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Defining cooking salt intakes for patient counselling and policy making

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SUMMARY. The role of salt (NaCl) in the development of high blood pressure has been a matter of debate, however, the Intersalt Study showed that sodium (Na) intake in various areas of the World is related to the slope of blood pressure with age. Accurate amounts of the total salt intake or that coming from a particular source are needed, both, for physicians who need to consider the salt intake of their patients and for public health workers who are in charge of the implementation of public health programs where salt is used as a carrier of other nutrients. An analysis of the literature suggests that exaggerated values for total salt intakes have often been obtained from indirect estimates; discretionary salt use, i.e. home-cooking salt has invariably been overestimated. A method is described for measuring the contribution of cooking salt to total salt intake since it is a confusing area where inappropriate methods have been used to assess its contribution. The method described is based on the use of small amounts of lithium carbonate fused with NaCl. Validation experiments were undertaken to determine the naturally occurring lithium (Li) in a number of foods including fresh, frozen and tinned vegetables, and the use of Li tagged salt for cooking vegetables and for direct use in cooked foods. We also assessed whether Li was taken up proportionally with Na into foods during cooking. In general vegetables contained variable but only small amounts of Li except aubergine and spinach, and Li was taken up proportionally with Na in a variety of vegetables. Results showed that 36,35 and 21% of the salt added during cooking was recovered in carrots, runner beans and potatoes respectively, the rest being discarded in the cooking water. This suggest that about a third of salt added during the cooking of vegetables will be ingested by the household. Attempts to rely simply on the total use of household salt supplies will clearly exaggerate, markedly, the true intake of individuals.
Key words: Salt, cooking, intake, policies, advice, patients.

RESUMEN. Cómo se valora el consumo de sal de cocina para dar consejo a pacientes y definir políticas de consumo. El papel de la sal (NaCl) en el desarrollo de la hipertensión arterial ha sido un área de mucho debate, sin embargo el estudio Intersalt demostró que, en varias partes del mundo, la ingestión del ión Na está correlacionada con las cifras de tensión arterial según la edad. Es necesario valorar con exactitud tanto la ingestión total de sal así como aquella que proviene de una fuente particular, i.e. fuentes discrecionales (sal de mesa y de cocina) y no discrecionales (sal de productos procesados, agua, etc). Esta información facilitará la orientación al paciente por parte del médico en cuanto a la fuente de sal que debe restringir, y los encargados de implementar políticas de salud, podrán decidir con mayor precisión, los programas de salud pública en los que la sal se usa como vehículo de otros nutrimentos. El análisis de la literatura sugiere que se han obtenido frecuentemente valores exagerados de cifras de ingestión de sal cuando esta se evalúa con métodos indirectos, i.e. el uso de sal de cocina en el hogar, que siempre se ha sobreestimado. Aquí se describe un método basado en el uso de pequeñas cantidades de carbonato de litio mezclado (en fusión a 800°C) con NaCl. Se llevaron a cabo experimentos de validación para determinar la cantidad natural de litio (Li) de una variedad de vegetales frescos, congelados y enlatados; el uso de esta sal marcada con Li para cocinar vegetales, así como su uso directo en alimentos cocinados. Se valoró si el Li era absorbido proporcionalmente con el Na en los alimentos durante la cocción. Los resultados mostraron que, en general, los vegetales contenían cantidades variables pero pequeñas de Li, excepto la berenjena y la espinaca, y el Li y el Na difundieron proporcionalmente en los vegetales. De la sal añadida durante la cocción sólo el 36,35 y 21% fue absorbida en zanahorias, ejotes y papas respectivamente, el resto fue descartado junto con el agua de cocción. Esto sugiere que solo, un tercio de la sal que se añade durante la cocción de los vegetales será ingerida en el hogar. Valorar la ingestión de sal y sus fuentes basados simplemente en la compra o el uso total de sal en la familia, claramente exagera, de forma muy marcada, la ingestión verdadera de sal de los individuos.
Palabras claves: sal, cocina, consumo, políticas, consejo, pacientes.

