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# Fluoride concentrations in salt marketed in Managua, Nicaragua

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**Abstract:** Nicaraguan legislation has established that fluoride concentrations in salt should be 200–225 mg/kg, but no report describes fluoride concentrations in salt marketed in this country. We evaluated the fluoride concentrations in 33 packages of salt of 11 brands (n = 3 each) purchased in Managua, Nicaragua. According to the package information, 9 of the 11 brands were fluoridated. Six aliquots of each package were weighed (mean 2.5 ± 0.3 g; n = 198) and dissolved in 0.025 g/ml water. Duplicates of 1.0 ml of solutions prepared were buffered (1:1; v/v) with TISAB II. Fluoride concentrations were determined with ion-specific electrode, calibrated with standard solutions (0.25–16.0 µg F/ml) mixed (1:1; v/v) with TISAB II added to 0.025 g (p.a.) NaCl/ml. The mean (± standard deviation, n = 3) fluoride concentrations of two fluoridated brands were in accord with Nicaraguan law (209.8 ± 48.0 and 211.4 ± 26.0 mg F/kg), and those of five brands were below the mandated range (131.0 ± 34.3, 180.6 ± 12.3, 184.6 ± 34.8, 190 ± 47.2, and 199.0 ± 18.9 mg F/kg); two brands contained only traces of fluoride. The two non-fluoridated brands had traces of fluoride. The findings show that the surveillance system for the salt fluoridation program in Nicaragua should be improved, as most salt analyzed violated the requirements of the national legislation.

**Keywords:** Fluoridation; Sodium Chloride; Dental Caries; Ion-Selective Electrodes.

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## Introduction

Community-based methods of fluoride use, such as water and salt fluoridation, play important roles in the control of dental caries.[1] When water fluoridation is not feasible, salt fluoridation is recommended as an alternative community approach.[2] In Latin America, the adoption of salt fluoridation programs has increased since 1986.[3]

An effective surveillance system is required as part of a salt fluoridation program to ensure balance between the anticaries effect of fluoride (benefit) and the minimization of dental fluorosis (risk). Thus, the Pan American Health Organization has emphatically recommended the monitoring of fluoride concentrations in salt marketed in countries with salt fluoridation programs.[4] However, fluoride concentrations in violation of local legislation have been found in salt brands marketed in México, Colombia, Peru, El Salvador, and Guatemala.[5,6,7,8,9,10,11,12,13]

In Nicaragua, a law mandating the fluoridation of salt for human consumption was approved in 2007,[14] with an acceptable fluoride concentration range of 200–225 mg/kg.[15] However, no report has described fluoride concentrations in salt marketed in this country. Therefore, the aim of this study was to evaluate whether salt marketed in Managua, Nicaragua, was properly fluoridated.

## Methodology

### Salt samples

This exploratory *in vitro* study with blinded laboratory analysis was conducted to determine the fluoride concentrations of 11 salt brands sold in three main supermarket chains and one popular market in the city of Managua, Nicaragua. Three packages of salt of each brand were purchased in July 2016, preferably from different stores. A fourth package of salt of each brand was purchased and stored for further analysis. Fluoridated and non-fluoridated salt used for cooking was included in the study. Salt packaged in small containers for table or barbecue use was not included. Each package (1, 2, 3 and x per brand) was coded according to the place of purchase to allow for blind analysis (Table 1). Information declared on the labels of salt packages about the producer, batch, expire time, granulation, declaration of fluoride addition, and fluoride concentration is presented in Table 2.

### Sample preparation

Pre-weighed plastic-capped tubes (10 ml each) were used to transport the salt samples from the country of purchase (Nicaragua) to the laboratory (Brazil) for analysis. Salt from each package was placed in a round plastic container and homogenized with rotatory movements for 2 min using a soup spoon.[16] Six salt aliquots of approximately 2.5 g each were harvested from the top of the container and transferred individually to codified tubes.

