Nickel in Danish Food

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Veien NK, Andersen MR. Nickel in Danish food. Acta Derm Venereol (Stockh) 1986; 66: 502–509.

The nickel content of food items consumed in Denmark was estimated on the basis of analysis by atomic absorption spectrophotometry. The highest concentrations (1–10 mg nickel/kg fresh weight) were found in cocoa, licorice, lucerne seeds, dried beans, peanuts, hazel nuts, sunflower seeds, oat meal and wheat bran. A diet instruction sheet is proposed as an aid to reduce the amount of nickel ingested. The nickel intake of 8 normal volunteers for 24-hour periods was measured when they 1) ingested their usual diet, 2) reduced nickel intake by adherence to the diet instruction sheet, and 3) when they made a conscious effort to increase nickel intake. It is concluded that it is possible to reduce daily nickel intake in food items. *Key words: Nickel diet instruction sheet; Nickel intake.* (Received February 26, 1986.)

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Nickel allergic patients with recurrent vesicular hand eczema may experience flare of their dermatitis following oral challenge with doses of nickel sulphate containing from 0.5 to 5 mg nickel (1). There has been some debate concerning the significance of this finding, and the relationship between a single oral dose of an inorganic nickel salt and the daily ingestion of food which contains nickel is unclear.

In order to study this relationship it is necessary to instruct certain nickel allergic patients to reduce their daily intake of nickel. The dietary instructions published in the past have, however, been based largely on analyses of the nickel content of foodstuffs carried out before accurate methods of analysis were available (2).

The present study had two purposes: 1) to determine the nickel content of more common Danish food items, and 2) to determine if by adherence to diet instructions nickel intake can be altered significantly.

MATERIAL AND METHODS

A literature search revealed that certain food items are unlikely to have a high nickel content. Included among such food are meat, fish, dairy products and some fruits. These items generally contain less than 0.1 mg nickel/kg, and for a food consumed in large amounts, like milk, the nickel content is approximately 0.02 mg/kg. Cured meats had a somewhat higher nickel content averaging 0.19 mg/kg (3). The nickel content of most foodstuffs was derived from a study carried out by Koivistoinen (4). A comparison of the results of other recent investigations of the nickel content in food showed no significant deviations from Koivistoinen's study (5, 6, 7) (Table I).

The amount of nickel released from nickel-plated and stainless steel kitchen utensils and taps has been dealt with elsewhere (7, 8). The level of nickel in drinking water is ordinarily low, but after standing in certain taps overnight the nickel content of water may reach levels of 490 µ/l. A large scale screening of the nickel content of tinned, ready-to-eat food has been carried out by the Danish National Food Institute (9).

We therefore concentrated our efforts on the analysis of vegetables and other food items suspected to contain significant amounts of nickel and items suspected to cause flares of nickel dermatitis (10). We also analysed the nickel content of certain popular health foods and herbs thought likely to contain nickel.

Most of the food samples used in the study were purchased from a single major Danish food store

chain to simplify the tracing of their origin. The samples were dried at 105°C and homogenized; wet ashing was then carried out using nitric acid and hydrogen peroxide. The samples were measured by means of atomic absorption spectrophotometry (Perkin-Elmer AAS 2280 equipped with a HGA-400 graphite furnace). The detection limit of this equipment was 2 parts per billion (defined as 3 times the standard deviation of the blanks.) Supra-pure reagents were used throughout the study, and all glassware was soaked overnight in nitric acid before use. All determinations were carried out twice, and the results given here are the mean of the two determinations. The accuracy of the method was checked using "control samples" previously analysed for nickel content by the Danish National Food Institute. There was good correlation between the results of the two institutions (11).

A slightly different procedure was used for wet ashing in the initial stages of the study; i.e. it was carried out using perchloric acid and nitric acid, and analysis was performed after extraction with 2% diethyldithiocarbamate in xylene.

Details of the analysis procedure are given elsewhere (11).

When the nickel levels of the individual food items had been determined, a diet instruction sheet was prepared on the basis of this information and data from the literature, including the results of a questionnaire follow-up study of a previous diet trial among nickel allergic patients (10). Normal consumption of the various food items was also taken into consideration in the preparation of the instruction sheet (7) (Table II).

