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Fluoride content in bottled waters, juices and carbonated soft drinks in Mexico City, Mexico

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Summary. *Objective.* The objective of this study was to analyse 283 samples of soft drinks available in the metropolitan market of Mexico City, Mexico: 105 juices, 101 nectars, 57 carbonated drinks and 20 bottled waters.

Materials and methods. Samples of the beverages were analysed using an Orion 720A potentiometer and an Orion 9609BN F ion-specific electrode.

Results. Fluoride concentration in the above-mentioned products ranged from 0·07 to 1·42 p.p.m. It was found that fluoride concentrations varied according to the brand, flavour and presentation of the product. The highest mean concentration of fluoride was found in the juices and cola drinks (0·67 ± 0·38 and 0·49 ± 0·41 p.p.m., respectively). The mean fluoride concentration for carbonated drinks was 0·43 ± 0·36 p.p.m. Bottled waters had a fluoride concentration of 0·21 ± 0·08 p.p.m.

Conclusions. The findings suggest that fluoride ingested through bottled drinks represents an important part of the total fluoride ingested by the population. In view of the wide variation of fluoride concentration in the tested products, it is necessary to implement regulatory guidelines for controlling its concentration in order to prevent dental fluorosis.

Introduction

One of the most important factors for the declining frequency of dental caries in some populations is probably the widespread use of fluoride and fluoridated drinks in various forms (e.g. water, toothpaste, dietary fluoride and fluoride supplements). Because of this widespread fluoride ingestion from many sources, there is now concern about the increased prevalence of dental fluorosis.

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It has been reported that drinking water consumed in some Mexican communities contains excessive amounts of natural fluoride [1–3]. Some investigations have suggested that increased consumption of bottled water, soft drinks and juices prepared with fluoridated water may be a significant source of systemic fluoride, and they have been implicated as risk factors for dental fluorosis in young children [4–9].

With the introduction of many national and imported products to the Mexican market, the total daily ingestion of fluoride has been altered. As in other countries, consumption of bottled water and another beverages has increased in our country [10]. However, studies of the fluoride content of bottled beverages in Mexico are limited [2,3,11].

In Mexico City, the mean fluoride level in drinking water is between 0·01 and 0·81 p.p.m. (mean = 0·16 p.p.m.) [11]. In view of the low fluoride levels in the Mexico City's water, a strong suspicion exists that beverages account for an important portion of the daily total fluoride intake, and that fluoride from these sources may play a role in the increased development of dental fluorosis in the Mexican population.

Mexico City is the largest and most populated city in the world, it has more than 8·6 million people within 1476·2 km^2. Except in winter, the weather in the city is normally warm and the annual average temperature is 20 °C.

Although Mexico City is not considered an endemic area for dental fluorosis, previous studies have shown that children may present with low-mild and mild mottled enamel in some areas of the city [12]. The mean fluoride concentration in the water in Mexico City is 0·16 p.p.m. [16], a level that is below the permissible range for the country [13].

Previous studies have shown that DMFT values in 12-year-old children from different areas of the Mexico City metropolitan area vary from 2·6 to 4·6 [14,15], and that fluoride concentrations in drinking water vary from 1·03 to 0·16 p.p.m. [11,12]. This is especially important since a DMFT value in 12-year-olds has been related to drinking water fluoride levels of between 0·26 and 1·03 p.p.m. and lesions of fluorosis have been reported in 50–60% of a sample of children from the same population who had a mean DMFT value of 2·66 [12,14]. Further data from the two studies showed that mild to severe fluorosis lesions were present in 1·0–4·5% of the affected children.

The purpose of this paper is to report on fluoride levels in bottled water, soft drinks and carbonated beverages consumed in Mexico City.

Methods

The fluoride content of drinks was determined by triplicate analysis of 283 bottled beverages of different trademarks.

One hundred and one nectars, 105 juices, 57 carbonated beverages (carbonated fruit drinks and cola drinks) and 20 bottled waters were analysed for fluoride ion content. Samples of each product were purchased from supermarkets and groceries in different areas of the Mexico City. The name of the product, lot number, the size of the bottle, the material of the container and the flavour were recorded. Nectar represents drinks made from fruits that contain small pieces of them.