The capped tubes with the salt samples were weighed using a precision balance (± 0.1 mg), and the weight of the salt was calculated (mean 2.5 ± 0.3 g; n = 198). The samples were dissolved in purified water in the proportion (w/v) of 0.025 g salt/1.0 ml water.

### Fluoride analysis

Within 2 months of sample acquisition, the fluoride concentrations of the salt solutions were determined with ion-specific electrode (ISE) by the direct method, using a protocol validated for fluoride analysis in salt.[13,16,17] This protocol has been shown to recover 96–98% of fluoride added to salt, and its analytical relevance for adjustment of the ionic strength of fluoride standards with pure NaCl has been confirmed.[13,16,17] Standard fluoride solutions

**Table 1.** Salt brands according to place of purchase and coding.

| Brand | Code | Place of purchase | | | |
|---|---|---|---|---|---|
| | | La Unión supermarket | La Colonia supermarket | Pali supermarket | Roberto Huembes market |
| Atlántida Gruesa | A | $A_1$, Ax | - | $A_2$, $A_3$ | - |
| Sabemas | B | $B_1$, Bx | - | $B_2$, $B_3$ | - |
| La Cocinera | C | - | $C_1$, $C_2$, $C_3$, Cx | | - |
| Atlántida fina | D | $D_1$, Dx | $D_2$ | $D_3$ | - |
| Atlántida refinada | E | $E_1$, $E_2$, $E_3$, Ex | - | - | - |
| Sol | F | $F_1$, Fx | $F_2$, $F_3$ | - | - |
| Suli | G | $G_1$, Gx | - | $G_2$, $G_3$ | - |
| Solar | H | $H_1$, $H_2$, $H_3$, Hx | - | - | - |
| Blanca Nieves | I | - | $I_1$, $I_2$, $I_3$, Ix | - | - |
| Cali-Sal | J | - | - | - | $J_1$, $J_2$, $J_3$, Jx |
| Flipper | K | - | - | - | $K_1$, $K_2$, $K_3$, Kx |

**Table 2.** Salt brand characteristics, according to label information.

| Brand | Code | Producer | Batch | Expire | Granulation | Declaration of fluoride addition | Fluoride concentration indicated (mg/kg) | Ingredients |
|---|---|---|---|---|---|---|---|---|
| Atlántida Gruesa | A | Cosermusalni, R.L e Nicasal (Nicaragua) | n.d. | n.d. | Coarse | Yes | 200–225 | NaCl (97%), F, I, potassium ferrocyanide (10 mg/kg) |
| Sabemas | B | Nicasal (Nicaragua) | n.d. | n.d. | Refined | Yes | 200–225 | NaCl, KF, $KIO_3$, $SiO_2$ |
| La Cocinera | C | Salnicsa (Nicaragua) | $C_1$, $C_2$, $C_3$: 0006 | $C_1$, $C_2$, $C_3$: Dec/20 | Fine | Yes | 200–225 | NaCl, KF, $KIO_3$ |
| Atlántida fina | D | Cosermusalnc, R.L e Nicasal (Nicaragua) | n.d. | n.d. | Fine | Yes | 200-225 | NaCl (97%), F, I, potassium ferrocyanide (10 mg/kg) |
| Atlántida refinada | E | Cosermusalni, R.L e Nicasal (Nicaragua) | n.d. | n.d. | Refined | Yes | 200–225 | NaCl (99.5%), F, I, $SiO_2$ (max. 2%) |
| Sol | F | Coonarprosal R.L (Costa Rica) | $F_1$: 0416<br>$F_2$: 0216<br>$F_3$: 1015 | n.d. | Refined | Yes | 200–225 | NaCl, F, I |
| Suli | G | Nicasal (Nicaragua) | $G_1$: 0025<br>$G_2$: 0026<br>$G_3$: 0021 | n.d. | Fine | Yes | n.d. | NaCl, KF, $KIO_3$, potassium ferrocyanide |
| Solar | H | Coonarprosal R.L (Costa Rica) | $H_1$: 0115<br>$H_2$: 0316<br>$H_3$: 0615 | n.d. | Ground | Yes | 200–225 | NaCl, F, I |
| Blanca Nieves | I | Salnicsa (Nicaragua) | n.d. | $I_1$: Jul/17 $I_2$, $I_3$: Jul/20 | Fine | Yes | 200–225 | NaCl, KF, $KIO_3$ |
| Cali-Sal | J | Producer María Calderón | n.d. | n.d. | Fine | No | Non-fluoridated | NaCl (98%), I, potassium ferrocyanide |
| Flipper | K | Producer María Calderón | n.d. | n.d. | Coarse | No | Non-fluoridated | NaCl, I |

