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Daily intake of selenium and concentrations in blood of residents of Riyadh City, Saudi Arabia

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Abstract Concentrations of selenium (Se) in food from local markets of Riyadh, Kingdom of Saudi Arabia (KSA) were measured and daily intake calculated based on information from a questionnaire of foods eaten by healthy Saudis. The daily intake of Se was then compared to concentrations of Se in blood serum. Primary sources of Se in the diet of Saudis were as follows: meat and meat products (31%), egg (20.4%), cereals and cereal products (16%), legumes (8.7%), fruits (6.8%), milk and dairy products (2.0%), beverages (2%), sweets (1.8%), pickles (0.2%), and oil (0.02%). Daily intake of Se, estimated to be 93 μg Se/person/day, was slightly greater than that calculated from the Food and Agriculture Organization (FAO) food balance sheet for KSA, which was approximately 90 μg Se/person/day. The daily intake of Se by Saudis in Riyadh was greater than that of Australians or Dutch but less that of Canadians and Americans. There was a statistically significant correlation ($R = +0.38$, $P < 0.05$) between daily intake of Se and concentrations of Se in blood serum of Saudis in Riyadh. The mean concentration of Se in serum was $1.0 \times 10^2 \pm 30.5$ μg Se/l. Taken together, the results suggest that the average Se intake and Se serum concentrations are within the known limits and recommendations, making it unlikely that Saudis are on average at risk of deficiency or toxicity.

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Introduction

Selenium (Se) is a naturally occurring element that is associated with deposits of ores containing other elements. It can be released as a result of weathering of rocks, from volcanic emissions, and during mining and smelting of ores. Selenium is present in air, water, soils, and plants. Selenium is an essential micronutrient in human and animal nutrition, but greater amounts can be toxic (ATSDR 2003; Goldhaber 2003; Chen et al. 2006). Selenium can be released by human activities, including mining, milling, refining, especially of copper, and oil and gas operations (U.S. Agency for Toxic Substances and Disease Registry; ATSDR 2003). Concentrations of Se in humans are dependent on the amount of Se in the diet, which is a function of the Se content of the soil upon which plants are grown.

Humans and animals require Se for normal functioning of more than 30 known selenoproteins, of which more than 15 have been characterized and their enzymatic functions identified (Brown and Arthur 2001; Jameson and Diamond 2004). Known selenoproteins include four glutathione peroxidases, three iodothyronine deiodinases, three thioredoxin reductases, selenoprotein P, selenoprotein W, and selenophosphate synthetase. Se is essential for normal functioning of the immune system and thyroid gland, which makes Se an essential element for normal development, growth, metabolism, and defense of the body (Dodig and Cepelak 2004). The supportive functions of Se in health and disease, including male infertility; viral infections including HIV, cancer, cardiovascular, and autoimmune diseases, have been documented by the results of clinical examinations and the results of controlled studies that have confirmed that Se in the diet is therapeutic in treating diseases (Ursini et al. 1999; Cepelak and Dodig 2003). Deficiency of Se can exacerbate iodine deficiency and affect synthesis of thyroid hormone (Dodig and Cepelak 2004). Se interacts with nutrients that affect the pro-oxidant/antioxidant balance of cells. Se, in combination with vitamin E, is involved in metabolic functions. The selenoprotein, glutathione peroxidase, enhances the antioxidant activity of vitamin E and limits oxidation of lipids in cell membranes. In this way, Se can prevent some of the damage resulting from vitamin E deficiency. The selenoprotein thioredoxin reductase can maintain antioxidant function of vitamin C by catalyzing its regeneration.

Excessive intake of Se can result in toxicity called selenosis. Symptoms of selenosis include gastrointestinal upsets, hair loss, white blotchy nails, fatigue, irritability, and mild nerve damage. More recently, several studies suggested a possible link between Se exposure and increased risk of developing type 2 diabetes mellitus and adverse cardio-metabolic effects (Stranges et al. 2007). Toxicity due to exposure to Se is rare in North America, with the only reported cases having been associated with industrial accidents and an error in manufacturing that led to great concentrations of Se in a food supplement (Goldhaber 2003; Hathcock 1997). A no observed adverse effect level (NOAEL) of 15 μg Se/kg bw/day has been developed from an epidemiological study of a population in China (Yang et al. 1989). Based on the results of an epidemiological study, an exposure limit of 5 μg Se/kg bw/day has been set by both the United States Environmental Protection Agency (US EPA 1991) and Agency for Toxicity and Disease Registry (ATSDR 2003).