A fluoride-ion-specific electrode (Model 9609BN, Orion, Cambridge, MA, USA) and a potentiometer (Model 720A, Orion) were used for fluoride measurements. Before the start a calibration curve was made using known standards between 0·1 and 10 p.p.m. fluoride. All samples were stored in a dark place and in their original closed plastic containers at room temperature until the fluoride analysis was made. For degassing, carbonated soft drinks were mixed at room temperature for approximately 30 min with a magnetic stirrer before analysis. pH was measured with a combined pH glass electrode (Model 266S, Orion).

Immediately after opening the bottles, a 10-mL sample of the product was pipetted into a polyethylene cup. Fluoride and pH measurements for each sample were made in triplicate. The sample had previously been diluted 1:1 with TISSAB II buffer solution (Orion) to prevent interference from other ions during measurements. Final millivolt readings were converted to fluoride ion concentration using the standard correlation curve.

The results were analysed using an analysis of variance and Student's *t*-test by means of the Epi-Info computer program.

Results

The fluoride concentrations found in the samples of juices, nectars, carbonated beverages and bottled waters are summarised in Table 1.

The samples were classified in four groups according to the type of container used, i.e. plastic, glass, can or cardboard box.

Approximately 49% of the juices had concentrations below 0·58 p.p.m., 36% had concentrations between 0·6 and 1·0 p.p.m, and 15% had fluoride concentrations above 1·0 p.p.m.

The results given in Table 2 show that white/red grape juices gave the highest fluoride concentration (mean = 0·75 p.p.m.), with one sample giving a value of 1·39 p.p.m. The mean fluoride concentrations for

Table 1. Fluoride concentration of soft drinks analysed in the study (n = 283).

Soft drink	Number	Concentration (p.p.m.) Mean ± SD	Range
Juices	105	0·67 ± 0·38	0·08–1·42
Cola drinks	14	0·49 ± 0·41	0·10–1·62
Nectars	101	0·44 ± 0·35	0·07–1·31
Carbonated fruit drinks	43	0·41 ± 0·34	0·11–1·70
Bottled waters	20	0·21 ± 0·08	0·08–0·37

Table 2. Fluoride concentrations of nectars and juices by flavour (n = 206).

	Concentration (p.p.m.)	
Flavour	Mean ± SD	Range
Nectars (n = *101*)		
Mixed fruit	0·91 ± 0·41	0·37–1·42
Pear	0·64 ± 0·43	0·14–0·91
Guava	0·59 ± 0·44	0·11–1·31
Peach	0·40 ± 0·33	0·11–1·22
Mango	0·37 ± 0·24	0·15–0·89
Strawberry	0·21 ± 0·01	0·20–0·22
Apple	0·20 ± 0·12	0·07–0·47
Juices (n = *105*)		
Grape	0·75 ± 0·34	0·22–1·39
Grapefruit	0·69 ± 0·41	0·40–0·98
Apple	0·57 ± 0·33	0·08–1·32
Pineapple	0·53 ± 0·42	0·13–1·18
Orange	0·50 ± 0·30	0·11–1·24

orange, pineapple, apple and grapefruit juices ranged from 0·50 to 0·69 p.p.m. However, the ranges given in Table 2 show that most of them included some samples with fluoride concentrations above 1·0 p.p.m.

Approximately 73% of samples of nectars had fluoride concentrations below 0·6 p.p.m., with five of the seven types having mean values that were less than this. Twenty-three per cent had concentrations between 0·6 and 1·0 p.p.m., and fluoride concentrations above 1·0 p.p.m. were found in at least one sample.

The highest fluoride concentrations in nectars were found in some samples of products made with more than one fruit (1·42 p.p.m.), and there was a mean of 0·9 p.p.m. for this type of drink. Pear, peach, mango, strawberry, guava and apple flavours had mean fluoride concentrations of between 0·21 and 0·64 p.p.m. However, some samples of peach and guava nectars had fluoride concentrations above 1·0 p.p.m. (1·22 and 1·3 p.p.m., respectively).

The maximum fluoride concentration seen in cola drinks was 1·62 p.p.m. (mean = 0·49 p.p.m.). Samples of carbonated fruit drinks had the highest fluoride concentrations of the whole sample (1·7 p.p.m.) with a mean of 0·41 p.p.m. (Table 1).

As can be seen from the results shown in Table 1, bottled water had fluoride concentrations between 0·08 and 0·37 p.p.m. (mean = 0·21 p.p.m.).

It could be seen that the highest mean fluoride concentration in the four groups was in juices, followed by cola drinks, nectars and carbonated fruit drinks (Table 1). None of the bottled waters tested in this study exceeded the standard value of 0·7 p.p.m. established by the Mexican authorities [16]. In

Table 3. Fluoride concentrations of juices, nectars and carbonated beverages according to type of container.