n.d.: not declared.

ranging from 0.25 to 16.0 µg F/ml, mixed with TISAB II (1:1, v/v) added to 0.025 g NaCl/ml, were used to calibrate the equipment (electrode Orion 96-09 coupled to an ion analyzer Orion Star A214; Thermo Scientific, Cambridge, MA, USA).

### Data analysis

Linear regression of the logarithm of fluoride concentrations of the standard solutions was performed and respective mV values were calculated. The mathematical equation of regression was used to determine the fluoride concentrations of the salt solutions (in milligrams fluoride/kilogram; Figure). Mean concentrations and standard deviations were calculated for the six aliquots from each package, and for the three packages of each brand. The results were compared descriptively with the fluoride concentration range established by the Nicaraguan regulations. The average coefficient of variation from duplicate analyses was 1.8% (n = 198). Analyses were conducted using Excel software (Microsoft Corporation, Redmond, WA, USA).

## Results

Of the 11 salt brands purchased in Managua, only one brand (D) was found in three different locations; four brands (A, B, F, and G) were found in two locations and six brands (C, E, H–K) were found in only one location (Table 1). According to the label information, salt of two brands (F and H) was imported from Costa Rica and salt of the

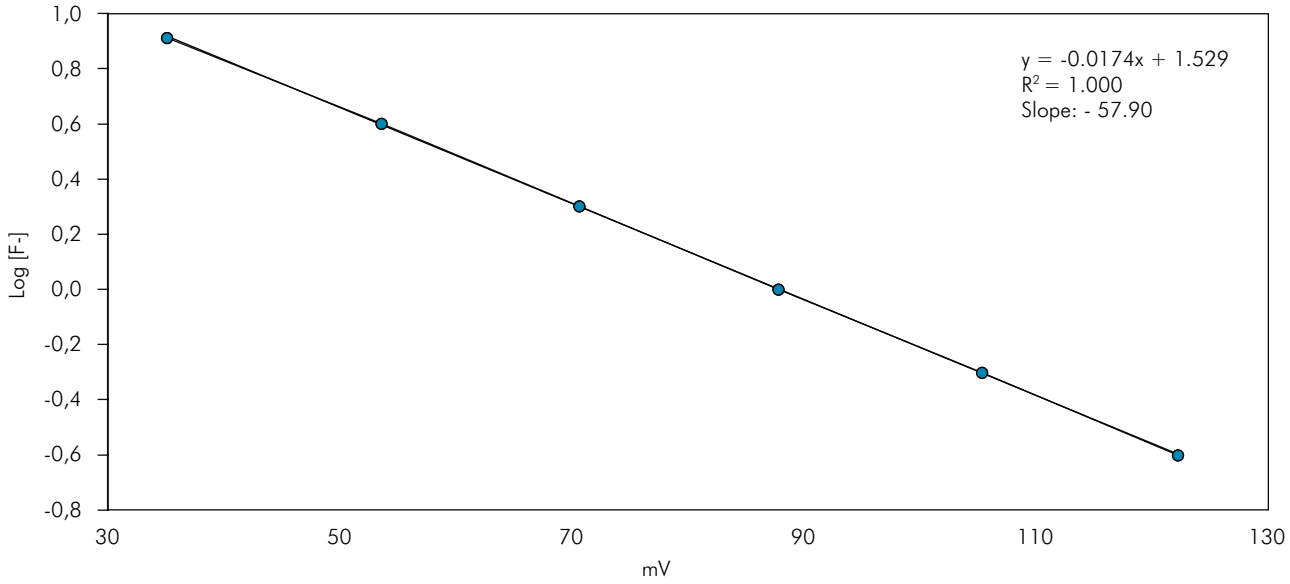


**Figure.** Calibration curve for correlation of the logarithm of fluoride concentrations in standards and the relative mV generated (mean = 9).

remaining brands was produced locally (Table 2). Two brands of salt (J and K) were not fluoridated and the remaining nine brands were fluoridated. Among the fluoridated brands, eight (A–F, H, and I) were labelled as containing 200–225 mg F/kg; the concentration of brand G was not declared. Labels indicated that potassium fluoride was used as the fluoride agent for four fluoridated brands; for the remaining five brands, the fluoride agent was not disclosed.

As declared on the labels, salt of five (45.4%) brands was finely granulated, that of three (27.2%) brands was refined and granulated, that of two (18.1%) brands was coarsely granulated, and that of one (9%) brand was ground and granulated (Table 2). Batch numbers were presented for four brands (C, F–H). The packages of brand C were from the same batch, and those of brands F–H were from different batches.