Since Se is both a required element and can also be toxic, there is an optimal range for daily intake. The RDA is the "average daily dietary intake that is sufficient to meet the nutritional requirements" of most individuals without causing toxicity. An upper intake level (UL) is "the greatest average daily intake level likely to pose no risk of adverse health effects to almost all individuals in a given life-stage and gender group" (Health Canada 2006). In other words, the RDA is the goal for usual intake by an individual (Health Canada 2006). The recommended dietary allowances (RDA) for children and adults are 1.5 and 0.8 μg Se/kg bw/day, respectively. The tolerable upper intake amounts for children and adults are 7.5 and 5.7 μg Se/kg bw/day, respectively (Health Canada 2004b). Similarly, the upper limits of intake calculated by the U.S. National Academy of Science (NAS 2000) correspond to a daily intake of approximately 5.5 μg Se/kg bw/day. In their review of the toxicity of Se, Lawrence and Chapman (2007) pointed out that no clinical signs of selenosis were reported in humans exposed to as much as 700 μg Se/day, which is the equivalent of 10 μg Se/kg bw/day for an adult. Thus,

the reference dose of 5 μg Se/kg bw/day might be overly protective. However, since neither the ATSDR (2003) nor US EPA (1995) has revised their exposure limits, and the least Health Canada UL is comparable to the US EPA (1991) and ATSDR (2003) values, the exposure limit of 5 μg Se/kg bw/day was used as a reference value in assessing the health impact of concentrations of Se measured in fish from the North Saskatchewan River (NSR) (Shell Canada Energy 1999).

Concentrations of Se in foods vary among geographical regions, mainly due to variations in total concentrations of Se in soils, even within the same country. Bioavailability of Se to be accumulated from soils into plants is also a factor that determines accumulation of Se into diets (European Commission, Health and Consumer Protection Directorate-general, Scientific Committee on Food 2000). Since plants do not appear to require Se, concentrations of Se in plants are directly proportional to those in soils. Se-containing compounds found in food are as follows: selenate, which is the major inorganic compound found in both animal and plant tissues; selenocysteine, which is the predominant selenoamino acid in tissues when inorganic Se is given to animals; selenomethionine, which is the major selenocompound found initially in animals given this selenoamino acid, but over time is converted to selenocysteine; and Se-methylselenocysteine, which is the major selenocompound in plants that tend to enrich Se relative to concentrations in the soil. Examples of plants that concentrate Se include garlic, onions, broccoli florets and sprouts, and wild leeks. Selenomethionine is the major selenocompound in cereal grains, grassland legumes, and soybeans (Dodig and Cepelak 2004).

Food is the main source of Se for humans. Dietary intake of Se is determined by the concentration in food and the amount of food consumed (Pappa et al. 2006). Concentrations of Se in food vary among locations depending on concentrations of Se in soils where plants and animals used as food are produced (Barclay et al. 1995; IOM 1998; Uden et al. 2004). In particular, meat and seafood are sources of Se in the diets of humans (Klapec et al. 2004; Sirichakwal et al. 2005). Because of variation in concentrations of Se in food, dietary intake of Se varies among populations around the world (McNaughton and Marks 2002). Therefore, it is necessary to monitor the Se content in representative and widely consumed foods in each region.

Because the Kingdom of Saudi Arabia (KSA) is arid and in most parts little food can be produced, most of the food consumed by people living in KSA is imported from other countries. Thus, dietary Se is not related to concentrations in soils in the KSA, but rather related to concentrations of Se in soils of other regions. Hence, the objectives of this study were to: (1) measure concentrations of Se in foods in local markets in Riyadh, KSA, (2) determine daily intake of individual foods by use of a Food Consumption Survey (questionnaire), which was conducted in 2010, (3) calculate the daily intake of Se from the concentrations of Se in food items and the amounts of foods consumed, (4) compare the calculated daily intake of Se intake with that given by the food balance sheet of KSA provided by the United Nations, Food and Agriculture Organization (FAO), (5) compare the daily intake for Se to suggested daily intakes and to thresholds for toxicity, and (6) examine the correlation between Se dietary intake and concentrations of Se in blood serum of healthy adults in Riyadh.

