FLUORIDE CONTENT OF DAIRY MILK FROM SUPERMARKET
A POSSIBLE CONTRIBUTING FACTOR TO DENTAL FLUOROSIS

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SUMMARY: Fluoride analyses were carried out on 42 different types and brands of milk obtained from supermarkets. The average fluoride content of dairy milk is 0.030 ppm, with a range of 0.007 to 0.068. Soy milk contains as much as 0.491 ppm fluoride. Infant daily fluoride intake as low as 0.04 mg/kg body weight can result in fluorosis of the permanent dentition. Therefore, in view of the very large variation in milk fluoride content, it is suggested that daily consumption of milk with high fluoride content could be a contributing factor to increased prevalence of dental fluorosis. In view of results of the present study, monitoring of fluoride content in dairy milk available from supermarkets may be necessary.

Key words: Fluoride; Dairy milk; Dental fluorosis.

Introduction

The deciduous teeth undergo substantial mineralization during the first year of life, and fluoride provided during this period is reported to give significant protection against caries in deciduous teeth, when available from birth onwards.[1,2] During the first year of life, besides rapid bone growth, enamel formation in the primary teeth is being completed, and hard tissue formation has begun for the permanent central, lateral, canine and first molar teeth. When systemic fluoride is incorporated into the developing teeth, it is believed to increase the crystallinity of the enamel and possibly also to enhance the morphogenesis of the teeth by making the pits and fissures shallower.[3] Fluoride has therefore been widely used as a caries preventive agent both topically and systemically.[4,5]

Milk is a universal food for newborn and growing mammals and contains all of the essential nutrients for their development and growth. Since purchased milk is consumed by a large percentage of children, the natural fluoride content in milk could conceivably play a significant role in enhancing the mineralization of deciduous teeth in children.[6,7] Milk has also been reported to be a useful vehicle to deliver fluoride to infants and young children for prevention of dental caries.[8,9] However, the dosage of fluoride to achieve optimum caries reduction appears to be extremely critical during the first year of life in order not to exceed levels which produce dental fluorosis.

According to the literature, the values for the fluoride content of cow's milk and milk formulas span a wide range, between 0.02-0.8 ppm.[10,11] It is the goal of this

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study to determine the fluoride level in dairy milk available in the typical US supermarket.

Recent studies have reported an increase of enamel fluorosis in the population of US children.[12] One of the suggested causes has been an increase of dietary fluoride intake by the children.[13-15] Therefore, the second goal of this study is to determine if the variation of fluoride content of different types and brands of dairy milk available in supermarkets could be a contributing factor in enamel fluorosis in the child population.

Materials and Methods

Forty-two different types and brands of milk were purchased from supermarkets in the Houston, Texas, area. All samples were kept at 4°C in a refrigerator. Within five days, fluoride analysis of all the samples was carried out by the hexamethyldisiloxane-microdiffusion method reported by Taves.[16] In order to facilitate the accuracy of fluoride determination, each milk sample was diluted 1:1, v:v, with an aqueous solution containing 0.19 ppm fluoride as sodium fluoride. This known amount of added fluoride was subtracted to provide the true fluoride content of the milk. The fluoride content of each milk sample recorded in this study represented the average value of quintuplicate analysis.

Fluoride measurements were performed with a Corning double junction reference electrode in conjunction with an Orion Research microprocessor pH/millivolt meter, Model 811. ANOVA and Tukey test were used to determine the significance of differences.

Results

The fluoride content of milk samples available from Houston supermarkets is rather low; however, it varies almost ten-fold, from 0.007 to 0.068 ppm (Table 1). Among the 42 different milk brands that were analysed for fluoride, 14 samples (33%) contained less than 0.02 ppm F; 20 samples (48%) contained 0.02 to 0.04 ppm F; and 8 samples (19%) contained more than 0.04 ppm F (Table 1).

Among the different types of milk, homogenized vitamin D milk contained the lowest fluoride content (0.018 ± 0.006 ppm), while the soy milk contained the highest fluoride content (0.491 ppm) (Table 2). The difference in fluoride content of these two types of milk was statistically significant ($P < 0.01$). The fluoride content in protein fortified milk was also significantly greater than that in homogenized milk, ($P < 0.01$).

Among the different brands of milk that were investigated, Oak Farms milks (0.042 ± 0.005 ppm) contained significantly ($P < 0.05$) more F than Borden milks (0.022 ± 0.005 ppm) (Table 3). With the exception of soy milk (a non-dairy soybean product) which has a fluoride content of 0.491 ppm, the average fluoride content of all the bovine milks that were analysed in this study was low (0.030 ± 0.02 ppm).

