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THE NON-CARCINOGENIC RISK OF FLUORIDE VIA CONSUMPTION OF COMMERCIALLY AVAILABLE SALT IN GERMANY

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ABSTRACT: The amount of fluoride ion (F) in salt is highly important for the health of consumers. So, in this study the F level, the range of daily fluoride intake, the average daily dose, and the non-carcinogenic risk of common salt brands in Germany were determined. The contents of F in a total of 15 salt samples were determined by ion-selective electrode. The mean F level in salt samples was 0.031 mg g^{-1} with a range of 0.0002–0.096 mg g^{-1}. The daily fluoride intake based on the salt consumption in different age groups in Germany was calculated and was in the range of 1.085–3.038 $\times$ 10^{-4} g F day^{-1} per person. The average daily dose (ADD) and Hazard Quotient (HQ) values were higher in brand B of salt samples and in the 4–8 year-old consumers compared to the other age groups. The HQ values in salt consumers with different age groups showed no significant adverse health effects due to salt consumption (HQ<1). Although salt consumers may not be exposed to high F health risk it is important to assess total F intake from other F sources in order to calculate the total intake.

Keywords: Fluoride; Hazard Quotient; Risk assessment; Salt.

INTRODUCTION

The fluoride ion (F) is widely present in different samples from the environment, various industries,[1] beverages,[2-5] and foods.[6,7] An extreme intake of F for a long time may cause non-skeletal fluorosis, such as thyroid dysfunction, as well as skeletal and dental fluorosis.[8-10] It has been reported that the consumption of prepared snacks and dinner with fluoridated table salt for periods of time may increase the F content in saliva and supragingival plaque.[11,12]Also, the salivary and urinary F concentration in healthy adults (19–45 years) showed a significantly higher level after the consumption of fluoridated salt, milk, and tablets.[13] The increasing trend of urinary F excretion in children consuming fluoridated salt was determined by using two procedures that covered the different periods of a day. [14]

Fluoride-containing salts can enter into the human body through various sources such as foods. In a study in Colombia the F content of table salt was determined in 28 different samples. [15] In another study, the F levels of fluoridated and non-fluoridated salt in Nicaragua were determined.[16]

Salt, as a source of F entry to the human body, is important as there is a universal high level of consumption. However, only a few studies have focused on the F levels of salt. Thus, in the present study we aimed to evaluate the F levels in the different

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types of salt that are commercially available in the Germany market. Also, the daily fluoride intake and human health risks from exposure to F via salt consumption were investigated.

MATERIALS AND METHOD

A stock F solution of 1000 mg L^{-1} was provided by dissolving 2.21 g NaF in 1 L of distilled water. To prepare Total Ionic Strength Adjustment Buffer (TISAB), 58 mL of glacial acetic acid and 12 g of sodium dehydrate were added to 300 mL of distilled water and stirred to achieved a homogeneous solution. Finally, pH of solution was adjusted to 5.2 by using NaOH and then diluted to 1 L.

Sodium hydroxide solution was prepared by dissolving 670 g NaOH pellets in distilled water. Then the solution was diluted to 1 L and stored in polyethylene containers until being used for sample preparation. All chemicals were obtained from Merck, Darmstadt, Germany.

A total of 5 brands of salt samples were chosen to assess F levels. From each brand of salt, 3 samples (total number of samples of = 15) were prepared, after purchase in the local market in Wiesbaden, Germany during summer 2020. Samples were transferred to laboratory and the label information for the salt samples was recorded. Before analysis, the samples were dried at 105 ºC for 1 hr and then homogenized. The homogenized samples were passed through 40 mesh sieves and 0.5 g of each prepared sample was transferred to a 130 mL nickel crucible. Then, a little distilled water was added slightly to the samples to moisten them. Next, the solution was prepared by dissolving with 6 mL sodium hydroxide. After that the samples were dried for one hour at 150 ºC. Dried solution was placed in a muffle furnace at 300 ºC; then, the temperature was raised to 600 ºC and samples remained at this temperature for 30 minutes. After removal from the muffle furnace the samples were permitted to cool; after that 10 mL of distilled water was added to them. The samples were heated slightly until dissolution of the sodium hydroxide fusion cake and then HCL was slowly added until the pH was adjusted to 8–9. During this process Fisher Alkacid Test Ribbon was used for evaluating the pH values. Then the samples were transferred to a 100 mL volumetric flask and diluted to volume. The samples were passed through a dry Whatman No. 42 filter paper. Representative blanks were also prepared through the same procedure for salt samples. The prepared samples were mixed at a 1:1 ratio with TISAB prior to analysis by an ion-selective electrode (model 781 pH/Ion meter, Metrohm, Switzerland). Measuring F content for each sample was repeated 3 times and the mean values are presented here. The measurements of fluoride in samples are expressed here in mg of F per g of salt (mg g^{-1}).