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INTRODUCTION

Salt intake has been linked to the development of hypertension which is a risk factor for both coronary heart disease (CHD) and stroke. The dangers of high salt consumption have been reported extensively; they are blacked by a great deal of experimental work in animals as well as evidence in man (1-10). The Intersalt study showed that sodium intake in various areas of the World is related to the slope of blood pressure with age, even after adjusting for body weight and alcohol consumption (11). In parts of Mexico the prevalences of hypertension are as high as 27% (12) and, according to official statistics, CHD is now becoming the leading cause of death among the adult population (13). It is therefore important to establish what the salt intake is in Mexico and its sources. Discretionary use of salt is that salt used by households in cooking or at the table, whereas non-discretionary salt includes that added in processing to the naturally occurring salt of the food itself. If an accurate assessment of these contributors can be made then public health workers will be in a position to give appropriate advice to the public on the most suitable way of reducing its salt intake and to identify the major sourcess of salt used in manufacture so that steps can be taken to persuade the industry to change their processing methods.

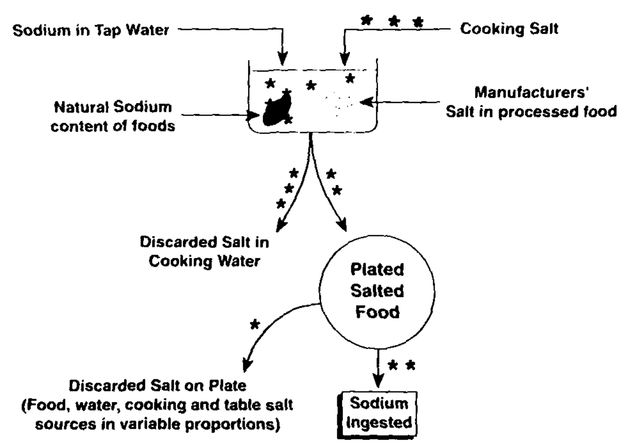
Accurate assessments of total salt intake or that coming from a particular source, e.g. cooking salt, are also needed for the implementation of public health programs where salt is used as carrier of other nutrients. Thus a salt iodine mixture has been used for many years to prevent certain types of goiter. Domestic salt has also been used as a carrier of fluoride for preventing dental caries (14). Other programs have used chloroquine or pyrimethamine salt mixtures as a suppressive against sporozoite induced vivax malaria (15). If this is to continue, then the quantitative significance of the salt source must be known so that any planned reductions can be accompanied by complementary increases in the nutrient or drug supplement.

Physicians who manage patients with hypertension also need to consider the salt intakes of their patients. Unfortunately most of them currently ignore the dietetic issues in hypertension management because it seems simpler to use drugs. Given the increasingly recognized hazards of drug therapy and the established value of dietary interventions (16) it now becomes important to identify how best to help patients by dietary means. In this paper we highlight the issue of cooking salt as a contributor to total salt intake because it is a confusing area where inappropriate methods have been used to assess its contribution.

Assessment of cooking salt: The assessment of cooking salt intake by an individual or population has always been looked upon as something very complex and tedious. Its accurate measurement usually required the analysis of pre-cooked and cooked foods, together with separate estimates of the sodium in tap water. Some investigators assumed that a great deal of cooking salt was discarded in cooking water; to check this entails the use of duplicate weighed samples of food eaten by the individual as well as monitoring food leftovers. Only then could the actual amount of cooking salt eaten be measured.

We proposed some years ago a new approach to evaluating cooking salt intake using lithium labelled salt (17). The tracer lithium was expected to track the sodium through the cooking and eating process and then to be absorbed and recovered in the urine. If lithium could be measured easily in the urine it should, from a knowledge of the background urinary recovery of ingested lithium and knowing the proportions of lithium in the tagged cooking salt, be possible to calculate the actual amount of cooking salt eaten. This method therefore avoided all the tedious analyses required in the traditional approach. The principles of the technique are shown in Fig. 1.

FIGURE 1
The tracking of cooking salt consumption



Cooking salt has been labelled with lithium which will make its way, in proportion to the sodium, into the food being cooked. Some of the lithium will be discarded in the cooking water whilst the rest will be ingested or discarded on the plate.