Materials and methods

Sampling

Samples of local foods were collected from local markets in Riyadh during September 2010. Approximately 104 foods and ingredients belonging to 12 food groups were collected (Table 1).

Sample preparation

For processed foods, those brands representing a high percentage of the domestic market were purchased. Three samples for each food item were purchased in September 2010. Samples were dried at 100°C until constant weight. To prevent contamination, subsamples were ground to a homogenous powder by use of special mills with parts made of aluminum and titanium. A 150 g of the sample was taken and stored in air-tight polyethylene bottles at 18°C until further analysis (Tülay et al. 2009).

Quantification of Se

Foods were wet digested by heating at 150°C on a hot plate (PC-351, Corning Incorporated Life Sciences,

Table 1 Food groups and types used for the determination of selenium contents

Food group	Types
Vegetables	Cucumber, Zucchini, Green peas, Carrots, Potatoes, Eggplant, Green peppers, Okra, Time, Green hot pepper, Taro, Onions, Garlic, Canned taro, Canned green peas, Canned carrots, Canned okra, Canned spinach, Canned potatoes, Canned Jews mallow, Radish, Spinach, Lettuce, Leafy lettuce, Mint, Coriander, Cauliflower, Watercress, Cabbage, Green onions
Fruits	Tomatoes, Bananas, Strawberry, Orange, Pears, Lemon, Apples, Canned strawberry, Dried dates
Pickles	Pickled cucumber, Pickled turnip
Legumes	Green kidney bean, Canned green kidney beans, Canned kidney beans, Canned beans, beans, Canned peas, Cowpeas
Cereal and cereal product	Pasta, Rice (Karos snow white), Rice (Abu sion), Bread, White bread, Biscuits (Tyoshob), Biscuits (Tyoshob strawberry), Tea biscuits, Biscuits (Loucker, Napolitaner)
Milk and milk products	Fresh milk, Danette banana, Flavored milk, Danette strawberry, Flavored milk, Yogurt, Cheese, Ice cream (plastic tray), Ice cream (paper canned), Vanilla ice cream (paper canned)
Beverages	Orange and carrot juice, Apple juice, Fruit juice, Orange juice, Lemon juice, Strawberry juice, Lipton tea packages, Lipton tea, Coffee
Sweets	Chocolate bars (Bounty, Galaxy, Snickers, Twix, Vip, Albeni, Triplex, Towers Gold), Rush, Halvah.
Meat and meat products	Sardines haakon hot, Light meat tuna (Eldiafa), Light meat tuna (C Harvest), Incheon rural slides, Light meat tuna (IFFCO), Light meat tuna (California), Sardines cooked (Milo), Chicken, Fish, Fresh meat (lamb), Eggs.
Oils	Shams, Noor, Abu Zahra, Afia

Lowell, MA, USA) according to standard methods (Welz and Melcher 1985; Salama and Radwan 2005; Ramesh et al. 2007; Chukwujindu Iwegbue et al. 2008; Edem et al. 2009). All utilized reagents including, nitric acid (70%), hydrochloric acid (36%), hydrofluoric acid, hydrogen peroxide, sulfuric acid, and ultrapure double deionized distilled water (18 MΩ cm), conformed to the specifications of the Committee on Analytical Reagents of the American Chemical Society. Containers and equipment used to process samples were cleaned according to the standard methods of Hageddorm (2008). The same pretreatment procedure was repeated until the darkness of the solution disappeared. After cooling, the digested solution was diluted with deionized distilled water and transferred to a 50-ml volumetric flask. Diluted solution was filtered through a filter paper into polyethylene tubes (50 ml); then Se concentrations in digested samples were determined by use of inductively coupled plasma atomic emission spectroscopy (ICP-AES) (Thermo Scientific ICAP 6500 ICP-AES with a Standard Introduction Kit, glass concentric nebulizer/cyclonic spray chamber) (van de Wiel 2003). Recovery of Se during the analytical procedure was determined by spiking and homogenizing several previously analyzed samples with several concentrations of Se and processed by the procedure described above. Average recovery of Se was 97.8 ± 1.3%.

