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Selenium analysis of selected Egyptian foods and estimated daily intakes among a population group

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Abstract

The selenium (Se) content of 67 local foods had been determined using electrothermal (ETAAS) and hydride generation (HGAAS) atomic absorption spectrometry. The richest sources of Se were chicken ($323 \pm 35\ \mu g\ kg^{-1}$); eggs ($166 \pm 19.4\ \mu g\ kg^{-1}$) and fish ($306 \pm 5.2\ \mu g\ kg^{-1}$). Vegetables and fruits contained trace amounts of Se ($1–33\ \mu g\ kg^{-1}$). Wide variations in Se content were reported between various bread types and values ranged from 14 (home-made bread) to 152 (flattened bread) $\mu g\ kg^{-1}$, respectively. The estimated adult Se intake was $49\ \mu g\ kg^{-1}$; bread being the major contributor (63.6%).

1. Introduction

Interest in dietary selenium (Se) intake has increased due to selenium's significance in health (Levander, 1987, 1991). Epidemiological studies from Finland (Varo and Koivistoinen, 1980) and the People's Republic of China (Yang, 1985; Yang et al., 1987) have associated low Se intakes with a number of deficiency syndromes, particularly cardio-myopathy (Keshan disease) and osteoarthritis (Kashin-Beck disease).

Babies, particularly neonates, have been reported to be susceptible to Se inadequacy because of their sole dependence on human milk or cow's milk-based infant formulae (Lombeck et al., 1978). Soil Se content varies geographically between countries and within the same country, e.g. various regions of China are seleniferous and Se deficient. Therefore, Se uptake by the (plant-animal) human food chain varies geographically.

To assess these variations, total diet studies of food Se content and intakes are required (Wolf et al., 1992). The purpose of this study is to conduct a total diet study in an extension to a previous work on zinc (Hussein and Bruggemann, 1997) and to analyze the Se content of a representative range of core foods in order to estimate the average Se intake per day for Egyptian adults.

2. Materials and methods

The collection and preparation of the foods for analysis have been previously discussed (Hussein and Bruggemann, 1997). Briefly, a variety of foods were sampled, including breads, grains, dairy products, meats and selected fruits, vegetables and leafy vegetables. The foods included both simple and complex cooked dishes prepared at home or furnished by a catering service. The selected foodstuffs were those of more general consumption and are considered typical of the average diet of the entire population.

Ten different bread types were collected from seven different parts of the country (Fig. 1); four types were obtained from the retail market of Cairo and Giza and were prepared from short (72%) or long (82–85%) extraction wheat flour. The other six bread types were home-made and were collected from Menoufiya, Dakahleya, Giza, Menya, the New Valley and Sinai governorates; the first four were prepared from a blend based on wheat:maize flour at a ratio of 3:1. Bread samples collected from the New Valley were sun-fermented, while bread samples collected from Sinai were prepared from long-extracted barley flour.

Preparations of other dishes were carried out using standard procedures and traditional Egyptian cooking practices as they would be in a home setting. The weights of all ingredients were recorded.

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2.1. Sample preparation

The bread samples were air-dried at room temperature. The vegetables and all other dishes were freeze-dried in a Heto freeze-drier. The fresh weight and final dry weight of edible portions of each food sample were recorded and the percentage moisture was calculated. The freeze-dried samples were transferred to Detmold, where they were ground with titanium knives, and stored in high-density polyethylene bottles; 100 ml capacity, with screw caps and metal liners removed to prevent sample contamination. The bottles were pre-washed with aqueous nitric acid (10%), rinsed with deionized water and oven dried at 100°C.

2.2. Selenium analysis

About 1 g of the finely-ground samples were weighed precisely into test tubes and were digested by wet acid ashing using 2 ml of a mixture of concentrated nitric (spec grav 1.43 g ml^{-1}) perchloric acid (spec grav 1.70 g ml^{-1}) (5.0:0.1 v/v ratio) for 16 h at ambient temperature.

The following day, the tube contents were heated to 50–70°C in an electric thermoblock (Gebr. Liebisch, Bielefeld 14, Germany) until effervescent and the red fumes of nitric oxide gas ceased (4–6 h).