TABLE 1. FLUORIDE CONTENT OF VARIOUS MILK BRAND IN PARTS PER MILLION

MILK BRAND	F CONTENT
Apple-Tree; GA, P, H; vit D milk	0.019
Apple-Tree; lowfat milk; 2% milkfat; vit A & D	0.043
Apple-Tree; GA, P; skim milk; vit A & D	0.033
Borden; H; vit D milk	0.015
Borden; skim-milk; vit A & D	0.013
Borden; Lite-line; GA, P, H; protein fortified skim milk; vit A & D	0.038
Borden; Hi-protein, 2% low fat; protein fortified; vit A & D	0.039
Borden; Golden Churn, Cultured lowfat Buttermilk 1.5% milkfat	0.016
Borden; GA, P; Dutch chocolate milk; vit D	0.028
Borden; half and half	0.007
Dairy Ease; lactose reduced; nonfat milk; H; ultra-P; vit A & D	0.040
Dairy Ease; lactose reduced, 1% lowfat milk; H; ultra-P; vit A & D	0.026
Fiesta; GA, P, H; lowfat milk; vit A & D	0.042
Fiesta; GA, P, H; vit D	0.013
Hygeia; H; vit D	0.022
Kroger; GA; vit D; 3.25% milkfat	0.016
Kroger; 2% milkfat; lowfat milk, vit A & D	0.019
Kroger; GA, P, H; a blend of cream and milk; half and half; 10.5% milkfat	0.035
Lactaid; special digestible; lactose reduced; ultra-P; lowfat milk; vit A & D	0.007
Lactaid; specially digestible; lactose reduced; H; ultra-P, lowfat milk, 1% milk; vit A & D	0.015
Nestle; Quik chocolate milk; GA, P, H; vit D.	0.017
Nestle; Quik artificial flavor; GA, P, H; strawberry milk; vit D	0.019
Oak Farms; GA, P, H; vit D	0.035
Oak Farms; GA, P, H; vit A & D; lowfat milk, 2% milkfat	0.031
Oak Farms; Cultured lowfat buttermilk; 1% milkfat	0.038
Oak Farms; Protein fortified skim milk; vit A & D	0.040
Oak Farms; ultra-P; half and half	0.039
Oak Farms; chocolate milk	0.068
Olde Tyme; GA, H; ultra-P; Heavy whipping cream; 36% milkfat	0.027
Plum Flower; soy milk	0.491
Randall; GA, P; vit A & D; 2% low milkfat	0.024
Schepps; GA, P, H; 2% lowfat milk; vit A & D	0.033
Schepps; H; vit D	0.011
Schepps; cultured lowfat buttermilk; 1% milkfat	0.022
Schepps; protein fortified; skim milk; vit A & D	0.050
Schepps; GA, P; half and half	0.063
Schepps; GA, P; chocolate milk	0.058
Sealtest; H; vit D	0.007
Sealtest; chocolate milk	0.038
Sealtest; cultured lowfat; buttermilk; 1% milkfat	0.032
Sealtest; ultra-P; half and half	0.050
Super Fresh; GA, P; vit D	0.027

GA = Grade A
P = Pasteurized
H = Homogenized

TABLE 2. RANGE AND MEAN FLUORIDE CONTENT OF DIFFERENT TYPES OF MILK IN PARTS PER MILLION

MILK TYPE	RANGE	MEAN ± SEM[a]
Homogenized milk(9)	0.011 - 0.035	0.018 ± 0.006
Lactose reduced milk(4)	0.007 - 0.040	0.022 ± 0.007
Skim milk(6)	0.013 - 0.050	0.032 ± 0.005
Butter milk(4)	0.020 - 0.038	0.032 ± 0.005
Low fat milk(6)	0.024 - 0.043	0.035 ± 0.017
Half & Half milk(5)	0.007 - 0.063	0.038 ± 0.009
Chocolate milk(5)	0.017 - 0.058	0.042 ± 0.009
Protein fortified milk(4)[b]	0.038 - 0.050	0.042 ± 0.003[c]
Strawberry milk(1)	0.019	0.019
Soy milk(1)	0.491	0.491

a Standard error of mean
b Three of these milks are also classified as skim milk
c Significantly differed from homogenized milk, $P < 0.01$

TABLE 3. RANGE AND MEAN FLUORIDE CONTENT OF DIFFERENT BRANDS OF MILK

MILK BRAND (N)	RANGE	MEAN ± SEM
Appletree (3)	0.019 - 0.043	0.032 ± 0.007
Borden (7)	0.007 - 0.039	0.022 ± 0.005
Dairy Ease (2)	0.026 - 0.042	0.030 ± 0.010
Fiesta (2)	0.013 - 0.042	0.028 ± 0.001
Hygeia (1)	0.022	0.022
Kroger (3)	0.016 - 0.035	0.023 ± 0.006
Lactaid (2)	0.007 - 0.015	0.010 ± 0.001
Nestle (2)	0.017 - 0.019	0.018 ± 0.001
Oak Farms (6)	0.031 - 0.068	0.042 ± 0.005
Olde Tyme (1)	0.027	0.027
Plum Flower, Soy Milk (1)	0.491	0.491
Randall (1)	0.024	0.024
Schepps (6)	0.011 - 0.058	0.040 ± 0.008
Sealfest (4)	0.007 - 0.050	0.032 ± 0.009
Super Fresh (1)	0.027	0.027

