Increasing the public health effectiveness of fluoridated salt

Summary

This paper aims at assessing the public health potential of salt fluoridation schemes. There is now solid evidence which shows that the cariostatic effectiveness of universal salt fluoridation is equivalent to that of water fluoridation in both the permanent and primary dentition. In countries of continental Europe, only domestic salt is fluoridated, and its consistent use may be expected to warrant a 30% reduction of caries prevalence. However, the effectiveness in the population at large is lower because only part of the population uses the fluoridated domestic salt. Under these conditions, it must be assumed that the effectiveness is further reduced because families in low S-E strata use fluoridated salt (FS) less frequently than those in the higher S-E strata who are known to use preventive methods like toothbrushing twice a day with a fluoride dentifrice more regularly. Model calculations tend to show that in Germany, where FS has reached a market share of 60%, the overall effectiveness is 14% instead of 30%. For France with a market share of 30% of the fluoridated domestic salt, model calculations lead to an overall effectiveness of 8%. In order to obtain a substantial decline of caries in the entire population, it is important to aim for a high market share of the FS of 80%, or preferably 90%. This goal can be reached with a relatively small budget. The task of health ministries would be to promote the switch from unfluoridated salt to FS; however, such promotion is often withheld by health ministries. It is possible, through modest price increases of salt, to finance effective campaigns inducing the majority of the population to use the fluoridated variety. On a world wide scale, fluoridation of salt has established itself as an efficient public health measure. It may be particularly beneficial for developing countries because it is by far the cheapest method and it is compatible with the use of fluoridated toothpastes.

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Corresponding Author:
Prof. T. M. Marthaler
Bellerivestr. 21, 8008 Zurich, Switzerland
Tel. 044 381 75 40
Fax 044 381 75 43
e-mail: tmarthal@zui.unizh.ch

THOMAS M MARTHALER

Clinic for Preventive Dentistry, Periodontology and Cariology, Dental Center, University of Zurich

Is the caries-preventive effectiveness of fluoridated salt (FS) equivalent to that of fluoridated drinking water?

Besides water fluoridation, salt fluoridation is the only measure by which entire populations can be automatically provided with fluoride in order to reduce caries prevalence. Accordingly, the WHO Technical Report 846 states that "salt fluoridation should be considered where water fluoridation is not feasible for technical, financial or sociocultural reasons" (WHO 1994, page 22).

There is, however, a fundamental difference between adding fluoride to either drinking water or salt for human consumption. Water fluoridation invariably reaches all subjects in a community, city or region. Salt fluoridation can also reach entire populations, as shown by the example of Jamaica; all salt destined for human consumption in this country has been fluoridated to 180–250 mg F/kg since 1986. The situation is similar in Costa Rica. In Europe, on the other hand, addition of fluoride is mostly limited to domestic salt, leaving salt used by bakeries, large kitchens of enterprises or institutions as well as by the food industry unfluoridated. When fluoride addition is limited to domestic salt and unfluoridated salt is available, a substantial part of the population may use unfluoridated salt (with or without iodine). Therefore, a fair comparison between the cariostatic effectiveness of water fluoridation and salt fluoridation requires schemes in which all or almost all salt for human consumption is fluoridated.

In fact, the two most important investigations into the cariostatic effectiveness of FS included towns in which virtually all salt for human consumption was fluoridated. In the Colombian trial, two towns were provided with salt containing 200 ppm fluoride (using NaF for one town and CaF_2 for the other, see GILLESPIE & BAEZ 2005). Two further towns, one with fluoridated water and another with no fluoridation at all, acted as reference. The results were published in Spanish (OPS 1976). The DMFT scores and percent reductions are presented by GILLESPIE & BAEZ (2005).

The extensive studies on all aspects of salt fluoridation, carried out from 1966 to 1984 in Hungary, were described by TOTH (1984). Toth provided FS to several villages, beginning in 1966 with concentrations of 200 and 250 ppm fluoride which in 1981 were raised to 350 ppm in all experimental villages. In both the Colombian and Hungarian studies, adequate concentrations of fluoride in salt were verified by documenting that the urinary fluoride concentration was close to 1.0 ppm, as found in the classical studies of water fluoridation. The conclusion was that under conditions of universal fluoridation, the caries-inhibiting effectiveness of fluoride when added to salt in adequate concentration was equivalent to that of water fluoridation. The results of the Colombian and Hungarian studies were summarized by BURT & MARTHALER (1996) and by ESTUPINAN-DAY (2005).