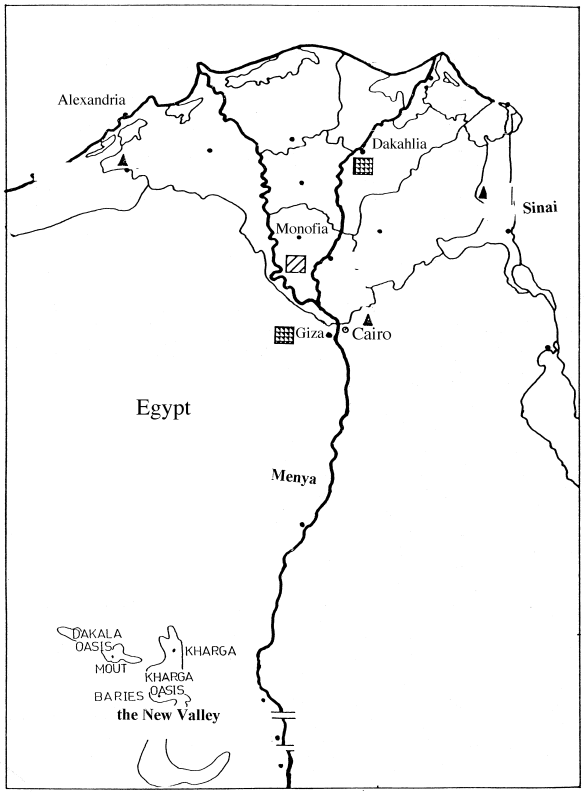

Fig. 1. Geographical sites for bread sampling. (C): Cairo; (D): Dakahleya; (G): Giza; (M): Menoufiya; (MYA): Menya; (N): the New Valley; (S): Sinai.

Finally the tubes were kept overnight at 150°C. After cooling, a mixture of 3ml concentrated nitric, sulphuric and 60% perchloric acids (2:0.5:0.1 ml) were added to each tube and a programmable circuit was used to raise the temperature from 70 up to 350°C within 42 h. The clear wet ash was redissolved in 2 ml of 20% hydrochloric acid and kept 1 h at 90°C before analysis of (Se).

2.3. Analytical instrumentation

Ultrapure grade chemicals (Merck, Darmstadt, Germany) were used throughout. Concentrated nitric acid was purified by sub-boiling distillation in a quartz still while perchloric acid was used without pretreatment. Water purified by ion-exchange and double-distillation from quartz was used.

A clean-air hood meeting the class 100 standard (less than 100 particles sized > 1 μm per cubic foot) was used in the final analytical steps. High purity Se was stock material used for preparation of standard. Volumetric transfers were carried out using Class A volumetric pipettes. A 0.2% (v:v) solution of nitric acid used in the preparation of the working standards, was used as a standard blank. Measurements were carried out on a Perkin Elmer Model 4000 atomic absorption spectrophotometer equipped with a MHS 10 Hydride generation system instrument was calibrated for the Se analysis using standards containing 0.025, 0.50, 0.10 ng Se ml^{-1} (Hack et al., 1996).

2.4. Hydride generator

The hydride generation of Se was based on the reaction of the acidic digest with a sodium tetraboro hydride/hydrochloric acid reaction system. The hydride was transferred into a reaction cell which was heated by an air-ethylene flame for the decomposition of the hydride. Instrumental parameters for AAS Measurement are given in Table 1.

2.5. Validation for each analytical batch

The series included analysis of three reagent blanks to monitor contamination and estimate detection limits,

Table 1
Instrumental parameters for AAS measurement

Detection limits	3 ng Se g^{-1},
Spectral band pass	2 nm
Burner head	10 cm single slot, titanium construction
Spray chamber	Standard, with glass impact bead inserted
1:1 Air/C_2 H_2 ratio	
Spectral line	Se 196.0 nm

plus at least one spiked recovery and at least one certified reference material (GRM). Standard reference materials GRM was analysed to check the accuracy and precision of the methods and were obtained from the Community Bureau of Reference (CBR) Brussels; wholemeal flour (CRM189) and brown bread (CRM 191), and from the Finnish Agricultural Research Centre (ARCL).

