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Salt as a carrier of iodine in iodine deficient areas

Summary

In the past 80 years, salt has proved a reliable, safe, cheap and stable carrier to correct iodine deficiency on a large scale. Salt is available and consumed everywhere in the world. The per capita daily consumption (a decisive figure for calculating the iodine dosage) is roughly the same under the most varied cultural conditions, namely 8 to 12 grams. An overdose of salt (and thereby of iodine) is virtually excluded. The iodine content of salt is reasonably stable, provided KIO_3 (instead of KI) and low-density polyethylene bags for packaging are used under adverse climatic conditions. The price of iodizing salt in Switzerland comes to approximately 15 US cents per capita and per year. Disadvantages of salt are that small local salt manufacturers may lack funds and know-how for proper iodization. Compulsory iodization of all salt may be unacceptable to some people on constitutional grounds, or because they claim to suffer from side effects. However, the advantages of salt as a carrier largely outweigh its drawbacks, and today iodized salt is available to over one billion people.

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Introduction

Until the beginning of the twentieth century the Swiss population was heavily afflicted with iodine deficiency disorders, a term which encompasses goitre, mental retardation, short stature and deaf-mutism or a combination of all four, called cretinism. For example, around the year 1800 a census ordered by Napoleon

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turned up 4,000 cretins among the 70,000 inhabitants of the Canton Valais, an enormous social burden (see reviews in MERKE 1984 and BÜRGI et al. 1990). Today, thanks to iodized salt, Switzerland is entirely free of the ill effects of iodine deficiency.

In this short essay we shall illustrate how the idea arose of using salt as a carrier of iodine, and why iodized salt turned out to be by far the best way to eliminate iodine deficiency. We shall also discuss the difficulties which were encountered, and which might be relevant to fluoridated salt, too.

The concept of iodized salt

"I am convinced that goitre would disappear from the Cordilleras, if the authorities made available in every district town [...] a depot of salt containing iodine." A mere twenty years after the discovery of iodine as an element, this remarkable statement was made by BOUSSINGAULT (1831), a French scientist who had travelled extensively in the South American Andes. He had identified trace amounts of iodine in the salt of goitre-free towns, and he

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supplied this naturally iodized salt to goitrous towns, and it seems to have been effective (see in MERKE 1984). Thus, priority for the idea of iodizing salt for prophylaxis on a large scale undisputedly goes to Boussingault.

The problem of the correct iodine dose in salt

Chatin, in 1870, was the first to start a large scale prophylaxis with iodized salt in endemic regions in France (see in MERKE 1984). Preceding this, he had compiled an enormous number of iodine measurements in various foodstuffs from all over Western Europe (CHATIN 1852). In principle, he concluded correctly that iodine was scarce in food from endemic regions, but we know from later and actual figures that the food iodine contents he had established were at least ten times too high. By consequence, he chose an excessive salt iodine content, namely 100 to 500 mg per kg salt (by comparison, actual salt in Switzerland contains 20 mg/kg). We know from modern data that this dose may cause iodine-induced thyrotoxicosis, and Chatin's program was stopped. It was only 50 years later that BAYARD (1919 and 1923), a general practitioner in the alpine valley of Zermatt, performed a correct dose-finding study: Three mg/kg salt had a modest effect on goitres, 6 mg was more effective, and even 15 mg/kg were well tolerated. With these results at hand, EGGENBERGER (1923) started a well-tolerated and lasting prophylaxis in the Canton of Appenzel Ausserrhoden in Switzerland. Over the next thirty years, iodized salt was adopted by all Swiss Cantons. The initial dose (3.75 mg/kg salt) was only partially effective. It was raised stepwise to 7.5 mg (1962), to 15 mg (1980) and to 20 mg (1998) and the last three steps were monitored by measuring the urinary iodine excretion, which should be 100 to 200 µg per litre or per day. That iodine dose in salt matters, is clearly evident from Table I.