In recent years, new data on the cariostatic effectiveness were reported from Jamaica, Costa Rica and Mexico and Uruguay. In the initial survey of Jamaican children in 1984, the national data from 12-year-old children indicated a DMFT average of 6.72 DMFT, whereas by 1995 the average had declined to 1.08 (ESTUPINAN-DAY et al. 2001). Similar reductions were obtained in children aged 6 (primary teeth, DMFT) and 15 (Tab. I). In a later local survey (western Montego Bay, 1999), the average DMFT at age 15 was 3.8 (MEYER-LUECKEL et al. 2002), 73% less than the 9.13 DMFT in 1984. The reductions at all ages studied were above 50% when compared with the 1984 data (Tab. I). A detailed analysis of other factors which may have influenced the decline of caries prevalence in Jamaican children was presented by WARPEHA et al. (2001).

In Costa Rica, the average DMFT in 12-year-old children was 9.13 in 1984 but only 2.46 in 1999 (Tab. I). The magnitude of the reduction, 73%, points to contributions of other favorable factors as for example fluoridated toothpastes, which, however, were already widely used in the mid-eighties. The authors of the report (SOLORZANO et al. 2005) state that "although several factors may have contributed to the decline in dental caries observed in Costa Rica, it appears that the most important has been the introduction of FS in 1987". Regarding primary teeth, "percent reductions were 45% for age 7 years and 47% for age 8 years".

In the State of Mexico (surrounding the Federal District of Mexico with the City of Mexico), large numbers of children aged 12 years were examined for caries in 1988, when salt fluoridation was introduced, and again in 1997. In the 9 year interval, DMFT averages declined by 44%. In Urugayan children, the average DMFT decreased from 4.1 in 1991 to 2.4 in 1999 (Tab. I). The market share of FS has now attained 90%.

Both the Colombian and Hungarian trials demonstrated a reduction of caries prevalence by FS in the primary dentition (BURT & MARTHALER 1996). The results of the national Jamaican survey confirmed a cariostatic effectiveness of FS similar to that of optimally fluoridated drinking water (Tab. I).

Regarding adults, the effectiveness of salt fluoridation was first documented in Swiss army recruits (MENGHINI et al. 1991, summarized in BURT & MARTHALER 1996). In 1991 and 1992, RADNAI & FAZEKAS (1999) examined 72 individuals aged 18–27 who had been consuming FS during 12 to 19 years since their early childhood (in the Hungarian studies, all salt used at home and in the school canteens was fluoridated except that used by bakeries). Their average DMFT was 7.68 while individuals who had been using water with 1 ppm fluoride throughout their lives had 5.45 DMFT. The 58 adults of the same age from the unfluoridated reference villages had a DMFT score of 13.82. The subjects of the

Tab. I Caries prevalence in Jamaica, Costa Rica, Mexico and Uruguay prior to salt fluoridation and in the latest available DMFT averages (age 6 in Jamaica: primary teeth, DMFT averages)

		Initial year	Final year	Initial DMFT	Final DMFT	Reduction in DMFT	%	Annualized % reduction
Jamaica	age 6 (DMFT)	1984	1995	4.8	2.3	2.5	52%	6.5%
	age 12			6.72	1.08	5.64	84%	15.3%
	age 15			9.60	3.02	6.58	69%	10.0%
Montego Bay	age 12		1999		2.2*	4.52	67%	–
	age 15		1999		3.8*	5.80	73%	–
Costa Rica	age 12	1984	1999	9.13	2.46	6.67	73%	8.3%
Mexico	age 12	1988	1997					
	DMFT			4.39	2.47	1.92	44%	6.2%
	DMFS			6.93	3.84	3.09	45%	6.4%
Uruguay	age 11–14	1991	1999	4.1	2.4	1.7	42%	6.5%

* These averages were compared with the 1984 data from Jamaica (obtained from the entire country; Montego Bay is a sea resort at the western tip of Jamaica)
Source of data. Jamaica: ESTUPINAN-DAY et al. 2001 and MEYER-LUECKEL et al. 2002 (Montego Bay 1999); Costa Rica: SOLORZANO et al. 2005; Mexico: IRIGOYEN & SANCHEZ. HINOJOSA 2000; Uruguay: MINISTERIO DE SALUD PUBLICA DE URUGUAY 1999

age groups 28–37 and 38–47 had consumed FS during approximately 19 years of their lives (not earlier than at age 6, from 1966 to 1984 or 1985). Their DMFT was midway between that of adults of the same age from the fluoridated town and those from the control villages. It has to be noted that during the study, 1966–1984, no fluoridated toothpastes or other fluoride products were on sale and the population was extremely stable.