2.6. Calculation

The mean absorbance produced by the standards (corrected for the standard blank) was plotted vs the concentration of the analyte in the sample to produce an external calibration curve.

The concentration of the analyte in the sample was calculated using the following equation: $[M] = (C \times V)/SW$; where [M] is the concentration (μg kg/ml^{-1}) of Se in original sample, and C is the concentration of Se in the analytical sample as calculated from standard curve in units of μg kg/$^{-1}$, V is a dilution factor, and SW is the weight of the sample employed in kg.

2.7. Assessments of dietary Se intake

Consumption data previously reported by one of the authors (Hussein et al., 1995) were combined with Se composition data (μg kg^{-1}) reported in this study to estimate adult daily Se intakes by calculating the weighed sum of Se in all servings of foods in accordance with Fig. 2.

Fig. 2 gives the % Se contributed by each food to the populations total Se consumption (Block et al., 1985). The percent contribution provided by a particular food (i)

$$\frac{\text{Se provided by food i}}{\text{Se provided by all foods}} \times 100; \text{ estimated by}$$

$$\frac{\sum_{J=1}^{98} d_{ij} \sum_{k=0}^{S_{ij}} \text{Se}_{ijk} \times W_j}{\sum_{J=1}^{98} \sum_{i=1}^{67} \sum_{k=0}^{S_{ij}} \text{Se}_{ijk} \times W_j d_{ij}} \times 100$$

where i is food items, 1,2... 67; j is persons, 1,2.., 98; k is servings of that food item to that person, 0,1,2..., S_{ij} is number of servings of ith food consumed by jth person; $d_{ij} = 1$ if jth person consumed ith food, $= 0$ otherwise; Se_{ijk} is amount of Se contained in serving K of food i to individual j; W_j is sample weight for that individual.

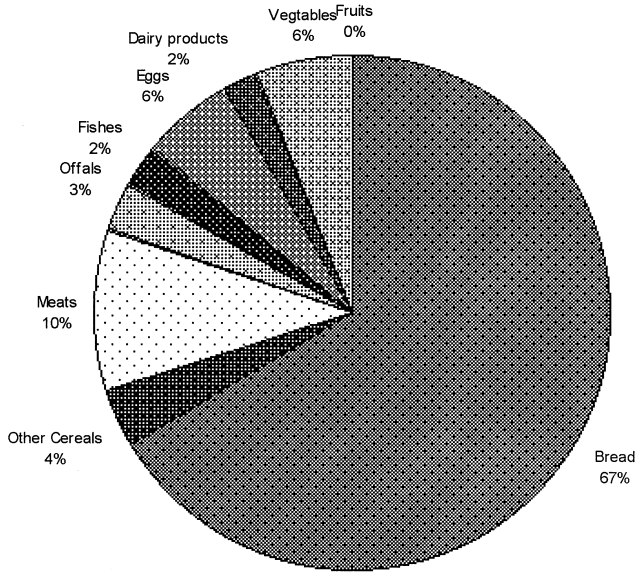

Fig. 2. Major contributors of Se in the Egyptian food supply (% of total estimated Se intake).

3. Results

The results of determination of Se in certified reference materials are presented in Table 2. The values for Se are almost in agreement with certified values. The detection limit by hydride generation AAS falls by 3 μg kg^{-1}; the respective determination limit was 10 μg kg^{-1}. The background analytical levels fall below 0.003.

Table 3 presents the means and standard deviation for Se concentration in foods per kilogram of table-ready edible foods. Food groups highest in Se are chicken and fishes over 300 μg kg^{-1}).

Wide variations were found in the Se concentration of the analyzed bread samples amounting to 10-fold differences ranging between 14 μg kg^{-1} (home-made) to 150 μg kg^{-1} (flattened bread).

Fig. 2 illustrates the major food contributors to Se intake. Roughly 67% of total dietary Se was provided

Table 2
Analysis of the ARCL standard reference material for Se content

Standard reference materials	Analytical value (μg kg^{-1})	Recommended value (μg kg^{-1})
Wheat flour ARCL * (Batch 68)		
Mean ($n = 15$)	53	57
Standard deviation	±7	±6
Detection limit D L	0.003	
Sample background	< 0.003	
Determination limit	0.01	

*(ARCL): Finnish Agricultural Research Centre.