Several steps were needed to approach the validation of the new technique with scientific rigour. A method of food digestion was required to determine the naturally occurring lithium in a number of foods. This was important because if foods contain a great deal of lithium then a small amount of tracer Li could not be used in the tagged salt source. A validation procedure was also needed to ensure that lithium penetrated into vegetables at a rate equivalent, on a molar ratio basis, to that of sodium. The validity and reproducibility of lithium and sodium uptake by vegetables had also to be assessed. The validity of using Li tagged salt for cooking vegetables and for direct use in cooked foods then had to be checked to ensure that whatever the route of use of the Li tagged cooking salt the Li was released once the food was eaten. This required a metabolic study where the amounts of cooking salt added to cooking vegetables and to other ingredients was known accurately and where the recovery of ingested Li could be meticulously monitored by collecting urine, faeces and sweat.

Finally we sought to compare the estimates of cooking salt consumption derived from a simple weighing method in the home with the new specific Li tracking technique. An epidemiological study was needed for this approach.

This paper therefore provides an overview of these studies and proposes some simplification of the technique which allow a coherent line of research on sodium intake to be developed in Mexico.

METHODS

The lithium content of foods and lithium uptake in cooking:

The lithium content of a number of foods including fresh, frozen and tinned vegetables, was measured. All three types of prepared vegetables were washed in deionized water, cut into small pieces and weighed before freeze-drying for several days. The samples were re-weighed, ground to a fine mixture and digested in concentrated nitric acid in acid washed pyrex crystal tubes before being measured for their Li content.

Two different digestion methods were compared in order to test for any differences in the extraction of lithium from foods. The importance of totally digesting food samples in heated concentrated nitric acid was compared with a partial digestion method using 1M nitric acid without heating for 12 hours. Raw cabbage, raw peeled potatoes and the peel of the potatoes were chosen for the experiment. After digestion and dilution with deionized water the Li content of the solution was measured by flame photometry in a Pye Unicam spectrophotometre.

Cooking experiments were conducted to investigate whether there was equivalent penetration of lithium and sodium into vegetables. Two vegetables, potatoes and cabbage were assessed in duplicate with their Li and Na content being measured before as well as after cooking. By measuring the volume of water used, the weight of cooking salt added and the final partition of Li and Na between the water and vegetables, it was possible to assess both total recoveries of Li and Na and whether the molar ratio Na/Li had been mantained as the elements penetrated the vegetables.

Metabolic and epidemiological studies: The use of lithium-labelled cooking salt was then tested both in a controlled study where defined quantities of labelled cooking salt were given to five volunteers in a metabolic ward for a period of 6 days and in an epidemiological study where *ad libitum* use of cooking salt was allowed. Details of the controlled metabolic study are given elsewhere (18) and other aspects of the epidemiological study have also been described (19).

In the metabolic study the vegetables for each of the volunteers were prepared in batches two or theree days before the start of the metabolic experiment. An extra amount was also prepared to allow for samples to be taken for duplicate analysis. Four cooking sessions were necessary to prepare the vegetables for five volunteers. Vegetables were weight into individual portions after being cooked and they were then stored at -20°C in the long-term freezer until needed.

The quantities of vegetables (0.5-6.5 kg), volume of water (1-13 L) and grams of salt (2.9-37.7 g) used in the cooking of labelled and unlabelled vegetables were substantial. The Li and Na content of all components were assessed at the end of the cooking time which varied depending on the vegetable involved. Li tagged salt was also added directly to several foods being prepared for cooking ie. jam tarts, omelette and gravy. This was to test the recovery of Li added to foods as distinct from those where Li occurred naturally. By Knowing the Li + Na content of the cooked vegetables and the absolute amount of tagged salt added to specific food items it was possible to estimate total Li and Na intake and then see how well these could be recovered in urine, faecal and sweat collections.

Finally, the study of cooking salt use was taken into an epidemiological context by using the tagged cooking salt for a one week period. The lithium cooking salt was tested in 83 free living adults from 54 households in a small market town in Cambridshire England. The 54 index cases were randomly selected from the age/sex register of a medical practice and 29 of their spousses agreed to take part. In addition to collecting 24h urines for 12 days to assess the Li output the weighed loss of tagged cooking salt was measured. This allows comparisons of the traditional method based on weighing with the new Li specific method.