The conclusion is that the results documented for pre-school and school age children as well as for adults up to the age of 47 confirm the statement in the WHO Technical Report (WHO 1994, page 20): "The results suggest that the effectiveness of FS in inhibiting caries is of the same order as that of fluoridated water when the appropriate concentration and use are achieved." In view of the equivalence of fluoride when added to salt instead of the drinking water it is reasonable to assume that salt fluoridation affords a level of protection similar to that of water fluoridation. Plaque fluoride studies as done by WHITFORD et al. (2002) would provide clues regarding a similar beneficial effect of fluoride when added to salt.

The problem of maximal coverage of entire populations

Possibilities and measures for conferring the benefit of "automatic" fluoridation to entire populations are an important issue. In Jamaica for instance, all inhabitants benefit from the FS as well as from "Universal Salt Iodization" (SULLIVAN et al. 1995). Tomato ketchup made in Jamaica is produced with salt containing both iodine and fluoride. Water fluoridation had earlier been planned to be implemented in the capital Kingston, but the rest of the population would not have been reached. With salt fluoridation, every individual living on the Island is benefitting from the FS.

On the level of entire countries (excluding the city states Hong Kong and Singapore with 100 percentage coverage), 70% to 80% of the populations of Ireland and Australia for instance are users of fluoridated water. Theoretically, the USA and Germany are at similar levels: around 60% are benefitting from either fluoridation of water or domestic salt, respectively. However, in spite of equal "coverage", the following chapter will show that "partial" coverage by FS is less effective in Germany than simple calculations based on percentages would suggest.

The possibility of covering entire populations with FS is a great advantage and challenge as well. This is exemplifed by respective percentage figures on usage of FS in 2004/2005: Jamaica 100%, Costa Rica 95% (some regions with optimal fluoride levels in water are not served by FS), Mexico approaching 90–95% (avoiding high water fluoride areas), Uruguay 90%, Switzerland 87%, Colombia 80%, Ecuador 80% (MILNER 2000, personal communication 2005). By contrast, the percentages of users in France and the Czech Republic are around 30%, and even lower in Austria, Belgium, Slovakia and Spain.

These percentages, however, must be seen in the context of the distribution systems. In Costa Rica, bakeries are supposed to use unfluoridated salt, but practically all salt packed in plastic bags of 500 g is fluoridated, and the same holds true for the 1-kg bags in Mexico. These bags are not only used in individual households, but in large kitchens as well. This implies that childrens' meals at school are made with fluoridated salt. In addition, large kitchens of restaurants, hospitals and institutions which often use the 500-g or 1-kg plastic bags automatically use fluoridated salt. In several Latin American countries, such as Mexico where 1-kg bags are common, these bags are labelled "Table salt" (sal de mesa, but most of the salt is added in the kitchen).

In Latin America, therefore, small packages up to 1 kg have a considerably wider distribution than in Europe where small size packages, often made from cardboard, are almost exclusively used in the individual housholds but seldom in larger kitchens. For packages up to 1 kg, the term domestic salt (the term "table salt" is misleading) does make sense in Europe; in Latin America, "domestic" salt packages (primarily plastic bags of up to 1 kg) have a far wider distribution and reach a far greater percentage of the population. In Germany and France, for example, the use of fluoridated salt in restaurants is not allowed (with one exception, see SCHULTE 2005).

With bread, the situation is again different. Bread is not allowed to be fluoridated in Costa Rica and Uruguay. In Jamaica and Colombia, bread is automatically made with FS because all salt for human consumption is fluoridated. In the Swiss cantons of Glarus and Vaud, part of the bread is fluoridated because the local bakeries use fluoridated salt (dispatched in 25-kg plastic bags). In another canton, Ticino, meals cooked at school are prepared with fluoridated (domestic) salt (since 1997), and part of the hospitals are using the 25-kg plastic bags with fluoridated (and of course iodized) salt. A detailed analysis of the respective situation is not at hand. But it is evident that in Latin America fluoridation limited to small packages affords a wider coverage of the population and accordingly does exert a stronger cariostatic effectiveness than "domestic" salt does in Europe. In Europe, there is also widespread use of condiments, based on a mixture of salt and glutamate. Such condiments are preferentially used on the table instead of plain salt. Ready-made soups and similar products are also common, but only low-salt products may be seasoned with FS.

Fluoridation of domestic salt and socio-economic aspects: consequences for the cariostatic effectiveness in entire populations

This section deals with the effectiveness of fluoridated salt when it is used for domestic purposes. This is the case in most European countries, and the effectiveness must be expected to be lower than the reductions presented in Table 1. At the present stage, evaluation of the Swiss material (mostly published in German) and other data suggests that consistent use of fluoridated domestic salt provides a 30% reduction of caries prevalence in children. For the model calculations made in this section, it is not important whether the cariostatic effect is in fact 25, 30 or 35% because the conclusions will be shown to remain largely unaffected.

