Caries Prevention through Salt Fluoridation: An Overview

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ABSTRACT

The purpose of this review was to give an overview of 62 years experience of salt fluoridation and draw conclusions about the applicability of the method using evidence-based approach. Use of salt fluoridation for dental caries prevention began in Switzerland in the mid 1950s and is currently practicing in several countries around the world. The addition of fluoride to salt for human consumption was officially authorized in 1980-82. Thenceforth salt fluoridation is practiced as a community-based alternative to water fluoridation in many countries. Salt fluoridation, at a minimum concentration of 250 mg F⁻/kg salt, should be considered as a practical alternative wherever water fluoridation is not socially acceptable or feasible. Today, a salt fluoridation programme could be useful in areas in which fluoridated toothpaste are not widely used. It can be used for small groups or large populations, is very economical and, where necessary, provides freedom of choice. The communication policy promoting the consumption of fluoridated salt is crucial to ensure the effectiveness of such a programme.

KEYWORDS: Caries, Cost-effectiveness, Fluoride, Prevention, Salt fluoridation

INTRODUCTION

Oral health is integral to general well-being, with profound individual and societal implications that extend well beyond the functions of the craniofacial complex. In 2010, untreated caries in permanent teeth was the most prevalent condition worldwide, affecting 2.4 billion people, and untreated caries in deciduous teeth was the 10th-most prevalent condition, affecting 621 million children worldwide. Research and practical experience in numerous industrialized countries have demonstrated, however that it can be controlled and reduced to very low levels. Fluoride continues to be the mainstay of any caries prevention protocol as it still remains the most effective and economical protective agent against dental caries. The addition of fluoride to drinking water was the first breakthrough in preventive dentistry to be followed by several forms of topical applications. Fluorides in toothpaste, perfectly compatible with water fluoridation, have become increasingly important since the 1960s. The first studies of the effect on dental caries of fluoride added to dietary salt were carried out in Switzerland, Hungary, and Colombia around 1965 to 1985 and this proved to be as effective as water fluoridation; the number of teeth affected by caries was reduced by approximately 50%. The first official authorization on addition of fluoride to salt was in 1980-82. Currently salt fluoridation is recognized worldwide as a proven and viable means of consumer choice-related, community-based fluoridation where water fluoridation is either technically or politically impossible. Salt fluoridation plans are achieving in excess of one hundred million in Mexico, Colombia, Peru, and Cuba, France, Germany, Spain, Austria, Hungary, Czech Republic. Salt fluoridation offers a realistic potential to ameliorate dental health in the poorer regions of the world.

HISTORICAL CONTEXT

The utilization of salt as a vehicle for fluoride has a long historical background. Salt fluoridation in Switzerland was based on 25 years of successful iodization. Between 1910 and 1920, the prevalence of endemic goiter was very high in Swiss countries. They successfully prevented endemic goiter by adding iodine to salt from 1918 onwards which was a breakthrough for the addition of fluoride to salt. Dr. Hans J. Wespi, the Director of the Clinic for Gynecology and Obstetrics in the Cantonal Hospital at Aarau in 1946 started adding sodium fluoride to already iodized salt which he gave to his patients became a success. The fluoridation project in Antioquia, Colombia in 1967 was the first South American salt fluoridation project. Later an International Symposium on Salt Fluoridation was held in Medellín, Colombia, in 1977. In Switzerland, initial investigations showed that a fluoride concentration of 90ppm was insufficient and later studies confirmed the positive effects of dental caries with a fluoride concentration at the level of 250ppm. France was the second European country adopting salt fluoridation in 1986. From 1991 onwards

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Germany began to import fluoridated salt from France. After a brief period, production of F-salt by German refineries was authorized by the government. Fluoridated salt is also available in countries such as Belize, Bolivia, Cuba, Dominican Republic, Ecuador, Peru, and Venezuela. Since 1986 an expanding number of nations, now around 15 and for the most part in Europe and the Americas, have embraced salt fluoridation schemes. Universal salt fluoridation that all salt destined for human consumption is fluoridated exists in numerous cantons in Switzerland, as well countries in South America, Jamaica, Costa Rica, Columbia. Given below is the comparison between the addition of iodine and fluoride to salt (Table: 1).

### PRODUCTION OF FLUORIDATED SALT

Fluoridated salt exerts both a systemic and topical effect. At the point when most salt for human utilization is fluoridated, the community effectiveness of salt fluoridation approximates that of water fluoridation. For effective caries prevention, fluoride must be present in ionic form when salt (NaCl) is dissolved in water. The concentration of fluoride in salt used around the world range from 90mg/kg to 350 mg/kg with recent studies showing an optimal concentration of 250mg/kg. Fluoride addition to salt can be either done through batch processing / continuous processing.