RESULTS

The total digestion method gave consistently higher lithium values for the potatoes ($p<0.001$) and their peel ($p<0.001$) than the partial digestion technique. On the basis of these results, the total digestion method was chosen for assessing the lithium content of foods. The results of the analysis of the Li content of vegetables are given in Table 1. Aubergine and spinach had remarkably high lithium contents but their country of origin was not known. Some care will therefore be needed to check the Li content of Mexican plants if the technique is to be applied in this country.

TABLE 1
THE MEASURED NATURAL LITHIUM CONTENT OF VEGETABLES *

Vegetables	µmol Li/kg (WW)** Mean ± SD	µmol Li/kg (DW)° Mean
Heinzed baked beans	5.9±0.6	16.5
Brussel sprouts	3.6	18.0
Cauliflower	1.1	6.1
Spinach	29.3 ± 0.3	168.0
Broad Beans	2.7 ± 0.2	10.9
Crosse & Blackwell Baked Beans	4.8 ± 0.2	14.3
Parsnips	2.6 ± 0.3	9.9
Processed Peas	8.8 ± 0.7	24.5
Garden Peas	3.4 ± 0.5	22.3
Green Beans	2.3 ± 0.3	11.3
Carrots	2.8 ± 0.8	15.4
Mushrooms	2.9 ± 0.2	18.9
Aubergines	132.2 ± 1.8	794.1
Swedes	1.8 ± 0.3	9.9
Leeks	2.9	16.4
Courgettes	2.9 ± 0.9	16.4

* Usually a minimum of 3 samples were analysed where an SD value is shown
** Wet Weight
° Dry Weight

Table 2 shows the aggregate results of the recovery of lithium and sodium added to the cooking water in the preliminary study with potaoes and cabbage. Despite the losses of water and the separate analyses of the cooking water and vegetables, good recovery figures for sodium and lithium were obtained varying from 91 to 107%. Table 2 also shows the proportion of the total added Li and Na which had penetrated int he cooked vegetables. Only 15-20% of the added elements was taken up by the potaotes and cabbage. There is a remarkable concordance in the results for Na and Li despite the Na/Li ratio in the added material being approximately 45:1. Confirmaton of the proportional penetraton of these two elements into the cooked foods is shown in Table 2 where the Li and Na are also expressed as their ratios in both the cooked vegetables and the final cooking water.

TABLE 2
SODIUM AND LITHIUM RECOVERIES AND VEGETABLE NaCl AND Li PENETRATION DURING COOKING*

	Total Recoveries		Penetration into vegetables			
	Na (%)	Li (%)	Na (%)	Li (%)	Na/Li** Molar Ratio Cooked Vegetables	Na/Li** Molar Ratio Cooking Water
Potato 1	96.0	90.9	15.4	17.1	53.9	45.7
Potato 2	97.6	96.8	18.4	18.9	48.9	44.0
Cabbage 1	106.6	100.4	20.6	20.5	44.6	48.0
Cabbage 2	96.6	101.6	17.2	15.7	41.0	42.6

* An allowance was made for the lithium and sodium content of the uncooked material by measuring their concentration of Na and Li prior to cooking.
** Na/Li ratio of labelled salt= 44.8

In the first part of the metabolic study the penetration of Li and Na was assessed in 3 different vegetables cooked for very different periods of time (Table 3) and with very different volumes of cooking water. The Mean ± SD recovery of Na in the batches, of runner beans was 92.5 ± 4.2%, for the batches of potatoes 95.5 ± 7% and for the batches of carrots 107.1 ± 3%. Total lithium recoveries in all batches ranged from 97 to 117% and for sodium the recoveries ranged from 87 to 112%. Similar recoveries were obtained in these batches cooked with unlabelled salt. The Na/Li molar ratios obtained in the twelve batches of vegetables cooked with tagged salt are also shown in Table 3. There was a reasonable similarity in the Na/Li ratio in the vegetable and cooking water despite all the sample manipulation during the preparation and cooking steps. The sampling, analytical and biological variation in the lithium and sodium content of the foods seemed therefore to be small. With a labelled salt having a Na/Li ratio of 73.1 it was noteworthy that the potaotes and runner beans showed a very similar response and that the Na/Li ratio varied from 66-81% which is probably within the error of the experiment given the number of analyses involved. Yet, despite the variation in the lengh of cooking and the amount of water used, the amount of sodium and lithium that diffused into the potatoes and runner beans were remarkably similar. There was also no evidence of differences in the Na/Li ratio despite a fourfold variation in cooking time.