The market share of the FS among the total of domestic salt in Germany in 2003 was 60%. When 60% of the population benefit from the 30% reduction, the resulting overall reduction may seem to be equal to 18% (=0.6*0.3). These 18% will be referred to as the "raw" effectiveness because it does not take into account that children in the low S-E stratum, when compared to those of higher strata, have a considerably higher caries prevalence which is essentially due to the very reason that they make less usage of caries preventive methods. Accordingly, it is to be expected that the use of FS is less frequent among children in the low S-E stratum, particularly if FS is more expensive than the unfluoridated varieties.

For the model calculations presented in Table II, the following assumptions are made:

– It is assumed that the low S-E stratum comprises one-third or 33% of the children of a population; this corresponds to the frequent choice of assigning approximately one-third of the

Tab. II Percentage reductions of DMFT experience through fluoridated domestic salt with an effectiveness of 30%. The population is split in a low S-E stratum (33% of the population) and a high S-E stratum, including the medium S-E stratum (67% of the population).

	France	Germany	Switzerland
Overall % of users of F-salt	30*	60*	85*
Overall initial DMFT	2.33	2.33	2.33
Users of F-salt in low S-E only half that in high S-E			
% users in high S-E	36	72	100
% users in low S-E	18	36	55
Users of F-salt in high S-E stratum as far as possible, "worst case"			
% users in high S-E	45	90	100
% users in low S-E	0	0	55
"Raw" reduction: reduction of 30% multiplied by the percentage of the market share (=% of users) of fluoridated salt			
Reduction of DMFT	0.21	0.42	0.59
% DMFT reduction	9.0 (9.0)	18.0 (18.0)	25.5 (25.5)
Model A			
% of F-salt users in the low S-E strata half than that % in the high S-E			
Reduction of DMFT	0.20	0.40	0.57
% DMFT reduction	8.5 (8.1)	17.0 (16.2)	24.3 (23.3)
Model A & B			
Assumed effectiveness: 40% in low S-E, 20% in high S-E stratum			
Reduction of DMFT	0.17	0.34	0.49
% DMFT reduction	7.2 (7.2)	14.4 (14.4)	20.8 (21.0)
Model C			
Assumed effectiveness: 40% in low S-E, 20% in high stratum and "worst case": minimal use of F salt in low S-E			
Reduction of DMFT	0.12	0.24	0.49
% DMFT reduction	3.9 (4.5)	10.3 (9.1)	20.8 (21.0)

* The percentages of users (equal to the percentage of the market share of the fluoridated salt among all domestic salt) corresponds to the one in the respective country in the last years (see text).

Assumed initial DMFT prior to salt fluoridation for all 3 countries:
High S-E stratum: 2.0 / Low S-E stratum: 3.0 DMFT.

(...) In parentheses: percentage reductions in parentheses computed from the same model, but assuming 2.0 DMFT in the high S-E stratum and 4.0 DMFT in the low S-E stratum.

children to the "high risk" group. Likewise, the Significant Caries Index (Bratthall 2000) focusses on the 33% of the children with the highest caries experience while disregarding the DMFT score in the remaining middle and high S-E stratum (67% of the children).

– It is further assumed that the average initial DMFT score (i.e. before salt fluoridation) is 3.0 in the low S-E stratum as opposed to 2.0 DMFT in the remaining children, pertaining to middle and high S-E strata.

Schemes of fluoridation of domestic salt are most developed in France, Germany and Switzerland. Both fluoridated and unfluoridated salt is on sale. For the following model calculations, market shares were set at 30% for France, 60% for Germany and 85% for Switzerland. This corresponds to the actual percentages in the years 2002–2004 (Marthaler 2005, Schulte 2005, Tramini 2005).

Based on these realistic assumptions, model calculations can be carried out predicting caries prevalences. The second row of Table II shows the overall average DMFT to be 2.33 in all three countries (0.33*3.0 DMFT+0.67*2.0 DMFT; 0.33=33%, 0.67=67%); 2.33 is called the initial average, meaning the one prior to the 30% inhibitory effect of FS. Assuming that the children in the high S-E stratum use FS twice as frequently as those in the low S-E, there would be in France 36% users in the high S-E stratum but only 18% users in the low S-E stratum (see upper part of Table II). In a "worst case" scenario, all users would be in the high S-E stratum; they would constitute 45% of the high S-E stratum, leaving no users in the low S-E stratum. Under the conditions in Germany the 60% users would constitute the vast majority of the high S-E stratum (90%), leaving again all nonusers in the low S-E stratum. In the case of Switzerland with 85% users, all children of the high S-E would invariably be users and the remaining nonusers (15% of all children) would necessarily fall into the low S-E stratum; within that stratum, the nonusers constitute only 45%, which is a minority.