Table 3
Selenium content of total diet study foods (g kg^{-1})

Food group	Moisture (%)	Selenium ($\mu g\ kg^{-1}$ as eaten)		
		Mean	SE	Range
Cereals, bread, cooked grains				
Wheat flour	7	193	< 10	
Bread, wheat flattened; 85% Extr.	24.6	152	16.4	63–274
Bread, wheat flattened; 72% Extr.	26.3	97	< 10	96–98
Bread, wheat rolls; 72% Extr.	24.8	136	28.4	84–182
Bread, wheat buns; 72% Extr.	21.4	89	< 10	
Bread-home made (sun-FERM.NV)	35.8	16	< 10	
Bread: home-made, wheat-maize (3:1) Delta	22.2	14	< 10	2–29
Bread Barley (Sinai)	31.0	31	< 10	25–40
Bars, rings, Zwieback	11.5	112	43.2	52–240
Macaroni, fine, home-made, raw	7.0	84	31	53–115
Macaroni raw, 2 brands	8.0	84	31	53–115
Macaroni cooked	48.8	59	< 10	
Macaroni lasagne	52.5	15	< 10	
Pizza	33.5	15	< 10	
Fattah, bread-rice, beef broth	65.0	21	< 10	
Puffpaste filled, ground beef	29.3	29	< 10	
Rice, raw	8.0	3	< 10	
Rice, cooked	58.8	2	< 10	
Maize, grilled	35.7	2	< 10	
Basbousa, heavy syrup	13.0	69	< 10	
Date bars, pressed date, wheat	16.6	83	21.4	29–148
Kahk, sugar cookies seasoning	6.0	161	< 10	
Keks, raisin, 3 brands	27.8	81	30.7	
Kunafa, heavy syrup	26.5	89	14.7	82–115
Oriental puff paste, heavy syrup	21.1	10	< 10	
Puff paste, home-made, sugar	16.1	246	< 10	
Waffles, filled; 2 brands	8.0	12	< 10	
Vegetables, tubers				
Potatoes, cooked	69.4	1	< 10	
Potatoes, fried	40.0	33	< 10	
Potato chips, in sandwich	55.0	19	< 10	
Taro, cooked + leaf celery	73.4	3	< 10	
Leafy vegetables				
Cabbage, stuffed with rice	67.9	1	< 10	1–2
Green mallow, in beef broth	80.6	3	< 10	
Jew mallow, cooked; chicken	85.0	2	< 10	
Lettuce, fresh	94.4	1	< 10	
Radish, white, fresh	90.3	3	< 10	
Rocket, *Eruca sativa*	89.7	2	< 10	
Spinach cooked + tomatoes	76.5	3	< 10	
Vegetables, beans/peas				
Beans, white, raw	7.8	7	< 10	
Beans, cooked, tomatoes	69.5	2	< 10	
Cowpeas,cooked, tomatoes	75.1	2	< 10	
Faba beans, in sandwich	46.0	37	4.0	26–49
Peanuts, peeled	18.9	13	0.5	12–14
Peas, cooked, tomatoes	72.3	3	< 10	
Vegetables, others				
Eggplant, fried and tomatoes	49.0	2	0.0	
Eggplant, stuffed with rice	62.3	2	0.2	
Lemon, pickled	78.0	2	0.0	
Tomatoes	92.0	1	< 10	
Vegetable soup	88.5	4	< 10	
Fruits				
Oranges	84.4	1	< 10	
Peaches	82.5	2	< 10	
Dairy products				
Milk, yoghurt	88.0	6	< 10	
Cheese, white soft	56.7	20	< 10	
Cheese, white defatted	70.4	16	< 10	
Cheese, salty	72.7	11	< 10	
Meats and fish				
Chicken leg, boiled	45.1	323	< 10	
Eggs, chicken, boiled	74.3	168	19.4	102–220
Liver, bovine, fried	45.0	62	1.5	60–65
Luncheon	46.1	7	< 10	
Luncheon, cans	58.8	100	< 10	
Beef, ground, raw	55.7	21	< 10	
Beef, steak	50.8	53	0.0	
Sausage, stuffed, bulgur	77.6	11	< 10	
Fish, marine, fried	45.2	387	5.8	377–397
Fish, river, fried, 2 brands	56.5	308	< 10	
Sardines, cans	75.1	223	< 10	
Wholemeal flour [CRM 189]*		132	10.0	
Brown bread [CRM 191]*		25		