Estimation of dietary intake of Se

Daily intake of Se was estimated from the food balance sheet for KSA given by FAO and from a 24-h food questionnaire for 260 subjects in Riyadh. Based on the relative proportions of foods in the diet and concentrations of Se in the respective foods, mean daily intake of Se was calculated.

Collection, preparation, and analysis of blood serum

Samples of venous blood were collected in polyethylene tubes (5 ml) from 260 randomly selected, healthy, non-smoking adults (140 men and 120 women) from Riyadh. Each subject signed an informed consent form for the procedures and use of subsequent information. Samples of blood were left at room temperature until clotting and centrifuged, and serum was isolated into Eppendorf tubes and kept frozen until analyses. Serum was digested with HNO_3, HCl, and H_2O_2 (30%) as described by (Bukhari et al. 2005). Concentrations of Se in digested samples were determined by use of ICP-AES and reported as μg Se/l serum (parts per billion; ppb). Mean recovery, determined by spiking several previously analyzed samples with several amounts of standard solutions of Se, was 98.1 ± 1.6%.

Statistical analysis

Parametric statistical analyses such as the two-sample t test and Pearson correlation analysis were used to analyze the data, choosing $P = 0.05$ as the level of significance. The analysis of the data was accomplished by use of SPSS program (version 17).

Results and discussion

Mean concentrations (μg Se/kg, wet weight) of Se in 104 different foods and food ingredients, typically found in Saudi diets, are reported with the range and standard error of means (Table 2). The greatest mean Se concentrations were found in meats ($3.0 \times 10^2 \pm 7.8$), eggs ($2.6 \times 10^2 \pm 0.3$), and canned fish ($2.2 \times 10^2 \pm 5.7$) μg Se/kg, ww, respectively. Legumes contained moderate concentrations of Se, with a mean of $1.8 \times 10^2 \pm 5.8$ μg Se/kg, ww, whereas leafy vegetables, non-leafy vegetables, cereals, and cereal products contained similar concentrations of Se with mean concentrations of approximately 5.0×10^1 μg Se/kg, ww. Canned vegetables, fruits, milk and dairy products, tea and coffee, beverages, pickles, and sweets contained mean concentrations of Se that were less than 4.0×10^1 μg Se/kg, ww. Oils contained the least mean concentration of Se, of 2.2 ± 0.17 μg Se/kg, ww. The major sources of Se intake by Saudis were meat and meat products (30.94%), egg (20.37%), cereal and cereal products (16.11%), legumes (8.66%), fruits (6.79%), milk (2.12%), beverages (2%), sweets (1.79%), pickles (0.2%), and oil and grease (0.02%) (Table 3). Protein-rich foods, such as fish, sea food, eggs, meat, and poultry, contain greater concentrations of Se, whereas foods containing less protein such as vegetables, fruits, pickles, cereals and cereal products, milk and dairy products, beverages, tea and coffee, and sweets contain lesser concentrations of Se. This finding was in accordance with the results of other studies (Holland et al. 1991; Barclay et al. 1995; New Zealand Institute for Crop and Food Research Limited 2000; McNaughton and Marks 2002).

Concentrations of Se in various foods consumed by Saudis were compared to those in foods of other countries (Table 4). The mean concentration of Se in legumes in Saudi diets was 1.8×10^2 μg/kg, ww (Table 2), which is greater than concentrations of Se reported for legumes from other regions (Pappa et al. 2006). Concentrations of Se legumes from Greece ranged from 2.4 to 4.4×10^2 μg Se/kg, ww with a mean value of 1.6×10^2 μg Se/kg, ww. The greatest concentration of Se among legumes was 2.8×10^2 μg Se/kg, ww, which was found in canned kidney beans. This result is likely due to the greater protein content in legumes, which is correlated with concentrations of Se (Klapec et al. 2004; Sirichakwal et al. 2005).