Model A was based on precisely this assumption: children from the low S-E stratum use FS half as frequently as those in the high S-E stratum (results are shown in Table II, discussed below). The assumption that families of the lower S-E strata make less use of preventive measures is documented by their higher caries prevalence, but specific investigations on the use of FS in different S-E strata have apparently not been made. It is the mothers who choose the type of salt, and the beneficial effects of fluoride are better known in the higher S-E strata. Therefore, there is no reason to reject assumption A.

There is an additional circumstance to be considered. Four research papers published between 1984 and 1992 demonstrated that the benefit from water-borne fluoride in children with high S-E status (and accordingly lower caries prevalence) is lower than the benefit for those with low S-E status (Burt & Fejerskov 1996, p. 286). This relation has since been confirmed for both the primary (Jones et al. 1997) and the permanent dentition (Jones & Worthington 2000). Figure 2 in the paper by Jones and Worthington suggests that in deprived children (Townsend Score 8 or higher), the effect of fluoridation (through water) reduced the DMFT by 50%. Conversely, in the well-to-do S-E stratum (Townsend score –3 or lower), the reduction due to fluoride was only 25%. The respective assumption B implies that the effectiveness would be a 40% reduction in the low S-E children as opposed to a reduction of only 20% in the high S-E stratum. This corresponds to the average 30% reduction by fluoridated domestic salt.

– Model A&B takes into account that the effectiveness of fluoridated domestic salt is 40% in the low S-E but only 20% in the high S-E children; in addition, it takes into account that usage of FS is twice as frequent in families of the high S-E stratum than in the low S-E stratum (Model A).
– Model C illustrates the "worst case". In addition to the assumption for Model B, it is assumed that all users, as far as mathematically possible, are children from the high (and middle) S-E stratum.

The effectiveness of FS derived from Model A, the underlying assumption of which is not well documented, is only slightly lower than that of the "raw" approach (Tab. II). In France, under the "raw" model (only the 30% users benefit from the 30% reduction by domestic FS) the reduction would be 9.0% (0.3×0.3); in Model A, however, the reduction is slightly lower, namely 8%; the loss of the caries-preventive effectiveness was similarly small for Germany and Switzerland.

When passing to Model A & B, which also takes into account the stronger effect of FS in the low S-E stratum, there is an additional decrease of the overall cariostatic effectiveness, from 9.0% (raw reduction) to 7.2% in France and from 18% to 14.4% in Germany. The decrease of the effectiveness is due to the fact that only a minority – the 33% low S-E "risk group" – benefits from the higher reduction.

In the "worst case" scenario, Model C, more than half of the effectiveness predicted from the "raw" effectiveness is lost in France: the percent reduction decreases from the "raw" 9.0% to only 3.9%. In Germany, the decrease is porportionally smaller, from 18% to 10.3%; this is the minimum possible of the public health effect in German children of the actual salt fluoridation scheme. In Switzerland, where the nonusers of FS constitute only 15% of the total population, the "worst case" overall reduction remains at 20.8%, which is a loss of only one fifth when compared to the 25.5% raw effectiveness. There is no further loss when passing from assumption B & A to assumption C because the user percentage is so high that even the majority of the 33%-risk individuals use FS. A high market share of FS is obviously the crucial point for an optimal public health result.

Which of the three models actually corresponds best to reality? Assumption A is justified but not tested, and its effect is small (see Model A). Assumption B has a solid scientific background; therefore model A&B would seem realistic. This means that the overall reduction to be expected may be at only four fifths of the "raw" reduction in all three countries. On the other hand, the "worst case" scenario severely lowers the percentage reductions in France and Germany, but not at all in Switzerland. In Switzerland, the market share of 85% users of F-salt garantees that more than half of the low S-E children benefit from the FS; and in the worst case, the reduction will be 20.8% (see the lower part of Tab. II).

The conclusion is that in order to obtain substantial public health benefits, efforts are indispensable to induce high percentages of the population to use FS, in the range of 75% to 85% at least. This is again a strong case for universal salt fluoridation, which is apt to provide a level of caries protection in all S-E strata similar to that provided by water fluoridation. Universal salt fluoridation corresponds to the term universal salt iodization, which is consistently recommended for the prevention of Iodine Deficiency Diseases (SULLIVAN et al. 1995).

On the other hand, a public health effect is virtually nonexistent in countries including Austria, Slovakia and Spain where less than 10% of domestic salt used is fluoridated. This demonstrates that mere authorization and availabilty, including labelling such as "helps to prevent dental caries", do not suffice to induce substantial parts of the population to use FS. When there is free choice between fluoridated and unfluoridated salt, campaigns aimed at inducing the vast majority of the population to use FS instead of unfluoridated salt are indispensable.