*Certified reference materials (Community bureau of reference, Brussels).

by bread, 11% by animal proteins, and 25% came from miscellaneous sources. The average estimated Se intake among the studied adult group was 49 $\mu g\ d^{-1}$.

4. Discussion

The analysed flours and breads showed a high variation in the Se concentration (14–193 $\mu g\ kg^{-1}$). The wheat flour from wheat grains grown in Egyptian soils (14 μg Se kg^{-1}) was Se quite poor when compared with published data (Wolf et al., 1992; Pennington et al., 1995). Our data are in good agreement with those of a Scottish group (Barclay and Macpherson, 1992), which reported Se levels of 28 μg per kg dry weight for the 1989 harvest of wheat and 518 $\mu g\ kg^{-1}$ dry weight for Canadian wheat used for bread-making in Scotland.

The recommended value obtained for the wheat flour reference material is 58.5 $\mu g\ kg^{-1}$ dry matter (Kumpulainen and Paakki, 1987).

Whole wheat breads have hereafter been reported to have a higher Se content than white breads (Barclay and Macpherson, 1992). Bread is considered low in Se content in bread from Germany (Bruggemann and Ocker, 1990). Table-ready edible foods with a high Se content (μg kg^{-1} as eaten) included chicken (323), fish (223–308) and chicken eggs (102–220). Values of 240–260; 170–790 and 242–270, respectively, have been reported (Wolf et al., 1992; Pennington et al., 1995). In Scotland, a Se-content of 175 μg kg^{-1} had been reported for eggs (Barclay and Macpherson, 1992).

Analytical Se figures from dietary survey data may not in general be applied for other countries. However, Se intakes estimated from composition data of foods consumed in a restricted geographical area showed a good correlation between calculated intakes and intakes determined by total diet studies.

In Egypt, bread wheat is largely imported from the USA having high levels of Se (Wolf et al., 1992). In Egypt, the majority of the rural population (57% of the whole population) depends on the locally harvested crop for home-made bread making. This results in a dietary intake of roughly 8 μg d^{-1} for an average consumer in the Egyptian villages using local wheat flour in bread and 30 μg d^{-1} for those purchasing bread from bakeries and catering services located in the big cities. In recent years the crop yield of wheat grown in Egypt has improved resulting in a considerable proportion of low Se wheat now used in bread making. This trend towards decreasing use of American wheat was identified by Egyptian authorities. From the present work, the average intake of Se for adults in Egypt is estimated as 49 μg d^{-1}. Estimates of adult daily dietary Se intakes in Europe, are 48 μg d^{-1} among Austrian adults (Wilplinger, 1998). 50–60 μg d^{-1} among British (Barclay and Macpherson, 1992), and 47 μg d^{-1} and 37 μg d^{-1} for German males and females (Oster and Prellwizt, 1989). The highest estimates of 105 μg d^{-1}. Se were reported among American adults (Pennington et al., 1984). The lowest estimate of intake was reported from the People's Republic of China, with a figure of 7 μg d^{-1} in the Keshan endemic (Yang et al., 1987). The recommended levels of Se intake quoted by the National Research Council (1989) are 70 and 55 μg d^{-1} for adult males and females, respectively. Dietary standards lower than those of the RDA have been proposed by international nutrition authorities. The Nordic countries, for example, have recommended a range of daily selenium intakes of 30 to 60 μg for adults with no increases for pregnancy or lactation (PNUN, 1989). WHO recommends 30 μg d^{-1} for women and 40 μg d^{-1} for men (Anon. 1996).

The different trends in dietary Se provision by cereal-based and animal-derived food groups identified here strongly suggest the need for a more comprehensive survey to establish the Se status of the Egyptian people.

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