**Batch Processing:** A fixed amount of a fluoride compound (mostly NaF or KF) is added to a fixed amount of refined salt. Example: 765g of KF are added to one ton (999,235g or roughly one million grams) of refined salt; 765g F salt contains 250mg of fluoride). Then fluoride concentration in the resulting mixture will be 250ppm F. Similarly, to produce one ton of salt containing 250ppm fluoride, 552g of NaF are needed. NaF being cheaper it is recommended in batch processing.

**Continuous processing of salt:** In large production plants where continuous processing of salt is common, the procedure is often to spray a dosed concentrated fluoride solution through a nozzle onto the salt passing on a conveyor belt below. The amount of salt passing under the nozzle must be continually assessed and determines the amount of fluoride solution to be sprayed, according to the fluoride concentration specified by law or decree.

On account of the high solubility of KF in water, it is the preferred compound. Even though the cost of KF is negligible in developed countries, developing countries may find the purchase of the relatively expensive KF from abroad prohibitive. Moreover the strong hygroscopic properties of KF are likely to pose storage problems.

### REQUIREMENTS FOR APPLICATION

1. Moderate or high dental caries prevalence, or the expectation that caries prevalence will increase.
2. Predominance of low-fluoride drinking-water.
3. Multiple sources of water posing a serious economic obstacle to water fluoridation.
4. Lack of political and community will and resources for fluoridation of drinking water.
5. Centralized salt production or recognised sites producing domestic salt with experience of including and monitoring additives.
6. Coordination between health agencies, salt producers, marketers, distributors, and the community, with inclusion of appropriate monitoring programmes, is suggested for effective implementation.
7. In the absence of local or national capability to produce fluoridated salt, the importation of fluoridated salt, or the addition of fluoride to imported domestic salt for human consumption, can be used. Coordination and monitoring similar to national production should be required.

### ADVANTAGES OF FLUORIDATED SALT

Advantages of fluoridated salt for developing countries can be considered under the following items.

1. The ability to reach a wider population at the minimum cost
2. Low cost; it saves an average of $250 per person per year in dental treatment for every $1 spent
3. Little or no intentional action is needed of the public to benefit safety
4. Irrespective of difference in water quality it can be implemented
5. Owing to the reasonably stable diet of developing countries, often based on the rice, beans, pasta or similar products it necessitate the use of table salt in their preparation.

### EFFECTIVENESS IN CARIES PREVENTION

The first epidemiological studies to evaluate the effectiveness of fluoridated salt in reducing caries prevalence were performed in Colombia, Hungary, and Switzerland from around 1965 to 1985. The outcomes of

<table>
<thead>
<tr>
<th>Intake level</th>
<th>Iodine</th>
<th>Fluoride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low intake</td>
<td>Below 150µg/day</td>
<td>Below 1.5mg/day</td>
</tr>
<tr>
<td>High intake / optimal</td>
<td>Above 600µg/day</td>
<td>Above 4mg/day</td>
</tr>
<tr>
<td></td>
<td>Iodine deficiency disease</td>
<td>Reduction of number of teeth affected by caries around 50%</td>
</tr>
<tr>
<td></td>
<td>Hyperthyroidism in part of the population</td>
<td>Slight to Unsightly mottled teeth, but no health hazard</td>
</tr>
</tbody>
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Table 1: Consequences of low or high total intake of iodine and fluoride. Intake figures apply to adults, they are lower for infants and children (source: Marthaler et al 2005)
these studies indicated that salt fluoridation generally showed very similar beneficial results to those observed for water fluoridation; the number of teeth affected by caries was reduced by approximately 50 percent.\textsuperscript{4} The results of the early clinical experiments performed in Szeged, Hungary, showed, after 17 years, a caries reduction of about 66 percent.\textsuperscript{9}

A meta-analysis done in 2010 reported that caries preventive effects of salt fluoridation had provided significant evidence on reduction in DMFT status of different age cohorts in different countries when compared to groups that had no exposure to this intervention.\textsuperscript{10} Similar results were reported in a meta-analysis conducted in 2011. They reported that the pooled estimates for each of the age cohort favored salt fluoridation over no exposure. However the contribution of fluoridated salt to the declines in DMFT could not be quantified due to the poor quality of the studies. Further high-quality studies in future are needed to confirm its efficacy.\textsuperscript{11} Another review published in 2017 reported that salt fluoridation leads to a significant reduction in caries indexes among treated children compared to a control group in the lack of topical fluoride support. The study also states that the prevalence of fluorosis is not markedly increased with fluoridated salt.\textsuperscript{12} A recent 12-month prospective randomized control study reported from the Gambia in 2017 investigated the anticaries effect of fluoridated salt in a communal feeding program for preschool children. After 12 months trial, the study reported a caries-prevented fraction of 66.3% suggesting that the use of fluoridated salt yielded a considerable caries-preventive effect in a communal feeding program and in an environment with negligible availability of fluoride from other sources.\textsuperscript{13}