Concentrations of Se in cereals and cereal products ranged from 0.2 to 1.2×10^2 μg Se/kg, ww with a mean value of 0.6×10^2 μg Se/kg, ww. Among cereal products, the greatest concentration of Se was found in white bread (1.2×10^2 μg Se/kg), while the least was found in rice (Brand name: Karos Snow white) (2.7×10^1 μg Se/kg, ww). These results are similar to those of Dumont et al. (2006) who reported that concentrations of Se ranged from 1.0×10^1 to 5.5×10^2 μg Se/kg, ww. Concentrations of Se, in both white and whole grain bread, ranged from 0.8 to 1.1×10^2 μg Se/kg, ww with a mean of 0.9×10^2 μg Se/kg, ww and 1.0×10^2 to 1.5×10^2 μg Se/kg, ww with a mean of 1.2×10^2 μg Se/kg, ww, respectively Marro (1996). Mean concentrations of Se in bread were reported to range from 2.0×10^1 to 1.3×10^2 μg Se/kg, ww in bread (Pappa et al. 2006). In the study upon which we report here, the observed differences in Se content between wholewheat bread ($1.0 \times 10^2 \pm 4.8$ μg Se/kg, ww) and white bread ($1.2 \times 10^2 \pm 6.2$ μg Se/kg, ww) were not statistically significant ($P > 0.05$).

Leafy, non-leafy, and canned vegetables contained lesser concentrations of Se (Table 2). Similar results are reported by Sirichakwal et al. (2005) who suggested that concentrations of Se tended to be less in vegetables than other foods. Concentrations of Se in fruits and vegetables from Portugal, which contained less protein than other foods, also contained less Se (Ventura et al. 2009). However, some vegetables, such as garlic, onions, broccoli, cabbage, and safflower, tend to have greater concentrations of Se (Dumont et al. 2006; Kápolina et al. 2007). These plants also contain a greater fraction of seleno compound such as Se-methylselenocysteine.

Concentrations of Se in beverages other than milk ranged from 2.2×10^1 to 3.7×10^1 μg Se/kg, ww with a mean concentration of 2.9×10^1 μg Se/kg, ww (Table 2). The greatest concentration of Se was found in orange and carrot juice (3.7×10^1 μg Se/kg, ww), while the least was found in apple juice. Concentrations