	Concentration (p.p.m.)	
Container	Mean ± SD	Range
Juices and nectars (general) (n = *206*)		
All	0·51 ± 0·38	0·07–1·42
Cardboard box	0·55 ± 0·37	0·08–1·42
Glass	0·52 ± 0·35	0·11–1·32
Can	0·19 ± 0·08	0·07–0·33
Nectars (n = *101*)		
Cardboard box	0·48 ± 0·35	0·08–1·31
Glass	0·20 ± 0·13	0·11–0·56
Can	0·18 ± 0·08	0·07–0·31
Juices (n = *105*)		
Cardboard box	0·64 ± 0·38	0·08–1·42
Glass	0·73 ± 0·28	0·27–1·32
Can	0·24 ± 0·06	0·19–0·33
Carbonated beverages (general) (n = *57*)		
All	0·43 ± 0·36	0·09–1·70
Cola	0·91 ± 0·41	0·10–1·62
Fruit	0·41 ± 0·34	0·09–1·70
Can	0·48 ± 0·39	0·18–1·62
Plastic	0·46 ± 0·39	0·09–1·70
Glass	0·33 ± 0·25	0·10–0·72
Cola drinks (n = *14*)		
Can	0·74 ± 0·56	0·24–1·62
Plastic	0·37 ± 0·27	0·12–0·80
Glass	0·34 ± 0·26	0·10–0·68
Fruit drinks (n = *43*)		
Can	0·37 ± 0·23	0·18–0·90
Plastic	0·48 ± 0·41	0·09–1·70
Glass	0·32 ± 0·26	0·10–0·72

contrast, the highest levels of fluoride were seen in some samples of carbonated soft drinks and cola drinks.

The difference between fluoride concentrations of juices and nectars proved to be statistically significant ($P < 0·0001$). Likewise, juices and nectars stored in cardboard box and glass containers showed significant differences ($P < 0·0001$) (Table 3).

Carbonated beverages with cola or fruit showed no significant differences, irrespective of whether they were enclosed in plastic, glass and can containers (Table 3). There was, however, a highly significant difference ($P < 0·0001$) between cola beverages from the two principal companies in Mexico (i.e. Coca-Cola Co. and Pepsi Co.).

Mexican consumers prefer three flavours of juices (i.e. orange, apple and grape) and four flavours of nectars (i.e. apple, peach, guava and mango) [17]. As can be seen in Table 1, important differences were seen in fluoride content for each type of these products when they were compared ($P < 0·0001$).

Discussion

The present study was designed to study fluoride levels in different beverages. The data obtained by analysing different brands of juices, nectars, carbonated beverages and bottled waters for fluoride concentration varied widely. Some brands showed higher fluoride levels than others. The most popular brands of soft drinks and juices, however, all appeared to have high fluoride levels, with some samples of each brand presenting values greater than 1·0 p.p.m.

Previous studies have reported on fluoride levels in products consumed in Mexico [3,18], but the fluoride content of beverages and the quantity of beverages consumed by children have not been extensively studied. The range of fluoride concentrations in drinks may differ as a result of factors such as geographical zone, temperature, altitude [19] and origin of the water supply [9]. The most important studies in Mexico have been made in those areas identified as zones of endemic fluorosis [2,3]. However, the custom of drinking water has begun to be replaced by soft drinks, bottled waters and carbonated beverages in cities throughout Mexico, including those not identified as risk areas for fluorosis [9,10,18]. This may be particularly important since, according to the report of Barón [10], the Mexican population lies in second place in the world for consumption of carbonated beverages, with Mexico City having the highest consumption of soft drinks in the country.

The finding that the products of the two main manufacturers of cola beverages presented different fluoride concentrations suggests that control of the water used for manufacturing these products may not exist in the products sold in the market in Mexico City. This could be connected to the fact that not all of them are manufactured in the Mexico City metropolitan area and they can be transported from different zones close to Mexico City. This means that water from different sources containing different fluoride concentrations is used in the manufacture of this kind of beverage.

It is known that fluoride has an affinity for metal and glass materials, reducing the fluoride concentration present in the contents. However, the majority of the beverages tested here are sold in plastic or cardboard containers [20]. In this study, products sold in glass and metal containers showed the lowest fluoride concentration when compared with those sold in cardboard or plastic containers. The Mexican Ministry of Health should perhaps recommend preferential use of glass or metal containers.

