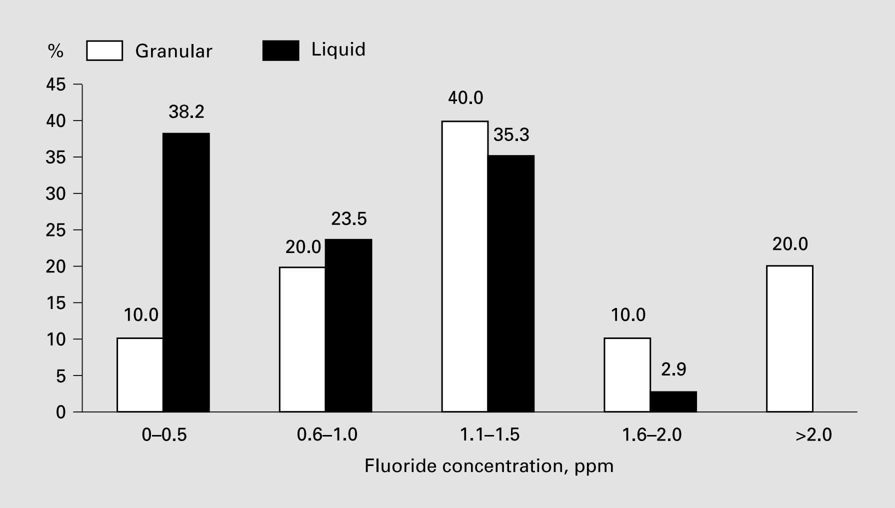

Fig. 1. Fluoride concentration of granular instant powder (n = 10) and ready-to-drink iced tea products (n = 34).

Table 2. Manufacturers' information on the content of sweetening substances

Sweetening substance	Products	
	n	%
Sugar	23	52.3
Sugar, dextrose	3	6.8
Sugar, maltodextrin	3	6.8
Sugar, glucose syrup	2	4.5
Sugar, noncaloric sweetener	8	18.2
Sugar, noncaloric sweetener, maltodextrin	1	2.3
Fructose, noncaloric sweetener	3	6.8
Noncaloric sweetener (acesulfame, aspartame)	1	2.3
Total	44	100.0

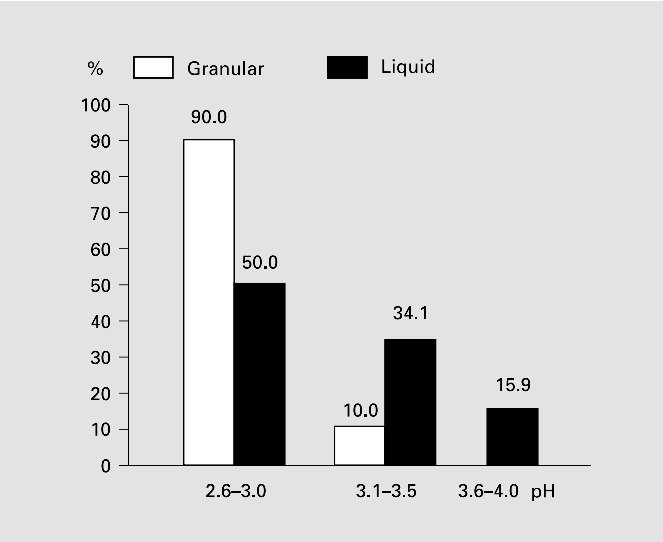

Fig. 2. pH of granular instant powder (n = 10) and ready-to-drink iced tea products (n = 34).

3.0 (fig. 2). The amount of base required to adjust pH to 7.0 varied between 0.75 and 2.39 mmol NaOH/50 ml for 5 liquid and 4 granular products (table 1).There was a statistically significant difference in pH between the granular instant powder (mean pH value = 2.8) and the liquid samples (mean pH value = 3.2, p = 0.001).

Discussion

In Germany, adults ingest up to 0.5–0.7 mg of fluoride daily via food and drinking water [Bergmann and Bergmann, 1987]. Tea beverages containing higher fluoride concentrations have not played an important role till now but it is well known that green or black teas can contribute considerably to the total dietary fluoride intake, if consumed regularly, because of their content of free and complex bound fluoride ions [Speirs, 1983].