Eight volunteers (7 women and 1 man) were asked to use the double-portion method in order to collect all the food they ingested during a 24-hour period. This trial was carried out before the volunteers were given the diet instruction sheet. During the collection period each person placed portions of food equal to those ingested in an acid-washed plastic container.

Approximately 1 week later, the same volunteers were given instructions on how to reduce nickel intake. These instructions were followed during a 24-hour period in which portions of food identical to those ingested were again placed in a plastic container. Finally, the volunteers were asked to "reverse" the diet and ingest as much nickel as possible during a 24-hour period, and again, equal portions of the foods ingested were collected.

The volunteers were asked to ingest their usual volume of food during each collection period; in other words, they were not to reduce the amount of food eaten while adhering to the low nickel diet or increase it while attempting to eat food containing nickel. The content of dry matter and the total amounts of food ingested were determined for each 24-hour portion in order to determine whether the volunteers had followed these instructions. All the food collected was minced before it was dried and homogenized.

Table I. *Mean nickel content of selected vegetables and other foodstuffs in mg/kg fresh weight (range in parenthesis)*

From Koivistoinen (4)

Grains and grain products

Maize 0.4 (0.03–1.1); Rice 0.3 (0.1–0.9); Puffed rice 0.1 (0.1–0.2); Macaroni 0.3 (0.03–1.7).

Vegetables

Lettuce 1.0 (0.3–1.4); Parsley 0.5 (0.1–1.2); Dill 0.3 (0.1–0.8); Cauliflower 0.3 (0.03–1.0); Horseradish 0.3 (0.2–0.3); Red beet 0.1 (0.05–0.2); Rhubarb 0.1 (0.01–0.2); Leek 0.1 (0.03–0.2); Champignon 0.02.

Fruits and berries

Raspberries 0.9 (0.2–1.2); Prunes 0.6 (0.5–0.8); Pineapple 0.5 (0.2–0.8); Peach 0.4 (0.3–0.5); Black currants 0.1 (0.2–0.2); Mustard 0.2; Pear 0.1; Apricot 0.1; Grapefruit 0.1(0.04–0.4); Raisin 0.03 (0.02–0.04); Apple 0.01.

Drinks

Coffee, liquid 0.008.

Other foods

Honey 0.2 (0.1–0.3)

RESULTS

The amounts of nickel in individual food items are given in Table III. The nickel content of fresh and tinned tomato, tomato ketchup and various types of potatoes is given in Table IV.

Tea leaves contained 7.28 mg Ni/kg, and of the items used for tea making the water contained 0.002 mg/l, the tea itself 0.03 mg/l, tea leaves after extraction 1.78 mg/kg, filter bags 0.03 mg/kg, and a metal tea ball released 0.04 mg Ni into one litre of water. Tea from a self-service dispenser contained 0.01 mg/l.

Table II. *Diet instruction for the reduction of nickel intake*

It is not necessary to restrict intake of the following:

All kinds of meat and poultry, fish, and eggs. Milk, unflavoured yoghurt, butter, margarine and cheese.

Vegetables: asparagus, red beets, broccoli, brussels sprout, white cabbage, cauliflower, champignons, Chinese cabbage, corn, cumumber, dill, egg plant, parsley, green and red peppers, and potatoes.

Grain products: finely milled rye and wheat flour, whole grain rye and wheat bread (in moderation), white rice and breakfast foods made of rice, cornflakes and popcorn.

Fruits: peaches, pears, raisins, rhubarb and all berries *except* raspberries.

Drinks: coffee and tea (not too strong, and in moderation), soft drinks, alcoholic beverages (destilled products and drinks made from these).

Miscellaneous items including spaghetti and yeast.

The following foods have a high nickel content, and intake should be restricted:

Shellfish like prawns and mussels.

Vegetables: beans (green, brown, white), kale, leeks, lentils, lettuce, spinach, peas and sprouts made from beans and lucerne.

The grain products, buckwheat, millet, oat meal, wheat bran, i.e. bran and fiber products including mussli, bran bisquits, and fiber tables and multi-grain breads.

Fruits: figs, pinapple, prunes and raspberries.

Drinks: chocolate and cocoa drinks, and tea from drink dispensers.

Miscellaneous items including almonds, baking powder (in large amounts), linseed, hazel nuts, peanuts, soya-containing foods such as meat with soya additives, sunflower seeds, sweets containing chocolate, marzipan, nuts and strong licorice and vitamins containing nickel.