The results of this study show that the highest fluoride concentration was in cola beverages, juices and nectars (1·70, 1·42 and 1·31 p.p.m., respectively) and that these results (except those for cola drinks) may be related to the recognizable fruit content [21].

A halo effect may occur when food and beverages are produced with fluoridated water, and then shipped for consumption in communities with lower fluoride levels in water. Manufacturers may distribute and sell products at a distance from where the product was manufactured or where the water source exists, and this may potentially contribute to an increase in prevalence of dental fluorosis in areas such as Mexico City where water supplies have low fluoride concentrations [11].

Although the main risk of developing dental fluorosis may be among the children of Mexican communities living in areas with high fluoride concentrations in drinking water [1,3], these results suggest that this situation may change as a result of the introduction of beverages, foods, supplements and dentifrices with variable and sometimes unknown fluoride concentrations [22–24].

The fluoride content of beverages prepared with water varied among products made by different manufacturers as well as among similar products made by the same company [9]. Variability in fluoride concentration among beverages is mainly determined by the fluoride content of the water used at the time of manufacture, but may also be affected by the fruit used, which may derive from several different places. We found wide variations in fluoride concentrations in all the fruit-based beverages tested here (range = 0·07–1·7 p.p.m.).

In contrast to other studies [7,18,25–30], the current results relating to fluoride concentrations in bottled waters showed these to be lower than in other drinks. This may be related to the fact that these products are manufactured and distilled by evaporation in Mexico, a method that eliminates minerals.

There have been several previous studies on the fluoride content of foods and drinks, but these studies have most often been limited to foods produced in the USA, Canada and the UK [4,6,8,21,31–34]. Some previous information is available for beverages used in Mexico. In one report on drinks in Toluca City, Mexico, the mean fluoride concentrations in soft drinks were 0·16 p.p.m. in bottled water (range = 0·052–0·48 p.p.m.), 0·34 p.p.m. in juices (range =

0·14–1·04 p.p.m.) and 0·23 p.p.m. in carbonated beverages (range = 0·055–0·46 p.p.m.) [18]. These results are similar to current findings. In San Luis Potosí City, Mexico, higher values were reported for the fluoride content in bottled water (0·27–1·01 p.p.m.), carbonated soft drinks (0·33–3·71 p.p.m.) and apple juices (0·2–2·9 p.p.m.) [18]. In the Mexican States of Jalisco, Zacatecas, Querétaro and San Luis Potosí, fluoride concentrations in juices have varied between 1·32–4·40 and 0·33–4·12 p.p.m. for carbonated drinks [3]. The differences in the fluoride concentrations of similar products sold in the Mexico City market could be related to the fact that the water in Mexico City has lower fluoride concentrations.

The results of the current study show that there were large variations in fluoride concentration among the brands tested, and even from lot to lot for a particular brand. The large differences between *F*-values found in this study and those reported previously in the Mexican literature suggest that the composition of the beverages is not uniform or necessarily consistent.

The wide ranges of fluoride concentrations in bottled waters and other beverages make the real fluoride intake by the population very difficult to assess. Wide variations in dietary patterns add further to the complexity.

The variation in fluoride sources assessed in this study, and the high values shown, suggest that there may be a risk of dental fluorosis in Mexico City. This should be evaluated by the authorities responsible for oral health, and it should be borne in mind that fluoride levels in water supplies and salt may not be the only fluoride risk factors [35].

All fluoride sources are important, and it is understood that total fluoride intake from all sources is critical in the development of fluorosis [9,36–40]. The amount of fluoride necessary to cause fluorosis is not precisely known, and variations among individuals probably exist [9].

In infancy, the main fluoride sources are thought to be from commercially available beverages and foods used during weaning, a period is coincident with the stage of calcification in several developing permanent tooth crowns [41]. In addition to fluoride concentrations in products, the quantities consumed and the age of the child are also important [6,9]. For young children who regularly consume juices, nectars, carbonated drinks and bottled water with variable fluoride concentrations, the relatively small fluoride quantities contained in them may substantially increase their total fluoride intake [34].

It is important that manufacturers recognize and monitor fluoride concentrations, especially in the water and fruits they are using to manufacture their products. If necessary, fluoride levels should be modified in the final product. It is important that labels should contain all the nutritional information about the product, including fluoride concentration.