Table 2 Concentration of selenium in analyzed food samples from the Saudi market

Food type	No.	Sample	Se (μg/kg ± SD)[a]
Non-leafy vegetables	1	Cucumber	$4.1 \times 10^1 \pm 0.07$
	2	Zucchini	$2.1 \times 10^1 \pm 0.12$
	3	Green peas	$2.1 \times 10^1 \pm 0.37$
	4	Carrots	$1.9 \times 10^2 \pm 1.07$
	5	Potatoes white	$2.0 \times 10^1 \pm 0.15$
	6	Eggplant (black)	$4.1 \times 10^1 \pm 0.07$
	7	Green peppers	$1.4 \times 10^1 \pm 0.08$
	8	Okra	$1.4 \times 10^1 \pm 0.07$
	9	Time	$5.1 \times 10^1 \pm 0.17$
	10	Green hot pepper	$4.1 \times 10^1 \pm 0.08$
	11	Potatoes	$5.1 \times 10^1 \pm 0.09$
	12	Taro	$2.0 \times 10^2 \pm 0.02$
	13	Onions	$2.4 \times 10^1 \pm 0.04$
	14	Garlic	$0.9 \times 10^1 \pm 0.02$
		Mean ± SD	$5.2 \times 10^1 \pm 6.26$
		Range	0.9×10^1–2.0×10^2
Canned vegetables	15	Canned taro	$2.7 \times 10^1 \pm 0.17$
	16	Canned green peas	$1.3 \times 10^1 \pm 0.05$
	17	Canned carrots	$6.1 \times 10^1 \pm 1.11$
	18	Canned okra	$5.1 \times 10^1 \pm 0.45$
	19	Canned spinach	$1.6 \times 10^1 \pm 0.27$
	20	Canned potatoes	$1.9 \times 10^1 \pm 0.91$
	21	Canned Jews mallow	$9.1 \times 10^1 \pm 0.64$
		Mean ± SD	$3.9 \times 10^1 \pm 3.01$
		Range	1.3×10^1–9.10×10^1
Leafy vegetables	22	Mallow	$0.1 \times 10^1 \pm 0.02$
	23	Purslane	$0.1 \times 10^1 \pm 0.06$
	24	Radish	$0.1 \times 10^1 \pm 0.05$
	25	Dill	$0.1 \times 10^1 \pm 0.03$
	26	Spinach	$3.9 \times 10^1 \pm 0.23$
	27	Lettuce	$8.1 \times 10^1 \pm 0.56$
	28	Lettuce	$3.1 \times 10^1 \pm 0.55$
	29	Mint	$0.1 \times 10^1 \pm 0.02$
	30	Coriander	$1.5 \times 10^2 \pm 2.07$
	31	Cauliflower	$1.3 \times 10^2 \pm 1.06$
	32	Watercress	$9.76 \times 10^2 \pm 0.65$
	33	Cabbage	$1.1 \times 10^2 \pm 1.97$
	34	Green onions	$9.8 \times 10^1 \pm 0.65$
		Mean ± SD	5.6 ± 5.56
		Range	0.1×10^1–1.5×10^2
Fruits	35	Tomatoes	$1.8 \times 10^2 \pm 3.07$
	36	Bananas	$1.6 \times 10^2 \pm 1.33$
	37	Strawberry	$1.2 \times 10^1 \pm 0.19$
	38	Oranges	$3.0 \times 10^1 \pm 0.87$

Table 2 continued

Food type	No.	Sample	Se (μg/kg ± SD)[a]
	39	Pears	$1.2 \times 10^2 \pm 2.88$
	40	Lemon	$1.8 \times 10^1 \pm 0.45$
	41	Apples	$1.5 \times 10^1 \pm 0.72$
	42	Canned strawberry	$2.9 \times 10^1 \pm 0.51$
	43	Dried dates	$7.3 \times 10^1 \pm 0.94$
	Mean ± SD	$6.7 \times 10^1 \pm 6.50$	
	Range	1.2×10^1–1.8×10^2	
Pickles	44	Pickled cucumber	$1.9 \times 10^1 \pm 0.18$
	45	Pickled turnip	$1.8 \times 10^1 \pm 0.24$
		Mean ± SD	$1.8 \times 10^1 \pm .070$
		Range	1.8×10^1–1.9×10^1
Legumes	46	Green kidney bean	$1.7 \times 10^2 \pm 0.65$
	47	Canned green kidney beans	$2.3 \times 10^2 \pm 0.28$
	48	Canned kidney beans	$2.8 \times 10^2 \pm 0.69$
	49	Canned beans	$1.4 \times 10^2 \pm 1.07$
	50	Canned beans	$1.2 \times 10^2 \pm 0.97$
	51	Broad beans	$1.7 \times 10^2 \pm 0.64$
	52	Canned peas	$1.1 \times 10^2 \pm 0.32$
	53	Cowpeas	$2.1 \times 10^2 \pm 0.61$
		Mean ± SD	$1.8 \times 10^2 \pm 5.81$
		Range	1.1×10^2–2.8×10^2
Cereal and cereal products	54	Pasta	$3.1 \times 10^1 \pm 0.87$
	55	Rice (Karos snow white)	$2.9 \times 10^1 \pm 0.63$
	56	Rice (Abu Sion)	$2.7 \times 10^1 \pm 0.51$
	57	Bread	$1.0 \times 10^2 \pm 0.48$
	58	White bread	$1.2 \times 10^2 \pm 0.62$
	59	Biscuits (Tyoshob)	$4.2 \times 10^1 \pm 0.41$
	60	Biscuits (Tyoshob strawberry)	$3.0 \times 10^1 \pm 0.22$
		Tea Biscuits	$6.0 \times 10^1 \pm 0.78$
	62	Biscuits (Loucker) (Napolitaner)	$4.8 \times 10^1 \pm 0.54$
		Mean ± SD	$5.4 \times 10^1 \pm 3.42$
		Range	2.7×10^1–1.2×10^2
Milk and dairy Products	63	Fresh milk	$3.2 \times 10^1 \pm 0.87$
	64	Danette banana-flavored milk	$1.1 \times 10^1 \pm 0.07$
	65	Danette strawberry-flavored milk	$2.8 \times 10^1 \pm 0.54$
	66	Yogurt	$2.0 \times 10^1 \pm 0.66$
	67	Cheese	$1.8 \times 10^1 \pm 0.83$
	68	Ice cream (plastic tray)	$2.3 \times 10^1 \pm 0.76$
	69	Ice cream paper canned	$2.9 \times 10^1 \pm 0.63$
	70	Vanilla ice cream paper canned	$2.8 \times 10^1 \pm 0.32$
		Mean ± SD	$2.4 \times 10^1 \pm 0.69$
		Range	1.1×10^1–3.2×10^1