Various other food items and drinks can aggravate nickel eczema, even though the nickel content of these foods may be low. Included among these are beer, wine (in particular red wine), herring, mackerel, tuna, tomato, onion, carrot and certain fruits, in particular, apples and citrus fruits (juice). The vegetables mentioned here can usually be tolerated when cooked.

The first litre of water taken from the tap in the morning should not be used in food preparation, as nickel may be released from the tap during the night. Nickel-plated kitchen utensils, such as egg beaters and tea balls, should be replaced.

Acid foods such as stewed fruits and rhubarb cooked in stainless steel utensils shold be avoided. The acids in the foods can cause nickel to be released from the utensils. Tinned foods shold be eaten only in moderation.

Although your eczema is probably mostly due to the intake of foods containing nickel, it should be pointed out that prolonged physical contact with nickel-plated items can make it worse.

It is important to follow the diet instructions for at least 1 to 2 months. It can be difficult to change eating habits for a long period of time, and it is therefore recommended that you adhere to the instructions as closely as possible when eating at home. When eating away from home, the diet can be modified as necessary.

The eczema will not necessarily clear during the diet period, but there will ordinarily be fewer and shorter flares, and these will gradually diminish in intensity.

If, after 1 to 2 months, the diet seems to have had good effect, it is recommended that you continue for 6 months to a year to eat only moderate amounts of those foods with high nickel content.

The nickel intake of the 8 volunteers when they ingested normal diets averaged 0.13 mg/24 h (range 0.06–0.26 mg/24 h), compared with 0.07 mg/24 h when nickel intake was reduced (range 0.02–0.14 mg/24 h), and 0.25 mg/24 h when food rich in nickel was ingested (range 0.07–0.48 mg/24 h). There was a statistically significant decrease of nickel intake when the volunteers reduced nickel intake ($p<0.01$, Wilcoxon's test for pair difference) and a statistically significant increase of nickel intake when the intake on a normal diet was

Table III. *Nickel content in mg/kg fresh weight of individual food items*

The percentage of dry matter is given in parenthesis. N.D. = not determined

Grain products

Fiber mussli 1.1 (91), containing sunflower seeds 1.9 (95), hazel nuts 1.9 (94), oat flakes 0.9 (90), oat meal 0.8 (88), soya fiber 0.7 (93), wheat flakes 0.1 (87), white raisins 0.1 (78), wheat fiber 0.07 (93); soy meal 5.4 (N.D.); fiber tablets containing barley and citrus fruit fiber 1.1 (92); oat meal 1.1 (90); wheat bran 1.1 (89); fiber bran (toasted) 0.8 (96); millet 0.5 (94); linseed flakes 0.4 (92); wheat bran (from the chemist) 0.3 (88); 5-grain white bread 0.2 (67); whole grain rye bread 0.1 (59); dark "fiber trim" 0.1 (60); rye flour 0.1 (90); rye bread 0.1 (60); dark rye bread 0.09 (58); whole grain white bread 0.08 (70); cornflakes 0.05 (95).

Vegetables

Lucerne 4.2 (91); soy beans (dried) 2.4 (90); brown lentils 1.9 (90); brown beans 1.4 (84); white beans 1.3 (89); split peas 0.6 (87); green beans 0.4 (16); toasted onions 0.4 (94); green peas 0.3 (21); kale 0.3 (N.D.); crisps 0.2 (98); bean pate 0.2 (27); spinach 0.2 (14); tomato ketchup 0.2 (22); onion 0.1 (N.D.); chips 0.1 (33); soy bean sausage 0.1 (38); Mexican bean dish 0.1 (29); tomato 0.09 (4.7); tomato (tinned) 0.07 (4.8); cabbage (white) 0.06 (6.6); potato (with peel) 0.06 (21); potato (without peel) 0.05 (21); Chinese cabbage 0.05 (6.0); brussels sprouts 0.04 (15); red cabbage (pickled) 0.04 (18); carrot 0.04 (11); broccoli 0.03 (7.9).

Dried fruits

Fruit sandwich spread 2.3 (78); fig sandwich spread 1.2 (78); figs 0.9 (67); dates 0.3 (79); prunes 0.3 (64); raisins 0.1 (78).