We recommend that more studies of fluoride concentration in beverages and foods be carried out, with the aim of determining the fluoride consumption of the Mexican population more precisely, particularly amongst infants and young children. It is important to note that the rising intake of bottled water, carbonated beverages, juices and flavoured juices in Mexico may be partially related to the fact that Mexican population is not confident regarding the potability of the water supply, but this phenomenon is also seen elsewhere in the world.

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Résumé. *Objectif*. L'objectif de notre étude a été d'analyser 283 échantillons: 105 jus de fruits, 101 nectars, 57 boissons sucrées et 20 eaux embouteillées disponibles dans les marchés de la ville de Mexico. *Echantillons et methodes*. Des échantillons de boissons ont été analysés à l'aide d'un potentiomètre Orion 720A et d'une électrode Orion 9609BN spécifique à ion F.
Resultats. La concentration en fluor des produits cités précédemment allait de 0,07 à 1,42 ppm. Les concentrations en fluor variaient selon la marque, le parfum et la présentation du produit. La moyenne en fluor la plus élevée a été retrouvée dans des jus et des boissons de type cola (0,67 ± 0,38 et 0,49 ± 0,41 ppm respectivement). LA concentration moyenne des boissons sucrées était de 0,43 ± 0,36 ppm. Les eaux embouteillées présentaient une concentration de 0,21 ± 0,08 ppm.
Conclusions. Nos données suggèrent que le fluor ingéré à travers les boissons embouteillées représente une partie importante du fluor ingéré par notre population. Etant donné les grandes variations de concentration en fluor dans les produits testés, il est nécessaire d'établir des recommandations pour le contrôle de la concentration afin d'empêcher les lésions de fluorose dentaire.

Zussamenfassung. *Ziele.* Ziel unserer Studie war es, 283 Proben zu analysieren: 105 Säfte, 101 Nektare, 57 kohlensäurehaltige Getränke, 20 in Flaschen abgefüllte Wassersorten, die in Mexico City käuflich zu erwerben sind.
Stichprobe und Methoden. Die Getränkeproben wurden mit einem Orion 720A Spannungsmesser und einer orion 9609 BN ionenselektiven Elektrode analysiert.
Ergebnisse. Die Fluoridkonzentrationen in den oben erwähnten Produkten lagen zwischen 0.07 ppm und 1.42 ppm, sie schwankten je nach Hersteller, Geschmack und Sorte des Produktes. Die höchsten Werte wurden gefunden bei Säften und Colagetränken (0.67 +/– 0.38 und 0.49 +/– 0.41). Die mittlere Fluoridkonzentration von kohlensäurehaltigen Getränken war 0.43 +/– 0.36 ppm. Wasser wies 0.21 +/– 0.08 ppm Fluorid auf.
Schlussfolgerungen. Unsere Ergebnisse zeigen, dass die Fluoridaufnahme durch Getränke einen nicht unerheblichen Teil der Fluoridaufnahme insgesamt ausmacht. Angesichts der großen Variation an Fluoridkonzentrationen in den untersuchten Getränken erscheint es erforderlich, in die entsprechenden Empfehlungen wirksame Kontrollmechanismen zur Fluoridkonzentration zu implementieren, um Dentalfluorose zu vermeiden.

Resumen. *Objetivo.* El objetivo de nuestro estudio fue analizar 283 muestras: 105 zumos, 101 néctares, 57 refrescos y 20 aguas embotelladas disponibles en el mercado metropolitano de Ciudad de Méjico.
Muestra y métodos. Las muestras de las bebidas se analizaron usando un potenciómetro Orion 720ª y un electrodo ion-específico Orion 9609BN F.
Resultados. La concentración de flúor en los productos arriba mencionados osciló entre 0,07 y 1,42 ppm. Se encontró que las concentraciones de flúor variaban según la marca, el sabor y la presentación del producto. La media más alta de flúor se encontró en los zumos y las bebidas de cola (0,67 ± 0,38 y 0,49 ± 0,41 ppm respectivamente). La concentración media de flúor para las bebidas carbonatadas fue 0,43 ± 0,36 ppm. Las aguas embotelladas tenían 0,21 ± 0,08 ppm de concentración de flúor.
Conclusiones. Nuestros hallazgos sugieren que la ingesta de flúor a través de las bebidas embotelladas representa una parte importante del Fl total ingerido por nuestra población. En vista de la amplia variación de la concentración de Fl en los productos probados, es necesario confeccionar guías reguladoras para controlar su concentración y prevenir lesiones de fluorosis dental.

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