How to obtain high market shares for fluoridated salt

Campaigns with the aim of increasing the market share of FS must be well organized and must operate professionally. In the case of Germany, the successful promotions, illustrated by SCHULTE (2005), had budgets of EUR 60,000 to 80,000 per year. For a small country like Slovenia (2 million inhabitants), a budget of 40,000 euros per year would correspond to EUR 0.02 per person and year. The same amount, EUR 40,000, would necessitate a contribution of only EUR 0.008 per person and year in Slovakia (5 million inhabitants; market share of FS some 5% in 2004). As evident from TRAMINI's (2005) report on France, such campaigns must be carried on. In fact, the market share in France had been 50% in 1991 and 60% in 1993; from 1999 to 2003, it has been varying between only 27 and 31%. Not surprisingly, the reduction of the use of FS in France corresponds to an almost complete lack of a secular decline of DMFT experience (national average 2.07 in 1993, 1.9 in 1998; BOURGEOIS et al. 2004).

Disease prevention is of high priority in the World Health Organization. By contrast, the population at large and their representatives in the governments are primarily focussing on treatment in both dental practices and clinics. However, it is evidently up to the health ministries to finance efficient campaigns for the use of FS, prevention of disease being one – if not the most – important task of any "health" ministry. In view of the low cost of prevention in dentistry, particularly with a view to the extremely low cost of salt fluoridation (GILLESPIE & MARTHALER 2005) and the billions spent for repair of preventable damage, annual budgets of 40,000 to 100,000 euros are very small. In spite of the low cost, none of the western European governments which authorized production and/or use of FS seems to have supported its use.

It is noteworthy that in spite of the antifluoridation lobby, universal or almost universal SF was introduced in two Swiss cantons. In 1970, when FS (with only 90 ppmF) was already available in more than half of the Swiss cantons, the canton of Vaud (retaining its cantonal monopoly of the salt trade), resolved to fluoridate all salt for human consumption to the level of 250 ppm F. This was done on the advice of Prof. H. R. Mühlemann (then Director of the Clinic now called "Preventive Dentistry, Periodontology and Cariology") and Dr. H. J. Wespi of Aarau, the first to propose and to actually use FS (MARTHALER 2005). Under similar premises, quasi-universal salt fluoridation was introduced in the canton of Glarus in 1975, including bakeries and restaurants (sacks with 25 kg of FS were made available for the large kitchens). In both cantons, surveys on the prevalence of caries were carried out from 1970 to 1991, providing evidence in favor of the FS (DE CROUSAZ et al. 1993, MARTHALER & STEINER 1981, MENGHINI et al. 1995). However, due to the educational school programs and liberal availability of fluorides in toothpastes, gels and rinses, the assessment of the importance of the FS within the decline of dental caries by 90% from 1964 until 2000 (MARTHALER 2004, MARTHALER et al. 2005) must await further research. In the other cantons of Switzerland, sales of FS in sacks of 25 kg have been increasing since 2003.

In the last two decades, the antifluoridation lobby has weakened in continental Europe. Considering the fading antifluoridationist activities, politicians in central and eastern Europe could be expected to recognize the introduction and promotion of salt fluoridation as the cheapest measure to reduce dental caries prevalence in the entire population. In Germany and Switzerland, the following strategy was most successful:

Step 1: Obtain legal bases for the introduction of fluoridated domestic salt.
Step 2: Increase the market share of FS to at least 40 or 50%.
Step 3: Persuade large distributors to offer only the FS; once the FS is preferred by the majority, offering other varieties of salt is not "good business" (special types of salt like "pure sea salt" and similar products, customarily quite expensive and seldom used, may still be marketed).

The initiative of a food chain to sell only FS originated in Switzerland from within the enterprise more than 12 years ago. In Germany, salt producers and dental associations joined ranks in attempting to persuade or convince food chains to restrict their sales to FS. In view of the market share soon exceeding 67% – or two thirds – in 2005 or 2006, further steps may be envisaged. The fluoride excretion studies reported by SCHULTE et al. (2002) point to opening the road for the use of FS in large kitchens. However, regulation is still complicated and EU directives are not helpful because public health is not on the agenda. The EU categorizes salt for human consumption as an industrial product and disregards health effects – beneficial or negative – of salt.

In continental Europe, few if any health authorities provided financial support for the promotion of FS; this was left to dental associations and the industry. For a given country let us assume that one producer provides FS to a population of 5 million. This corresponds to sales of roughly 10 million kg of domestic salt, or 20 million packages of 500 g. If the price of the "fluoridated package" is 5 cents higher than the "unfluoridated package", the additional revenue in commerce is one million euros, of which 700,000 may eventually reach the producer. This is far beyond the yearly running cost of fluoridation (GILLESPIE & MARTHALER 2005). A fraction of it, say approximately EUR 80,000, would be available for promotion of FS, which in 12 years leads to a market share of 60%. This process was, however, very slow when compared to the rapid introduction of FS in Jamaica and Costa Rica.