Seeds and nuts

Peanuts 2.9 (N.D.); peanuts (diff. brand) 2.4 (95); sunflower seeds 2.0 (96); hazel nuts 1.5 (N.D.); buck's horn seed 1.5 (92); linseed (food store) 1.4 (93); cracked linseed (chemist) 0.9 (94); almonds 0.9 (96); fleawort seed 0.3 (90); nut pate 0.3 (39); peanut butter 0.3 (99); margarine 0.05 (N.D.)

Fish and shellfish

Mussels 0.6 (24); mussels (diff. brand) 0.4 (25); mackerel in tomato sauce 0.1 (32); marinated herring 0.06 (48); scallops in sauce 0.03 (24); prawns 0.03 (23).

Licorice, cocoa, etc.

Cocoa powder (German) 10.0 (N.D.); English licorice 8.3 (92); Cocoa powder (Dutch) 7.5 (N.D.); raw licorice 1 (Haribo) 4.9 (85); raw licorice 2 (Haribo) 4.4 (87); raw licorice (Lagerman) 4.4 (85); licorice powder (Lagerman) 4.3 (94); bitter chocolate 1.8 (N.D.); marzipan sweet 1.0 (91); milk chocolate 0.8 (N.D.); 100% pure marzipan 0.5 (86); carob powder 0.4 (95); white chocolate (with nuts) 0.3 (99); white chocolate (with rice) 0.1 (99); carob bar 0.1 (97).

Drinks

Tea leaves 7.3 (N.D.); tea powder 0.8 (N.D.); tea made with tea bags 0.03 (N.D.); apple juice 0.03 (7.3); orange juice 0.02 (N.D.); red wine 2: 0.02 (N.D.); red wine 1: 0.01 (N.D.); beer 0.01 (N.D.); red currant juice 0.01 (N.D.); tea made with powder 0.01 (N.D.).

Tablets (µg/tablet)

Scanalka 1.5 (95); fiber 0.6 (92); seaweed 0.5 (88).

compared with the high nickel diet ($p<0.05$, Wilcoxon's test for pair differnce). The total intake of food and the amounts of dry matter for the 8 volunteers are given in Table V.

DISCUSSION

It is not possible to estimate the daily nickel ingestion in every detail since the nickel content of individual vegetable food items may vary considerably depending on the soil and the environment in which they are grown. Many vegetables sold in Denmark are imported from a wide range of countries, especially during the winter months. It has been shown that carrots fertilized with sewage sludge high in nickel may accumulate significant amounts of nickel (12). Drinking water in areas where nickel is mined may be contaminated with nickel (13), and nickel may be released from taps under certain conditions or enter the food via nickel-plated kitchen utensils (7).

The results of the present investigation, in combination with the results of similar recent studies carried out in Denmark and other European countries, confirm that nickel content is highest in vegetable food items. It has been estimated that roots and vegetables account

Table IV. *Comparison between fresh and industrially processed products*

Product	Dry matter (%)	Fresh matter (mg Ni/kg)	Dry matter (mg Ni/kg)
Tomatoes			
Fresh	4.7	0.07–0.10	1.49–2.13
Tinned	4.8	0.07	1.46
Ketchup	22.2	0.20	0.91
Potatoes			
Unpeeled	20.7	0.05–0.07	0.24–0.34
Peeled	20.9	0.04–0.07	0.19–0.33
"Fresh", frozen	33.2	0.12–0.14	0.36–0.42
Crisps	97.7	0.22–0.27	0.22–0.28

Table V. *Total intake of food and drink, as well as intake of dry matter, during 24-hour periods on a normal diet, a low nickel intake diet and a diet intended to increase nickel intake, given in grams*

	Normal diet		Low nickel intake		Increased nickel intake	
Volunteer no.	Total intake	Dry matter	Total intake	Dry matter	Total intake	Dry matter
1	2 020	272	1 097	227	1 438	404
2	2 502	246	2 055	160	1 498	242
3	2 366	286	2 171	319	2 732	550
4	2 578	443	2 453	404	2 622	524
5	2 307	403	2 002	276	2 645	619
6	1 322	244	2 029	190	2 762	423
7	1 947	269	1 555	214	1 238	163
8	1 848	338	1 883	369	1 231	305
Mean	2 111	313	1 906	270	2 020	404

for 30% of daily nickel intake, while grains account for 25% (7). The individual food items, with the highest concentrations of nickel are cocoa, soy meal, oat meal, wheat bran, peas and beans. Many of the food items high in nickel content are among those frequently ingested by those who prefer "health foods". We therefore analysed the health food items listed in Table III.