Overall, the mean fluoride concentrations in salt of the 11 brands (n = 3 each) ranged from traces (< 1.8 mg/kg) to 211.4 mg/kg (Table 3). Among fluoridated salt brands, fluoride concentrations of two brands (D and F) were in accord with the Nicaraguan legislation (209.8 ± 48 and 211.4 ± 26.0 mg/kg, respectively) and those of five brands (A, B, E, G, and H) were below the legislated range (131.0 ± 34.3, 180.6 ± 12.3, 184.6 ± 34.8, 190.0 ± 47.2, and 199.0 ± 18.9, respectively); salt of two brands (I and C) contained only traces of fluoride (below the ISE detection limit). Traces of fluoride were also found in the two non-fluoridated brands (J and K). Among the three packages per brand tested, greater variability was observed for brands A, B, D, and G, than for brands E, F, and H.

**Table 3.** Means and ranges of fluoride concentrations (mg/kg; n=3/brand) found in salt samples.

| Brand | Code | Found mean | Range |
|---|---|---|---|
| Flipper | K | trace (<3.2) | - |
| Cali-Sal | J | trace (<3.3) | - |
| Blanca Nieves | I | trace (<1.8)a | - |
| La Cocinera | C | trace (<18.6)b | - |
| Atlántida Gruesa | A | 131.0 ± 34.3c | 104.9–169.8 |
| Atlántida refinada | E | 180.6 ± 12.3 | 168.4–191.6 |
| Sabemas | B | 184.6 ± 34.8 | 151.2–221.8 |
| Suli | G | 190.0 ± 47.2 | 135.7–221.9 |
| Solar | H | 199.0 ± 18.9 | 186.3–219.0 |
| Atlántida fina | D | 209.8 ± 48.0 | 156.1–243.8 |
| Sol | F | 211.4 ± 26.0 | 190.3–240.4 |

[a,b,c]Concentrations confirmed with ion-specific electrode after microdiffusion (< 1.7, < 8, and 115.5 ± 14.2, respectively).

## Discussion

Salt fluoridation has been widely implemented as a public health strategy to reduce dental caries,[2] but the monitoring of the fluoride concentration in salt is mandatory to guarantee the balance between benefits and risks of this way of fluoride use.[4] In Nicaragua, the salt fluoridation program is supported by law since 2007,[14] but there is no study about the fluoride concentration in salts marketed in this country. We believe that this is the first study that evaluated fluoride concentration in salts for human consumption marketed in Nicaragua.