TABLE 3
TOTAL LITHIUM AND SODIUM RECOVERIES AND ELEMENTAL RATIOS IN INDIVIDUAL BATCHES OF VEGETABLES AFTER THEY HAVE BEEN COOKED FOR A VARIABLE LENGTH OF TIME WITH LITHIUM-TAGGED SALT

Batch No	Vegetable	Volume Cooking Water (1)	Total Cooking Time (min)	Na (5)	Li (%)	Na/Li Water	Na/Li Vegetable
1	Potatoes	4	37	104	117	57.7	81.3
2	Potatoes	8	63	87	98	61.5	79.3
3	Potatoes	4	35	97	103	68.2	72.9
4	Potatoes	4	41	94	100	68.1	72.2
5	Runner Beans	1	16	87	98	58.4	74.8
6	Runner Beans	2	19	97	100	72.0	69.4
7	Runner Beans	1	14	94	97	69.8	71.6
8	Runner Beans	1	14	92	101	67.4	65.8
9	Carrots	1	17	105	99	69.6	100
10	Carrots	2	19	112	100	75.9	100
11	Carrots	1	17	106	101	71.9	89.4
12	Carrots	1	15	104	102	71.6	83.7

* Labelled salt Na/Li ratio= 73.1

The carrot studies suggested that Na entered this vegetable rather more easily than Li. However, the recoveries of Li and Na from the total study were good and there was no real evidence of the Na/Li ratio being lower in the cooking water at the end of the study. Thus, with only 36% of the total salt being taken up by the vegetables some other factor could be involved. A small interference in the spectrometric analysis of the Li content of the carrots because of quenching by the carotenoids also present in the carrots would lead to an underestimation of the lithium content of carrots. This in turn would give the observed Na/Li ratios in the water, but higher ratios in the carrots after cooking.

Metabolic studies: The mean lithium content of the daily portion of vegetables assigned to the volunteers during a metabolic study, was 106.6±25.3 μmol Li. the greatest intake was calculated for the vegetable batches of one subject (NG). The intake assigned to each volunteer was based on the actual Li and Na content of the duplicate portions from each subject's batch of vegetables. Each volunteer had a standard amount of vegetable but the variability in calculated lithium content indicates the importance of testing each batch for their mineral content.

Table 4 sets out the recoveries of Li from 5 subjects who had received Li in both the cooked foods and the vegetables. The dominant route of excretion proved to be the urine 93% and the high recovery rates shows thats there was no unusual binding of Li by the cooked vegetables or other dietary ingredients. This contrast with a residual Li excreted in faeces of about 1.7 μmol per day when the naturally derived Li from plants amounts to 4.7 μmol/day in young English adults (unpublished observations). Thus, about 36% of plant food lithium, presumably associated with ressidual plant cell walls, is normally excreted in the faeces. The results in Table 4 show, however, that it is legitimate to use the Li tagged salt for tracking the amount of cooking salt actually eaten in households because of the very high intestinal uptake and renal excretion of lithium.