Table 2 continued

Food type	No.	Sample	Se (μg/kg ± SD)[a]
Beverages	71	Orange and carrot juice	$3.7 \times 10^1 \pm 0.82$
	72	Apple juice	$2.2 \times 10^1 \pm 0.71$
	73	Fruit juice	$2.7 \times 10^1 \pm 0.12$
	74	Orange juice	$3.1 \times 10^1 \pm 0.07$
	75	Lemon juice	$3.0 \times 10^1 \pm 0.55$
	76	Strawberry juice	$2.7 \times 10^1 \pm 0.07$
		Mean ± SD	$2.9 \times 10^1 \pm 0.50$
		Range	2.2×10^1–3.70×10^1
Tea and Coffee	77	Lipton tea packages	$2.2 \times 10^1 \pm 0.91$
	78	Lipton Tea (Loose)	$2.4 \times 10^1 \pm 0.88$
	79	Coffee	$2.8 \times 10^1 \pm 0.36$
		Mean ± SD	$2.5 \times 10^1 \pm 0.30$
		Range	2.2×10^1–2.79×10^1
Sweets	80	Bounty	$2.2 \times 10^1 \pm 0.41$
	81	Galaxy	$3.0 \times 10^1 \pm 0.57$
	82	Snickers	$1.3 \times 10^1 \pm 0.53$
	83	Vip	$3.2 \times 10^1 \pm 0.93$
	84	Albeni	$2.8 \times 10^1 \pm 0.17$
	85	Triplex	$1.5 \times 10^1 \pm 0.52$
	86	Towers gold	$3.1 \times 10^1 \pm 0.64$
	87	Twix	$3.8 \times 10^1 \pm 0.82$
	88	Rush	$4.4 \times 10^1 \pm 0.26$
	89	Halvah	$4.0 \times 10^1 \pm 0.37$
		Mean ± SD	$2.9 \times 10^1 \pm 1.0$
		Range	1.3×10^1–4.4×10^1
Canned fish	90	Sardines Haakon hot	$2.7 \times 10^2 \pm 3.07$
	91	Light meat tuna (Eldiafa)	$1.5 \times 10^2 \pm 0.26$
	92	Light meat tuna (C Harvest)	$2.3 \times 10^2 \pm 0.32$
	93	Incheon rural slides	$2.5 \times 10^2 \pm 0.57$
	94	Light meat tuna (IFFCO)	$1.4 \times 10^2 \pm 0.81$
	95	Light meat tuna (California)	$2.9 \times 10^2 \pm 0.72$
	96	Sardines cooked (Milo)	$2.1 \times 10^2 \pm 0.86$
		Mean ± SD	$2.2 \times 10^2 \pm 5.70$
		Range	1.3×10^2–2.9×10^2
Meats	97	Chicken	$2.5 \times 10^2 \pm 0.33$
	98	Fish	$2.6 \times 10^2 \pm 0.89$
	99	Fresh meat (lamb)	$3.9 \times 10^2 \pm 2.34$
		Mean ± SD	$3.1 \times 10^2 \pm 7.79$
Eggs		Range	2.5×10^2–3.9×10^2
	100	Chicken eggs	$2.6 \times 10^2 \pm 0.30$
		Mean ± SD	$2.6 \times 10^2 \pm 0.30$
		Range	2.6×10^2