Using an intelligent packaging policy increases the market share of FS without any cost. In Switzerland, the fact that FS is offered in several package sizes while unfluoridated salt is available only in the not very popular 500-g packages increased the market share of the FS from 75% to 83% (MARTHALER 2005). When the vast majority of customers, say 90%, prefer FS, FS could be declared or labelled the "regular" salt, while unfluoridated salt could be made available in drug stores and/or pharmacies. This, however, might entail vociferous antifluoridationist protests and it may be better to be content with the 90% market share.

The potential of salt fluoridation on a world-wide scale

In a number of industrialized nations with a total population of approximately one billion, caries prevalence in schoolchildren declined substantially in the last quarter of the 20th century (PETERSEN 2003). Generally, the habit of brushing teeth with fluoridated toothpastes – recommended twice a day – is considered to be the primary single reason for this improvement. Therefore, the twice daily use of such toothpastes should universally be promoted. In spite of this measure, however, teeth will continue to be at risk for caries, particularly in the lower S-E strata. Therefore, it is in the interest of public health to combine the use of fluoride toothpastes with other measures which are compatible with fluoride dentifrices. Apart from the possibility of using hygienic and dietary methods, which are effective against caries on a limited scale on a community level, water fluoridation, salt fluoridation and milk fluoridation are practiced world-wide. The millions benefitting from fluoride either via water or via salt are generally users of fluoridated toothpastes. In Araucania (Chile), the children of the rural areas with a population of 200,000, benefit from a milk fluoridation scheme, while also using fluoridated toothpastes. Of course, salt fluoridation is not applicable everywhere. Conditions favoring or precluding the introduction of FS were discussed by WHO (1994) and more recently by MARTHALER & PETERSEN (2005). An important factor is the extremely low cost of salt fluoridation. Once the equipment including a laboratory for quality control has been set up, cost per annum and person are very low, less than US$ or EUR 0.05 (GILLESPIE & MARTHALER 2005).

In the case of the highly industrialized countries where there has been a secular decline of caries prevalence over many years, children at the age of 12 have DMFT scores as low as 1.0 on average (DMFT experience is still considerably higher in central European countries) (MARTHALER & POLLAK 2005). While it is true that approximately half of the children – those with a DMFT = 0 ("caries free") – would apparently not benefit from additional preventive fluoride, those with 2 and more DMFT certainly would. What is more important: part of the children still caries free at age 12 will not be caries-free at the age of 15, and the percentage of caries free individuals will again be substantially lower at the age of 20. Even in countries where prevention has been successful over decades (Denmark, Germany, Norway, Sweden, Switzerland), average DMFT counts in military recruits were still in the range of 4.8 to 10.1 in the nineties (MENGHINI et al. 2001). In the case of the lowest average (4.8 in Switzerland in 1996), only 69 of the examined 416 recruits, or 17%, had remained caries free (DMFT = 0, not considering precavity lesions). Even in the affluent countries where low caries levels have been attained at school age, teeth continue to decay in adults, albeit less rapidly than prior to the secular decline which began in the seventies and eighties in many industrialized countries. In the growing segment of adults beyond 60 and 70 years of age, the effectiveness of fluoride toothpastes is diminishing as levels of oral hygiene are decreasing. Fluoride in salt (and water) would automatically provide protection at all ages.

Outside of the industrialized countries, dental caries has remained a great problem. Lack of prevention and very limited access to dental treatment, not affordable for the majority of the population, is the fate for the majority of mankind. Cheap prevention measures, particulary salt fluoridation where it is feasible, would certainly improve the dental health situation. Global DMFT averages are still closer to 3.0 than to 2.0 in 12-year-old children (PETERSEN 2003). Public dental health measures will be most successful when combinations of available means of prevention, as far as they are compatible, are applied and will reach populations all over the world.