TABLE 4
THE RECOVERY OF LITHIUM LABELLED COOKING SALT EXPRESSED AS A PERCENTAGE OF INTAKE

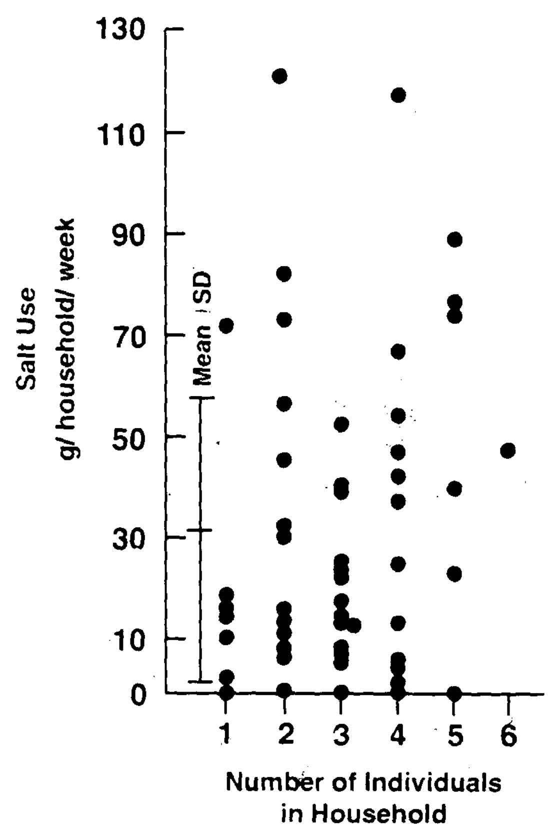
Subject	Urine	Sweat	Faeces
NG	98.9	1.0	0.6
RT	98.9	2.1	1.1
JP	98.7	2.9	0.9
JW	89.3	1.4	1.0
RG	95.1	1.0	2.0
Mean	96.2	1.68	1.12
SD	4.17	0.82	0.53

Lithium in urine: Baseline lithium excretion was measured during the first experimental period in which subjects were put on a metabolic diet. Baseline excretion in individuals ranged from 4.1 to 5.3 μmol Li with a coefficient of variation between individuals of 9.2%.

However, during the 6-day labelled cooking salt period, urinary lithium excretion was remarkably similar from subject to subject. Thus, total recoveries of lithium used as cooking salt were 100.5, 102.1, 102.5, 91.7 and 98% for the 5 subjects (mean 99% ± 4.4% SD). Of the total Li intake 96.2 ± 4.2% of cooking salt was excreted through the kidneys. This reflected the constant amounts of labelled cooking salt used and shows how uniform the response of the volunteers was in terms of the route for Li excretion.

Epidemiological study: In Figure 2 the variation in cooking salt use in households of varying size is shown. The total amount of cooking salt used per household did not seem to increase in proportion to the number of members in the household. Thus, households with two occupants had a similar average cooking salt use to that of households with five inhabitants. Thus salt use per individual was less in those from larger families. The weekly cooking salt intake per household member was 12.3 ± 14.1 g (Mean ± SD) but there was substantial scatter with a range from 0 to 72 g salt used. There was no relationship between table and cooking salt intake in either the men or women. Thus, there seemed to be no tendency for women to salt the food heavily during cooking and then to add extra salt to their own food.

FIGURE 2
The household use of labelled cooking salt



Weekly cooking salt intake in fifty three households

DISCUSSION

It is remarkable how little information there is on the gains and losses of salt during the domestic preparation of food. Only a small proportion of the salt added to water for cooking foods will in practice be eaten. During the metabolic study parallel cooking experiments were conducted with different batches of vegetables where the proportions of sodium uptake by the foods and of that remaining in the cooking water were determined. The results showed that 36 ± 3%, 34.5 ± 3% and 20.8 ± 1.5% of the salt added during cooking was recovered in carrots, runner beans and potatoes respectively, the rest being discarded in the cooking water. These figures suggest that about a third of the salt added during the cooking of vegetables will be ingested by the household. The proportion distributed among the members of the household will, of course, depend on the amounts of food allocated to each person. Food wasted in saucepans or on plates will further reduce the contribution of this source to the total intake in each individual. Nevertheless, if the household purchase of cooking salt are expressed per head, then perhaps only 30% of the household salt use might be expected to be consumed.

The epidemiological data provided a direct check on these estimates because not only was total cooking salt use by the hosehold measured, but individual intakes could be quantified from the lithium data. A value of 24% was obtained for the average intake per head of the «purchased» cooking salt, this value also being expressed on a per head basis.

The only other data in the literature on this point is that of Toth and Sugar from Hungary (1975) (20) who claimed that 41% of the salt purchased by households is actually ingested. This figure of course includes table salt where the assumption is that a very much higher proportion of the salt is actually consumed. If the weight loss of table salt by adults taking part in the epidemiological study is added to the weight loss of cooking salt, and when these are related to actual intakes, then perhaps 33% of salt purchased is actually eaten. This illustrates the importance of a proper assessment of cooking salt intakes. Attempts to rely simply on the total use of household salt supplies will clearly exagerate markedly the true intake of individuals.

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