The problem of estimating salt intake

In order to compute the iodine content of salt, one must know the average salt intake per capita. This is best done by measuring urinary 24 hour Na excretion. Surprisingly, in most populations which have access to salt, the daily per capita NaCl intake is found to be around 8 g for women and 12 g for men. If, by law, all salt for human consumption is iodized, one may safely base the calculation on an average daily salt intake of 10 g. If non-iodized salt is also available one must deal with a considerable uncertainty factor. If, in addition, only household salt is iodized (which is the case in many countries) the estimation becomes even more difficult, because in affluent societies household salt contributes only approximately 2 g to the total daily intake of 10 g (JAMES et al. 1987, BUERGI 1993). The rest of salt is ingested with food prepared outside the household such as sausages or bakery and dairy products (so-called hidden salt). Table I illustrates the problem: in the 1990ies, despite a constant salt iodine content, the iodine intake, measured by its urinary excretion,

showed a tendency to decline in Switzerland. Sales of iodized household salt remaining constant (see accompanying article by MARTHALER 2005), and salt imports being prohibited by a state monopoly, the decline must be attributed to importation of food processed with non-iodized salt. As of 1999 the tendency was reversed thanks to an increase of iodine in salt.

Technical and stability problems with iodized salt

Eggenberger had devised a simple hand-and-shovel method, whereby he mixed a solution of KI with salt (see BÜRGI et al. 1990). Transposed on an industrial scale, salt on a conveyor belt passes under a spray of a KI solution and is subsequently dried. Many countries have encountered problems of stability of iodine when using KI which easily oxidizes to the volatile I₂. This problem is overcome by the use of KIO₃ which is much more stable than KI. Under tropical conditions, low-density polyethylene bags must be used for packaging (WHO et al. 2001).

The problem of opposition to iodized salt

In Switzerland, opposition to iodized salt arose as soon as its introduction had been decided. Ironically, it was mainly from some influential members of the medical profession (BIRCHER 1929); they predicted a massive outbreak of iodine-induced thyrotoxicosis, which in fact never took place, probably because the initial salt iodine content was deliberately chosen too low, and then raised stepwise. Opposition continues to this day, now mostly from advocacy groups of persons claiming to be intolerant to iodine, even to physiologic doses of 100 to 200 µg per day. More recently, proponents of restricting salt intake for the prevention of hypertension have joined the opposition, despite that the two aims (preventing hypertension and eliminating iodine deficiency) are not in conflict with each other, since it would be easy to compensate for a lower salt intake by raising the salt iodine content.

Conclusions and outlook

Salt is unsurpassed as a vehicle of iodine. It is consumed by virtually all populations; the amount consumed is fairly constant, and overdose is virtually excluded, since too salty food is not palatable. Iodized salt now is available to over 1 billion people of the world. It probably is the cheapest and most effective preventive measure ever taken. It has paved the way for the introduction of fluoridated salt, and for the supplementation of other trace elements.

Zusammenfassung

Während der vergangenen 80 Jahre hat sich Salz als zuverlässiger, sicherer, billiger und stabiler Träger für die grossräumige

Tab. I Urinary iodine excretion in Switzerland from 1923 to 1999. For simplicity, only mean or median values for iodine are indicated.

| Year | 1923 | 1974–79 | 1981–88 | 1994 | 1997 | 1999 | 2004 |
|------------------------|------|---------|-----------|--------|-------|--------|--------|
| Iodine in salt (mg/kg) | none | 7.5 | 15 | 15 | 15 | 15–20 | 20 |
| Urinary iodine (µg) | 18* | 76–93** | 127–160** | 118*** | 96*** | 115*** | 141*** |

* µg per 24 hours. ** µg per gram creatinin. *** µg per litre. The 3 different units for iodine excretion may be considered as roughly comparable. 1999 was the year of transition from 15 to 20 mg iodine per kg salt. (From BÜRGI et al. 1990, TRUONG et al. 1997, ZIMMERMANN et al. 1998, HESS et al. 2001). The figures for the year 2004 are from ZIMMERMANN et al. (to be published).

Prävention von Jodmangelkrankheiten bewährt. Salz ist überall erhältlich und wird überall konsumiert. Die tägliche Salzeinnahme pro Kopf (eine wichtige Messgröße zur Festlegung der Jodkonzentration im Salz) ist unter den unterschiedlichsten kulturellen Bedingungen identisch, nämlich 8–12 Gramm. Eine Überdosierung von Salz (und damit von Jod) ist praktisch ausgeschlossen. Der Salzjodgehalt zeigt eine akzeptable Stabilität, vorausgesetzt, man verwendet KIO_3 (an Stelle von KI) sowie in feucht-tropischem Klima Polyäthylen niedriger Dichte zur Verpackung. Der Preis für die Jodierung von Salz in der Schweiz beträgt ungefähr 15 US Cents pro Kopf und Jahr. Ein Nachteil von jodiertem Salz ist, dass kleinere handwerkliche Salzproduktionsbetriebe über zu wenig Kapital und Kenntnisse verfügen, um Salz korrekt zu jodieren. Ein gesetzliches Obligatorium für jodiertes Salz ist für gewisse Kreise nicht annehmbar, sei es aus verfassungsrechtlichen Gründen, sei es, dass sie behaupten, an Nebenwirkungen zu leiden. Die Vorteile von Salz als Jodträger überwiegen jedoch eindeutig, und heute steht jodiertes Salz weltweit über einer Milliarde Personen zur Verfügung.