Human health risks were evaluated from exposure to F via salt consumption based on a Hazard Quotient (HQ). An HQ value of less than 1 for a long duration of sample consumption implies that no probability adverse health effects. Average daily exposure to F due to salt consumption and the HQ values were calculated based on the equations as follows:[17-20]

$$ADD = \frac{C \times IR}{BW} \qquad \text{Equation 1}$$

$$HQ = \frac{ADD}{RfD} \qquad \text{Equation 2}$$

Where:

ADD = the average daily dose of F via salt (mg kg^{-1} day^{-1})

RfD = the daily oral intake reference dose of F (0.06 mg kg^{-1} day^{-1}); as suggested by the United States Environmental Protection Agency (USEPA)

C = the mean F content in salt (mg kg^{-1}, dry weight)IR

= the consumption rate of salt (g $person^{-1}$ day^{-1})

BW = the average body weight (kg)

F risk assessment in salt was investigated for different age groups with different daily average consumption of salt based on available data (Table 1).[21, 22]

Table 1. The daily consumption of salt and average body weight of different age groups.[23]

Age group	Average body weight (kg)	Daily consumption (g day^{-1})	Daily fluoride intake (g F day^{-1}) $\times 10^{-4}$ [a]
4-8	23.9	3.5	1.085
9-13	42.6	4.75	1.473
14-18	62.75	6.2	1.922
19-29	71.9	8.4	2.604
30-39	76.8	9.4	2.914
40-49	78.8	9.35	2.899
50-59	79.3	9.8	3.038
60-69	79	9.5	2.945
70-79	75.7	8.85	2.744

[a] Daily intake of F from salt (g F day^{-1}) = Concentration of F in salt (g F g^{-1} of salt) × Daily salt intake (g of salt day^{-1})

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RESULTS AND DISCUSSION

The mean (± SD) and range of F levels in 5 brands of salt are presented in Table 2.

Table 2. Fluoride levels in salt samples in the present study.

Type of sample	Brand (n=3)	Range (mg g^{-1})	Mean±SD (mg g^{-1})
Salt	A	0.0002-0.047	0.017±0.024
	B	0.046-0.068	0.056±0.011
	C	0.0008-0.034	0.018±0.009
	D	0.006-0.023	0.011±0.007
	E	0.015-0.096	0.053±0.049
Total		**0.0002-0.096**	**0.031±0.021**

The F level of salt samples was in the range of 0.0002–0.096 mg g^{-1} with a mean value of 0.031 mg g^{-1}. In the salt samples, the highest mean value of F was determined in the brand B while the lowest was determined in the brand D. The highest daily intake of F was observed in the salt consumers aged 50–59 yr compared to the other age groups (3.038×10^{-4} g F day^{-1}). In a study, Matinez-Mier et al. determined F content of fluoridated salts in Mexico. They have reported a mean F content level of 0.230 mg g^{-1}; that was higher than that found in the present study.[24] In another study in Mexico, the F content in 44 different brands of salt showed a high level with a mean value of 3.245 mg g^{-1}. The results indicated a higher F content in marine salt compared to F content in the salt samples from earth.[25] Báez-Quintero et al. also reported a high trend of F content in the salt table in Colombia compared to this study.[15] In a study in Iran a higher F content (0.0424 mg g^{-1}) in 91 edible salt samples was reported compared to this study. Also, the daily F intake of edible salt and total daily F intake from edible salt and drinking water for adults were reported in the ranges of 0.020–0.066 and 0.96–1.21 mg F day^{-1}, respectively.[26] In a study, it was reported that urinary excretion of F in the adults (18–37 years) increased from 0.65 mg day^{-1} to 1.52 mg day^{-1} with increasing ingestion of extra salt from 1 g day^{-1} to 9 g day^{-1}.[27] In another study, the F content in saliva after consumption of a dinner meal prepared with fluoridated salt was investigated. The results showed that the mean intake of F increased significantly in saliva after the consumption of food. [12]

The main sources of salt intake are: (i) salt that is added during cooking; (ii) the salt in food, e.g. bread, meat, grains, and dairy products, etc.; and (iii) the direct use of salt on the food table.[28] Therefore, a high consumption of salt-containing sources canexpose consumers to a high F level and consequently to adverse health effects.