The annual consumption of iced tea products, which are classified as 'innovative refreshments', rose from 0.2 liters per capita in 1991 to 8.2 liters in 1998 [Bundesverband der Deutschen Erfrischungsgetränke-Industrie e.V., 1999]. At the same time, iced tea products changed from being originally typically a beverage of the hotter season to being a popular refreshment all year round in the German market. But with regard to the high amounts of car-

Table 3. Fluoride concentration of tea (overview of the available literature)

Authors	Region	Products	Fluoride concentration ppm	
			range	mean
Ramsey et al. [1975]	England	28	0.48–3.20	1.20
Strübig and Gülzow [1981]	Germany	37	0.56–2.73	1.40
Wei et al. [1989]	Hong Kong	26	0.73–3.46	1.52
Chan and Koh [1996]	United States	44	0.02–5.20	1.53

bohydrates and lemon acid and to the fruit aroma dominating the flavor, the original character of the teas had become secondary. This would also explain the fact that evidently more and more parents serve these frequently caffeine-containing refreshments to their children in larger amounts even as beverages in baby bottles. Our concerns with regard to iced tea products arose from clinical experience. In 2001, 5.2% of 193 children suffering from nursing-bottle syndrome were documented in the Department of Pediatric Dentistry, University of Giessen, as having drunk iced teas from baby bottles and/or vessels with bill-shaped extensions.

The fluoride concentrations (0.03–3.35 ppm) of the 44 iced tea products ascertained in this study largely agree with the results of other authors (table 3), who, however, only evaluated tea beverages without any further specification such as ‘iced tea’. For the German market, Strübig and Gülzow [1981] found fluoride concentrations between 0.56 and 2.73 ppm in 37 different tea products. The rather large variations of fluoride concentrations discovered between some tea growing regions were put down by these authors to, among other things, the prevailing condition of the soil or the trade quality of the individual tea types. They further assumed that tea plants were especially capable of absorbing fluorides through their roots and of storing them, so that older and therefore later picked tea leaves would generally contain more fluoride. Moreover, the sorting of the leaves also played an important role insofar as finer tea blends, due to their extended surface, could release fluoride more rapidly after brewing [Strübig and Gülzow, 1981].

Chan and Koh [1996] found significantly higher fluoride concentrations, between 1.01 and 5.20 ppm, in decaffeinated than in nondecaffeinated tea products. They suggested that this could be due to fluoride in natural spring water used in the decaffeination process. Compared to decaffeinated and caffeinated tea types, Chan and Koh [1996] also found relatively low concentrations (0.02–0.14 ppm) in herbal teas. These results are very similar to those for fruit tea products in the present investigation. Chan and Koh [1996] found that the fluoride concentration in tea suspensions increased up to 120 min after infusion, although the majority was released within 30 min.

The differences in the fluoride concentrations between the powder and ready-to-drink products might originate in the guidelines of the German Tea Association. According to these guidelines, the powder products have to contain at least 1.2 g of tea extract per liter without any added tea aroma. However, there is no obligation for the manufacturers to use tea extracts exclusively in the ready-to-drink products. Consequently, they also make use of more or less artificial aromas [Test Eistee, 1998]. Furthermore, the sources of the tea extracts commonly vary. This could partly explain the considerable differences between the manufacturers' information and our measurements of fluoride concentration.

The bioavailability of fluorides from tea is good, and might be enhanced by the caffeine content [Chan et al., 1990]. According to the German consumer advice center ‘Stiftung Warentest’ [Test Eistee, 1998], iced tea contains 32–157 mg/l caffeine, which is less than in freshly brewed tea (200–300 mg/l caffeine) but is comparable with Coke (100 mg/l caffeine). Consequently, iced tea products could contribute to an increase in dental fluorosis, if consumed by children. In Kenya where tea consumption is common both among adults and children, a raised prevalence of fluorosis was observed by Opinya et al. [1991]. Most children of this community were introduced to tea during the 1st month of life and Opinya et al. [1991] suggested that tea might have been a major contributor to the fluorosis.

Considering that the concentration of fluoride was not declared on any of the packaging, it becomes obvious how difficult it would be to include these beverages in the dental and pediatric fluoride anamnesis in the future.

Besides presenting a possible risk of excessive fluoride intake, iced tea products might also present other dental risks. Most sweetened iced teas have a sugar content of 70–95 g/l, reaching the known concentrations of sugary lemonades (80–115 g/l) [Test Eistee, 1998], so must be considered as potentially cariogenic, despite their fluoride content, which might not be sufficient to compensate for the challenge presented by the sugar.

Iced tea beverages also seem to have an erosive potential. According to O'Sullivan and Curzon [2000], dental erosion could develop into a general health problem for children as well as for adults in the future. The pH values and buffering effect measured in this study (2.63–4.04) are comparable with those of various lemonade beverages investigated in other studies [Lussi et al., 1995; Larsen and Nyvad, 1999]. Larsen and Nyvad [1999] established a logarithmic increase in the erosive dissolution of dental hard tissue with a decrease of pH to 4.0 or below. The fluoride concentrations in iced tea products are unlikely to have a significant effect on erosive potential, in view of the results of Larsen [2001] and Larsen and Richards [2002].

In conclusion, our results indicate that iced tea products potentially present risks for excessive fluoride intake, for caries and for erosion. Studies to evaluate these risks would be desirable. In addition, studies to determine the frequency and volume of consumption of these products by children are needed. Such studies should consider other countries besides Germany, because these products are sold predominantly by international companies, so are already reaching beyond the German consumer market.

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