\section*{PUBLIC HEALTH ASPECTS OF SALT FLUORIDATION}

With water fluoridation, the situation may be characterized as follows. Through fluoridated water, all consumers are reached within the region served by the respective water supply. In recent decades ‘mineral’ water has become fashionable, and among parts of the population drinking water is being replaced by bottled water. Hence the caries reduction benefits from water fluoridation are not extensively reached. Moreover, in a developing country like India, there is no extensive community water supply. Hence the applicability in India is limited. On the other hand, fluoridated salt reaches the user through several channels. The initiatives to obtain full effectiveness should focus on both domestic salt and on salt distributed to large kitchens in restaurants, canteens, hospitals, etc. bakeries and large bread factories, and catering enterprises. During the 1990s further reports appeared from countries where salt fluoridation has been implemented demonstrating the persistence of the caries-protective effect into adulthood. The full potential of salt fluoridation, at least equivalent to that of water fluoridation, will be reached when most of the salt for human consumption is fluoridated.\textsuperscript{4} It is important to distribute fluoridated salt through channels used by the low socio-economic strata; in these strata caries prevalence is highest and dental care is often unaffordable or neglected.\textsuperscript{14}

Evidently, Jamaicans have had greater advantage from salt fluoridation on the grounds that basically all salt bound for human utilization on the island has been fluoridated since 1987. The Figure 1 shows the decline in the mean number of Decayed, Missing and Filled Teeth (DMFT) in the Jamaican.

\section*{COST-EFFECTIVENESS}

Costs are minimal compared to treatment costs of water fluoridation and coverage can be universal. Effective programme implementation depends upon collaboration between health authorities, salt processors, distributors, and the community. The cost of salt fluoridation in a given country depends primarily on the number of salt factories and on the technical level available in the country. Frequently 85–90% of the costs are devoted to infrastructure; in combination with salt iodization, the cost for fluoride equipment is 30–50% less. Running costs for salt fluoridation are 10 to 100 times lower because the amount of fluoride chemical needed and its handling are up to 100 times less than with water fluoridation.\textsuperscript{15}

Cost-benefit studies conducted in the region of the Americas comparing anticipated fluoridation costs versus economic resources that will no longer be needed on dental treatment after implementation of salt fluoridation indicated benefits were considerably higher than the investment required for implementing the programme.\textsuperscript{16} A cost-effectiveness model study done in 2011 compared the seven dental caries prevention programmes among schoolchildren in Chile: three community-based programmes: water-fluoridation, salt-fluoridation and dental sealants; and four school-based programmes: milk-fluoridation; fluoridated mouth rinses; APF-Gel, and supervised tooth brushing with fluoride toothpaste. The study reported that based on cost required to prevent one carious tooth among schoolchildren, salt fluoridation was the most cost-effective.\textsuperscript{17} Similarly another cost-effectiveness study done in Peru also reported salt fluoridation as cost-effective. The study reported that through a salt fluoridation programme for 25000 children, after 6 years, an investment of S/.0.32 per annum per child would result in a net saving of S/.11.95 per decayed/missing/filled teeth prevented [1 US$ = S/. (2009) 3.01].\textsuperscript{18}

The fluoride-containing dentifrice cost at the least 5 € every year and person (the cost of the toothbrush may be delegated as being paid for by maintaining up gingival and periodontal health). For fluoride reaching the tooth from salt in food, the cost is less than 0.05 €, a ratio of 1/10,000. Assuming that fluoride in dentifrices is four times more effective than salt fluoridation, the cost ratio
is still favorable: 1/2,500. The combination of fluoride-containing toothpaste with fluoridation of either water, salt or milk has been successful in lowering caries prevalence in virtually all regions of the world.7

HEALTH AND SAFETY

Considering the public health messages which encourage the reduction of consumption of salt to decrease the risk of hypertension, promotion of the dental benefits of fluoridated salt would be objectionable. However, currently the major programmes are using potassium fluoride, rather than sodium (associated with hypertension) fluoride as the added ingredient, and the populations of the countries having salt fluoridation are not encouraged to consume more salt to improve their dental health. Individual table salt consumption has not increased and no adverse effects from the small amount of sodium noted. In other words, for benefit, people do not have to change their usual behavior; they simply need to change the product. Indeed, reduced consumption of salt could and should be encouraged and, where this is successful, the concentration of fluoride in salt could simply be increased appropriately if necessary.4

WORLD HEALTH ORGANIZATION

A Conference on Fluorides was held in Vienna, Austria in 1992 organized by Federation Dentaire Internationale (FDI), the W. K. Kellogg Foundation, and the World Health Organization (WHO). This conference encouraged to implement salt fluoridation as fast as possible in as many countries as possible. A WHO document” WHO technical report series 846 -Fluoride and Oral health”, published in 1994 provides some valuable suggestion for salt fluoridation9,