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The F levels of the salt samples in the present study compared to former reports as are presented in Table 3.

Table 3. The fluoride contents in salt samples reported in previous studies.

Number of samples (n)	Mean (mg g^{-1})	Range (mg g^{-1})	References
44	3.245 ± 3.623	0-12.13	25
60	0.23 ± 0.049	-	24
28	3.35	0.12-5.64	15
33	Trace (<0.001) to 0.211	0.104-0.243	16
37	0.0424±0.012	0.020±0.066	26
15	**0.031±0.021**	**0.0002-0.096**	**Present study**

Exposure to excessive F from salt can have harmful effects on human health. So in this study for assessing the risk values, the average daily dose (ADD) of F, in salt consumers with different age groups, was specified. The ADD values for F via salt consumptions in the different age groups are shown in Table 4.

Table 4. Average daily dose (ADD) and Hazard Quotient (HQ) induced by fluorideexposure via salt consumption.

Age category	ADD (mg kg^{-1} day^{-1})					HQ				
	A	B	C	D	E	A	B	C	D	E
4-8	0.0025	0.0082	0.0026	0.0016	0.0078	0.041	0.137	0.044	0.027	0.129
9-13	0.0019	0.0062	0.002	0.0012	0.0059	0.032	0.104	0.033	0.020	0.098
14-18	0.0017	0.0055	0.0018	0.0011	0.0052	0.028	0.092	0.030	0.018	0.087
19-29	0.002	0.0065	0.0021	0.0013	0.0062	0.033	0.109	0.035	0.021	0.103
30-39	0.0021	0.0069	0.0022	0.0013	0.0065	0.035	0.114	0.037	0.022	0.108
40-49	0.002	0.0066	0.0021	0.0013	0.0063	0.034	0.111	0.036	0.022	0.105
50-59	0.0021	0.0069	0.0022	0.0014	0.0065	0.035	0.115	0.037	0.023	0.109
60-69	0.002	0.0067	0.0022	0.0013	0.0064	0.034	0.112	0.036	0.022	0.106
70-79	0.002	0.0065	0.0021	0.0013	0.0062	0.033	0.109	0.035	0.021	0.103

The ADD values for salt consumers ranged from 0.0011–0.0082 mg kg^{-1} day^{-1} (Table 4). Based on the results, the brand B of salt had the highest amount of ADD in the salt consumers in the 4–8 year-old age group.

The HQ values via F exposure in salt samples were also assessed and shown in Table 4. The risk estimates indicated that the highest value of HQ in salt (0.137) was related to the brand B consumers of salt in 4–8 year-old age group. The HQ values in salt samples showed that salt consumers with different age groups were not exposed to an immediate significant health risk (HQ<1).

If we consider a consumer using all the salt brands studied, the ranges of ADD and HQ values would be 0.003–0004 mg kg^{-1} day^{-1} and 0.05–0.08, respectively. Although the 4–8 year-old age group is more exposed to F, compared to other studied age groups studied, even in this group the HQ value was at an acceptable level (HQ<1).

According to our survey of the literature, we found that there was no other study available that evaluated the average daily dose and HQ values in salt consumers.

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Beside salt, there are other various sources of F such as drinking water,[29-35] different foods,[36] beverages,[3,4,37] etc., that should be considered in the evaluation of the overall risk of the daily F intake. Removal of high F level in water by simple and inexpensive methods is needed, especially in the rural area.[38-46]

CONCLUSIONS

In the present study, the F content in 5 common brands of salt that are available in the Germany market was evaluated and the health risks of F via salt consumption were assessed. Based on the results, the highest values of ADD, and HQ were related to the brand B of salt in the age group of 4–8 years old. The HQ values in all age groups were lower than 1 indicating that there no probability of significant adverse health effects for salt consumers from the F contained in salt. However, it should be noted that people may have a high total intake of F when the F in salt has added to the F from the consumption of other foods and beverages that contain F. Therefore, the total intake of F via the various different sources should be considered in order to assess of the adverse health effects of F in an individual.

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