The findings of this study reveal several problems with the salt fluoridation program in Nicaragua. The first issue is program coverage; although the legislation mandates that all salt sold in the country is fluoridated,[14] 2 of the 11 salt brands analyzed in this study were not fluoridated and 2 brands contained only traces of fluoride. Thus, salt of these four brands (36% of those tested) had no anticaries potential. The other seven (64%) brands were fluoridated, but concentrations were sufficient in only two (29%) brands. Although in violation of the legislation, the low fluoride concentrations in most of this salt (except brand A) do not raise concern regarding anticaries effects, as they were very close to optimal. Salt of brand A, which had a low fluoride concentration, was coarsely granulated; the proportionally smaller surface area relative to those of fine particles may affect the final fluoride concentration.[4] The concentration in brand H salt, which was ground, was very close to the minimum permitted. As no salt was over-fluoridated, our findings raise no concern regarding the increased risk of dental fluorosis.

Fluoride concentrations varied not only among brands, but also among packages of the same brand. The greatest variability among packages was observed for brands A, B, D, and G, which are produced by the same manufacturer; thus, these results appear to reflect poor quality control of fluoride concentration during salt production.

The problems that we found with salt marketed in Nicaragua have also been reported for salt sold in other countries in which salt fluoridation programs have been implemented.[6,7,8,10,11,12,13] In El Salvador, 80% of 26 salt samples analyzed had fluoride concentrations below the minimum recommended range.[11] In Guatemala, only 3% of salt samples tested had fluoride concentrations consistent with the legislation.[12] In México, only 1% and 7% of salt samples analyzed in 1995[6] and 2008,[7] respectively, were in accord with national legislation. Twenty-five percent of Colombian salt samples analyzed in 2003 had values consistent with national regulations.[8] A 2005 analysis showed that only 1 of 10 salt brands sold in Peru was fluoridated, but its concentration (152 ppm F) was below the legislated range (200–250 mg F/kg).[10] In a recent analysis, 57% of fluoridated Peruvian salt samples had fluoride concentrations in accord with the legislation.[13]

The impact of our findings from Nicaragua, in terms of benefits and risks of fluoridation, is not known because no data indicate which salt brands are consumed by most Nicaraguans. If most of the population consumed salt with optimal or nearly optimal fluoride concentrations, the maximum anticarious benefits and lowest risk of fluorosis would be achieved. In contrast, if salt consumed by most of the population is not fluoridated, the relevance of the salt fluoridation program would be reduced. In addition, the established "optimal" fluoride concentration is based on the daily per capita consumption of salt. We could not find data on the daily salt consumption of Nicaraguans or on variability in salt consumption within the country.

We used a validated method, as required for the precise and accurate determination of fluoride concentrations in salt;[13,16,17] however, the direct ISE method could result in underestimation ranging from 67% to 90%.[18] Thus, we checked the results for brands A, C, and I by ISE after microdiffusion.[19] We confirmed the reliability of the direct ISE results, as both analyses revealed only traces of fluoride in brands C and I and under-fluoridation of brand A (Table 3, footnote). Considering that Managua is the most populous city in Nicaragua and that the salt samples were purchased in the city's main places of sale, we believe that our sample included most salt brands used for cooking that were available in July 2016 in Nicaragua.

## Conclusion

This study revealed the following issues with salt fluoridation in Nicaragua: a. the sale of non-fluoridated salt brands, b. the labeling of brands without added fluoride as fluoridated, and c. concentrations below the legislated minimum in fluoridated salt. No salt with a mean fluoride concentration above the optimal range was found. The results suggest that the surveillance system for the salt fluoridation program in Nicaragua should be improved, as most salt analyzed was in violation of the national legislation. In terms of public health, the findings of this study are relevant not only to the Nicaraguan population, as salt fluoridation programs have been implemented worldwide.

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A preliminary report of this study was presented at the 64th European Organization for Caries Research (ORCA) Congress, Oslo, Norway, 2017 (*Caries Res.* 2017;51: abstract 167:367).

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