1. Salt fluoridation should be considered where water fluoridation is not feasible for technical, financial or sociocultural reasons

2. The optimum concentration must be determined on the basis of salt intake studies. A concentration of 200 mg F/kg salt may be regarded as a minimum when several type of salt (domestic and salt for bakeries, restaurants and other large kitchens) are fluoridated, but twice this concentration may be appropriate when only domestic salt is fluoridated

3. The technical operations of salt fluoridation systems should be monitored and recorded regularly. In addition the correct concentration and homogeneity should be periodically ascertained in the packages offered to the consumer

4. The fluoride concentration should appear on all salt packages

5. Surveys of dental fluorosis and dental caries should be conducted periodically

WHA 60:17 (World Health Assembly) resolutions passed in 2007 recommends “salt and milk as alternatives where water fluoridation cannot be implemented for whatever reason.”

DISCUSSION

Salt fluoridation is practiced as a community-based alternative to water fluoridation in many countries where there are few central water systems or other factors preclude the use of water fluoridation or where water infrastructure is otherwise not appropriate.7 It is recommended that a national fluoride program use only one of these approaches.20

Fluoridated salt raises ambient oral fluoride concentration throughout life in a manner similar to water fluoridation.21 For salt fluoridation, potassium fluoride and sodium fluoride are used at a concentration of 250-300mg F per kg of salt (250-350ppm). At this concentration, the level of fluoride in saliva was very similar to that found in the saliva of individuals exposed to water fluoridation at 1 mg/l. The concentration of 200 mg/kg of fluoride is regarded as the minimally acceptable level of fluoride in salt to achieve a meaningful effect on caries control.22

It has been estimated that between 40 million and 280 million people worldwide use salt fluoridation, mainly in European, South American and Central American countries.23 Some Asian countries, including Cambodia and Laos, have recently adopted salt fluoridation. In Africa, Madagascar has also implemented salt fluoridation.24 In Columbia, a fluoridated salt trial was initiated in 1963 and upon successful completion in 1972 was shown to have preventive results comparable to water fluoridation.16 In Peru in 1984, a law was passed mandating the addition of fluoride to salt for human consumption.17 In 1985, the Peruvian Ministry of Health agreed on a technical norm for enriching table salt for human consumption with F, as the main method for administering F to the Peruvian population. Fluoridated salt is widely available to consumers at supermarkets and retail stores throughout the country.

The most extensive use of fluoridated salt is in Jamaica, Costa Rica and the canton of Vaud, Switzerland. In other Swiss cantons, France and Germany, the salt fluoridation program are mainly based on domestic salt.23 France was the second European country adopting salt fluoridation in 1986.25 Mexico began a fluoridated salt program in 1991. Of the total Mexican population of 112 million in 2010, an estimated 90 million had access to fluoridated salt, with another 20 million with access to water with naturally occurring fluoride concentrations at or above optimal.26

In addition to Colombia and Peru, there are fluoridated salt programs in Belize, Bolivia, Cuba, Dominican Republic, Ecuador, Uruguay and Venezuela.26 Fluoridated salt is also available in certain countries that do not have identified programmes, such as Trinidad and Tobago and other Caribbean and Latin American countries except Panama Brazil and Chile.7 In the Caribbean where municipal water supplies are less reliable, salt fluoridation has demonstrated guarantee as a
successful option.27 Thirty five percent of the domestic salt is now fluoridated in the Czech Republic.28

The efficacy and impact of salt fluoridation depend upon the programme implementation. However, factors such as distribution, marketing, pricing and method of implementation affect community coverage, impact and health.7 For example, Jamaica prohibited the importation and sale of all non-fluoridated salt for human consumption and achieved reported caries reductions of up to 82% in 12 year-olds.29,30 The Center for Global Development, Washington DC in 2004 cited the Jamaica salt fluoridation programme as one of the 17 most relevant public health initiatives taken worldwide in recent years.31

Fluoridated salt, when feasible, can easily reach entire populations even in remote regions, at very low cost. The cost is about 6c (US) per person per year. Salt fluoridation programmes have the flexibility to be either national or limited geographically, provide choice or be obligatory, be combined with iodized salt or not and still be effective and viable. The development, implementation, and maintenance of an epidemiological surveillance system are essential.7

CONCLUSION

Salt fluoridation should be considered where water fluoridation is not feasible for technical, financial or sociocultural reasons. It can be used for small groups or large populations, is very economical and, where necessary, provides freedom of choice. The full potential of salt fluoridation, at least equivalent to that of water fluoridation, is reached when most of the salt for human consumption is fluoridated. It is important to distribute fluoridated salt through channels used by the low socio-economic strata; in these strata, caries prevalence is highest and dental care is often unaffordable or neglected.1

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