Zusammenfassung

Ziel dieser Arbeit ist es, das Potenzial der Salzfluoridierung für die öffentliche Gesundheit auszuloten. Mehrere Studien belegen, dass die karieshemmende Wirksamkeit umfassender Salzfluoridierung mit 50% Hemmwirkung derjenigen der Trinkwasserfluoridierung ebenbürtig ist, dies sowohl bei den bleibenden Zähnen wie auch im Milchgebiss. In kontinentalen europäischen Ländern ist die Fluoridierung bisher auf das Haushaltsalz beschränkt, von dessen regelmässigem Gebrauch man eine 30-prozentige Hemmwirkung erwarten darf. Diese fällt aber, auf die Gesamtbevölkerung bezogen, deswegen tiefer aus, weil nur ein Teil der Bevölkerung fluoridertes Salz verwendet. Dabei muss man mit einer weiteren Wirkungseinbusse rechnen, weil die unteren sozio-ökonomischen Schichten fluoridiertes Salz in geringerem Ausmass verwenden als höhere s-ö Schichten, die allgemein mehr Vorbeugung betreiben, beispielsweise durch täglich zweimaliges Zähnebürsten mit fluoridhaltiger Zahnpaste. Modellrechnungen zeigen, dass in Deutschland, wo in den letzten Jahren ein Marktanteil des Fluoridsalzes von 60% erreicht wurde, statt 30% nur etwa 14% Hemmwirkung in der Gesamtbevölkerung erreicht werden. Für Frankreich, mit einem Marktanteil des Fluoridsalzes von nur 30%, kann man einen Rückgang der Kariesprävalenz von nur 7% erwarten. Es ist deshalb sehr

wichtig, einen Marktanteil von mindestens 80% zu erreichen. In der Schweiz ergäbe sich beim Marktanteil von 85% eine Hemmwirkung von 21% in der Gesamtbevölkerung. Ein hoher Marktanteil des fluoridierten Salzes lässt sich auch bei freier Wahl der Konsumenten mit relativ geringem finanziellem Aufwand erreichen. Allerdings sind Gesundheitsministerien oft nicht zu entsprechender Unterstützung bereit. In diesem Fall lässt sich durch eine bescheidene Preiserhöhung des Salzes nicht nur die Beigabe des Fluorids, sondern auch ein Werbebudget bezahlen, mit welchem die Mehrheit der Bevölkerung für die Benützung des fluoridierten Haushaltsalzes gewonnen werde kann. Weltweit ist die Salzfluoridierung ein erprobtes Verfahren der öffentlichen Gesundheit. Sie kann vor allem für Entwicklungsländer von grossem Nutzen sein, denn sie ist bei Weitem die billigste Methode der Kariesprävention und mit dem Gebrauch von Fluoridzahnpasten kompatibel.

Résumé

Ce travail a pour but d'explorer le potentiel de la fluoration du sel de cuisine au niveau de la santé publique. Plusieurs études ont démontré que l'efficacité inhibitrice de la carie, de l'ordre de 50%, de la fluoration globale du sel est égale à celle de la fluoration de l'eau potable, tant en ce qui concerne les dents permanentes que les dents de lait. Dans les pays européens continentaux, la fluoration se limite jusqu'à présent au sel de cuisine, dont l'utilisation régulière permet d'attendre un taux d'inhibition de 30 pour cent. Du fait que seule une partie de la population utilise du sel fluoré, ce taux est toutefois plus faible au niveau de l'ensemble de la population. En réalité, ce taux est encore pus faible, car les couches socioéconomiques défavorisées utilisent dans une moindre mesure le sel fluoré par rapport aux couche socioéconomiques plus aisées. En outre, ces dernières se caractérisent par un niveau de prévention bucco-dentaire en général plus élevé, par exemple par deux brossages des dents par jour à l'aide d'un dentifrice fluoré.

Dans des modèles théoriques, des calculs type ont montré qu'en Allemagne, où la part de marché du sel fluoré a atteint 60% au cours des dernières années, l'effet d'inhibition dans la population globale n'est que de 14%, au lieu des 30% théoriquement possibles. En France, avec une part de marché du sel fluoré de 30% seulement, on peut s'attendre à une réduction de la prévalence de la carie de 7% seulement. Pour ces raisons, il est très important de viser une part de marché d'au moins 80%. En Suisse, où la part de marché du sel fluoré est de 85%, on peut s'attendre à une efficacité d'inhibition de 21% dans la population globale.

Même en cas de libre choix du consommateur, il est possible d'obtenir une part de marché importante du sel fluoré avec des investissements financiers relativement peu importants. Force est toutefois de constater que les ministères de santé publique ne sont dans bien des cas pas prêts à apporter un soutien adéquat. Dans ce cas, il est possible, par une augmentation modeste du prix du sel fluoré, de compenser non seulement les frais de l'adjonction du fluorure, mais également de générer des fonds pour un budget publicitaire qui permette de convaincre la majorité de la population des avantages de l'utilisation du sel de cuisine fluoré. Sur le plan mondial, la fluoration du sel est une méthode éprouvée dans le cadre de la santé publique. Elle est particulièrement utile pour les pays en développement, du fait qu'il s'agit de la méthode de prévention de la carie de loin la moins chère et de surcroît compatible avec l'utilisation de dentifrices fluorés.

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