Résumé

Pendant les 80 dernières années, le sel iodé a fait preuve de véhicule fiable, sûr, bon marché et stable pour combattre à grande échelle la carence en iode. Le sel est mis en vente et consommé partout dans le monde. Sa consommation journalière pour des adultes est pratiquement identique sous les conditions culturelles les plus variées, soit 8 à 12 grammes par personne. Un surdosage de sel (et ainsi d'iode) est pratiquement exclu. Le contenu en iode du sel est raisonnablement stable, à condition qu'on utilise du KIO_3 (à la place de KI) et des sacs tapissés de polyéthylène à basse densité comme emballage dans des climats humides et chauds. En Suisse, le programme de sel iodé coûte environ 15 US cents par habitant et par an. Un désavantage du sel iodé est le fait que des petits producteurs artisanaux de sel manquent de fonds et de connaissances techniques pour assurer un sel iodé de qualité suffisante. Une ioduration de tout le sel imposée par la loi serait inacceptable à certains groupes, soit pour des raisons constitutionnelles, soit qu'ils prétendent souffrir d'effets secondaires. Néanmoins, les avantages du sel comme véhicule d'iode dépassent largement ses désavantages, et à ce jour, plus d'un milliard de personnes sont mis à son profit.

References

- BAYARD O: Beiträge zur Schilddrüsenfrage. Benno und Schwabe, Basel (1919)
- BAYARD O: Über das Kropfproblem. *Schweiz Med Wschr* 53: 732–737 (1923)
- BIRCHER E: Jodiertes Kochsalz für die ganze Schweiz? *Schweiz Med Wschr* 59: 123–126 (1929)
- BOUSSINGAULT J-B: Recherches sur la cause qui produit le goitre dans les Cordillères de la Nouvelle Grenade. *Annales Chimie Physique (Paris)* 48: 41–69 (1831)
- BÜRGI H, SUPERSAXO Z, SELZ B: Iodine deficiency diseases in Switzerland one hundred years after Theodor Kocher's survey: A historical review with some new goitre prevalence data. *Acta Endocrinologica* 122: 577–590 (1990)
- BÜRGI H: Iodization of salt and food. Technical and legal aspects. In: F. Delange (Ed): *Iodine Deficiency in Europe*. Plenum Press, New York, 261–268 (1993)
- CHATIN A: Recherche de l'iode dans l'air, les eaux, le sol et les produits alimentaires des Alpes de la France et du Piémont. *Compt Rend Acad Sci (Paris)* 34: 51–54 (1852)
- EGGENBERGER H: Die Verhütung des Kropfes und des Kropfrecidives. *Schweiz Med Wschr* 53: 245–249 (1923)
- HESS SY, ZIMMERMANN M B, TORRESANI T, BÜRGI H, HURRELL R F: Monitoring the adequacy of salt iodization in Switzerland: a national study of schoolchildren and pregnant women. *Eur J Clin Nutr* 55: 162–166 (2001)
- JAMES W P, RALPH A, SANCHEZ-CASTILLO C P: The dominance of salt in manufactured food in the sodium intake of affluent societies. *Lancet* 426–429 (1987, 1)
- MARTHALER T M: Overview of salt fluoridation in Switzerland since 1955, a short history. *Schweiz Monatsschr Zahnmed* 115: 651–655 (2005)
- MERKE F: *History and Iconography of Endemic Goitre and Cretinism*. Hans Huber, Berne (1984)
- TRUONG T H, GERBER H, HAENEL A F, BÜRGI H: Iodine nutrition in various life stages and ultrasonographic thyroid volumes in schoolchildren in a region of Switzerland. *Schweiz Med Wschr* 127: 715–721 (1997)
- WHO, UNICEF, ICCIDD: *Assessment of iodine deficiency disorders and monitoring their elimination*. 2nd ed. WHO/NHD/01.1. WHO, Geneva, p 22 (2001)
- ZIMMERMANN M B, HESS S, HURRELL R F: Urinary iodine concentrations in Swiss schoolchildren from the Zurich area and the Engadine valley. *Schweiz Med Wschr* 129: 770–774 (1998)