Discussion

The level of fluoride in milk has been a subject of disagreement for many years. With advances in analytical technology, the reported fluoride content has steadily declined. More recent studies have reported the level of ionic fluoride in bovine milk to range from 0.007 to 0.086 ppm, while those in human milk ranged from 0.009 to 0.065 ppm.[14,17-20] Therefore, the fluoride content of cows' milk found in this study is within the range obtained by other laboratories.

However, unlike a previous report of 1978,[20] the present study demonstrates large variation in fluoride content of different brands of milk, and even within the

same brand that is processed in a different geographical location. Thus, Borden milk processed in Columbus, Ohio, with a mean fluoride concentration of 0.022 ppm, contained the lowest level of fluoride; Oak Farms milk bottled in Dallas, Texas, with a mean fluoride concentration of 0.042 ppm, contained almost twice as much fluoride (Table 3). Such variation could be introduced by the difference in water fluoride content of the farms where these dairy cows are being raised and by the water fluoride level of factories where cows' milk was being processed.[21,22]

The fluoride content of milk may be influenced by the interaction between fluoride and milk, as well as by the wide variety of heat-treatment processes used for pasteurization.[23,24] The variation in fluoride content between different brands and types of milk may be due to differences in the source of the "raw" milk, the heat-treatment, and the type of milk product.

On average, homogenized milk contained the lowest level of fluoride (0.018 ppm). This value is similar to values reported from other laboratories.[20,22] The mean fluoride content of skim milk, buttermilk, low-fat milk, and "half & half" milk is slightly higher than that of homogenized milk and lactose-reduced milk. However, this difference is not statistically significant. Protein-fortified milk contains twice the amount of fluoride found in homogenized milk, and the difference is statistically significant at $P<0.01$. Five different brands of chocolate milk were also analyzed for fluoride: the values varied from 0.017 ppm (Nestle) to 0.058 ppm (Schepps), with a mean figure of 0.042 ppm. The above difference may due to variation in the fluoride content of water and/or cacao beans from which the chocolate was obtained.

Recently there has been growing concern about the increase in the prevalence of dental fluorosis in the US child population.[12,15,25] It has been suggested that, apart from systemic fluoride supplementation,[26,27] other potential contributing factors to dental fluorosis include fluoride in the water supply,[15] canned juices,[28] carbonated beverages,[29] infant formulas,[11,28] commercially prepared infant food,[11,30] tooth-paste used at an earlier age,[31] and mouthrinses[15].

Milk consumption in infancy and early childhood increases with the age and weight of the child. An infant may depend entirely on cows' milk for his or her daily source of caloric intake. Even though the average fluoride concentration in cows' milk is low, because of the very large variation in fluoride content of different brands of dairy milk, an individual dairy milk with an unusually high fluoride content could contribute significantly to the increase in prevalence of dental fluorosis in the US population. Although milk is known to interfere with the rate of fluoride absorption, a human study has demonstrated that 67 to 82% of total fluoride in milk is absorbed.[32]

A typical six-month old infant weighing about 7 kg consumes about 1.2 liters of fluid daily. If the fluid happens to be a certain brand of milk that contains 0.068 ppm fluoride, then the daily fluoride available from milk alone could be as much as 0.059 mg. In view of the estimation that, for infants, a daily intake of fluoride as low as 0.04 mg/kg body weight can result in dental fluorosis of the permanent dentition,[33] a daily fluoride intake of 0.059 mg from milk will represent 21% of daily fluoride intake of the borderline ($7 \times 0.04 = 0.28$ mg) for dental fluorosis. Even though consumption of milk alone is not likely to cause dental fluorosis, intake of

milk with high fluoride content together with fruit juices, beverages such as tea,[34] and baby food, especially those with meat containing considerably more fluoride than milk, the safety level of daily fluoride consumption could easily be exceeded by such combination of diet.

Furthermore, in infants who are allergic to cows' milk, soy-based milk is often substituted, and this contains as much as 0.491 ppm fluoride (Table 1), easily exceeding the safety level for prevention of dental fluorosis. Health-care providers therefore need to take into consideration the fluoride level of the milk that is being consumed by their pediatric patients when prescribing fluoride supplementation. Results from the present investigation show that there is a need to monitor the fluoride content of milk available from supermarkets. Dairy companies should consider providing the public with information on fluoride content of all dairy products.

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