Milk products, meat and fish appear to contribute very littel to the total consumption of nickel (7). Margarine has previously been reported to contain nickel due to the use of catalysts containing nickel in its manufacture (14). We could not reproduce this finding in Danish margarine which contained only 0.05 mg/kg.

Adherence to the diet instructions prepared in accordance with the results of the current study as well as various other recent reports resulted in a reduction of nickel intake to almost half of the pre-diet level. By consuming food rich in nickel it was possible to double nickel intake compared with pre-diet levels. Each determination was for only one 24-hour period; it is, of course, possible that some variation could occur from day to day.

The instruction sheet used in this study differs to some extent from previously published diet instructions used in our clinic (2). The previous diet instructions were based on research carried out before modern methods of analysis were widely used, and the chemical analyses upon which earlier lists were based are considered less accurate. A previous depletion study of nickel allergic patients showed a reduction of nickel in the urine during the diet period, which indicates that it is indeed possible to reduce nickel intake (2).

There is little information available on the consequences of a reduction of nickel intake on the nickel levels in the body. Presumably very little storage of nickel takes place in mammals, including man. Animal experiments indicate that some nickel is accumulated in the skin (15). This could be of significance, since the skin is the target organ of nickel allergy. Nickel appears to be an essential metal for some animal species (16). Its role in human biochemistry is not clear, but it is probably difficult to deplete the content of nickel in the human body to a degree that would induce deficiency symptoms. Such symptoms have not yet been described in humans.

Nickel allergic patients who experience aggravation of their dermatitis after ingestion of nickel presumably react to small amounts of nickel in the blood which stimulate immunologically active cells in the skin.

The bioavailability and the variation of the nickel concentration available to these cells, and, on the other hand, the immunological status of the cells in the skin are largely unknown.

Variations in these parameters could occur due to variations in intake, absorption and excretion of nickel, variations in sweating (nickel is accumulated in sweat) (16) and possibly the accidental ingestion of various chelating agents. Treatment of nickel dermatitis with disulfiram may lead to an initial flare of the dermatitis and a simultaneous increase of nickel excreted in the urine (17).

The most common type of nickel dermatitis thought to be aggravated by ingested nickel is a recurrent vesicular eruption on the hands. There are regularly reports of this type of dermatitis reproduced by single dose oral challenge with nickel sulphate containing from 0.5 to 5 mg of nickel (1). It may be that the improvements which have been reported as a result of following restricted diets are due to a reduction of the mean daily intake of nickel, but such improvement could also be due to an elimination of peak intake of nickel on particular occasions. The eruptive nature of hand dermatitis caused by nickel speaks in favour of the latter assumption.

There is a dissociation among the daily mean intake of 0.13 mg of nickel among the 8 volunteers, and 0.25 mg which was the mean intake when food rich in nickel was ingested,

and the dose of 2.5 mg we usually use for oral challenge. The single dose oral challenge with an inorganic nickel salt is a convenient challenge procedure, but this procedure does not necessarily reflect the clinical situation. Due to the many unknown factors in the bioavailability of nickel, it is very difficult to determine what a clinically relevant challenge dose should be. The present dose of 2.5 mg nickel has been maintained because one-half to two-thirds of nickel allergic patients in whom a systemic aggravation is suspected experience a flare of their dermatitis after challenge with this dose. An important support of the clinical relevance of this dose would be improvement after depletion of nickel in the patients whose dermatitis was aggravated after challenge.

The results of a questionnaire follow-up of nickel allergic patients placed on a nickel restrictive diet indicated that food items which contained or released vasoactive substances may play a role in the precipitation of flares of dermatitis. Those food items most commonly mentioned by the patients in this questionnaire are therefore included in the instructions given in Table II even though they do not necessarily have a high nickel content. These items could act as non-specific aggravating substances due to their effect on the blood vessels and/or the inflammatory response.

ACKNOWLEDGEMENTS

Financial support was provided by the following: Aalborg Kommunes Fond for Medicinsk Forskning, Sygekassernes Helsefond, Fonden af 1870 and P. Carl Petersens Fond.

The advice of J. Aa. Hansen, B. Kristensen and A. Marnæs, The Environmental Engineering Laboratory, University of Aalborg, is greatly appreciated.

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