Table 2 continued

Food type	No.	Sample	Se (μg/kg ± SD)[a]
Oils	101	Noor	0.2 ± 0.01
	102	Shams	4.0 ± 0.14
	103	Abu zahra	1.5 ± 0.06
	104	Afia	3.4 ± 0.11
		Mean ± SD	2.2 ± 0.17
		Range	0.2–0.4

[a] Values are mean of triplicate analysis expressed on a wet weight basis

Table 3 Daily intake of selenium daily intake (μg Se/person/day) and contribution (%) in relation to food questionnaire

Food kind	Daily consumption of food (g)	Concentration (μg Se/kg)	Daily Se intake (μg/person/day)	Contribution (%)
Vegetables	203.59	5.1×10^1	10.32	11.1
Fruits	90.54	7.0×10^1	6.33	6.80
Pickles	10.39	1.9×10^1	0.19	0.205
Legumes	44.91	18.0×10^1	8.07	8.66
Cereals and cereal product	276.93	5.4×10^1	15.02	16.12
Milk and dairy products	83.79	2.4×10^1	1.97	2.12
Beverages	66.71	2.8×10^1	1.83	1.97
Sweets	54.77	2.9×10^1	1.61	1.72
Meat and meat products	116.69	24.7×10^1	28.84	31.0
Eggs	75.73	25.0×10^1	19.00	20.38
Oil	10.00	0.23×10^1	0.02	0.03
Daily Se intake (μg/person/day)			93.20	

of Se in milk vary among species with concentrations decreasing in the order: human > sheep > goat > cow milk. Concentrations of Se in milk are negatively correlated with fat content (Pappa et al. 2006). A similar trend was observed in different types of cheese (Barclay et al. 1995). Concentrations of Se in milk sold in Riyadh were 3.2×10^1 μg Se/kg, ww in fresh milk, 1.1×10^1 μg Se/kg, ww in Danette banana milk and 2.8×10^1 μg Se/kg, ww in ice cream (paper canned) (Table 2).

Fresh meat, chicken, eggs, and canned fish, which contain large amounts of protein, contained the greatest concentrations of Se (Table 2). These results are consistent with those of other studies conducted in other regions (Klapec et al. 2004; Sirichakwal et al. 2005; Pappa et al. 2006). The primary forms of Se in food of animal origin are selenocysteine and selenomethionine, which are biologically available to consumers (van der Torre et al. 1991). Concentrations of Se in fresh meat were greater than those of chicken, egg, canned fish, or fresh fish. Concentrations of Se in meats from KSA were greater than the same products from Australia, the United Kingdom, the United States, and New Zealand (Table 4). Concentrations of Se in meats varied among countries due to different concentrations of Se in the foods the animals were fed. The mean concentration of Se in whole eggs was greater than those previously reported for eggs from other regions of the world (Bratakos and Ioannou 1989; Pappa et al. 2006).

Fresh vegetables, canned vegetables, fruits, kidney beans, baked beans, eggs, beverages, chicken, and fresh meat from Saudi markets contained greater concentrations of Se than that from the other countries (Table 4). Fresh vegetables from Saudi markets had greater concentrations than those in Australia (McNaughton and Marks 2002), UK (Barclay et al. 1995) and in New Zealand (New Zealand Institute for Crop and Food Research Limited 2000). Moreover, concentrations of Se in chickens for the KSA were greater than those in Australia, UK, USA, and New Zealand (Table 4).

Table 4 Comparison of food composition data for selenium (μg Se/kg, ww) from Saudi Arabia, Australia, United Kingdom, United States, and New Zealand

Sample	Saudi Arabia (μg/kg) (this study)	Australia (McNaughton and Marks 2002)	United Kingdom (Holland et al. 1991)	United Kingdom (Barclay et al. 1995)	United State (United States Department of Agriculture 1999)	New Zealand (New Zealand Institute for Crop and Food Research Limited 2000)
Fresh vegetables	52	0.6–33	Trace-30	2.0–30	2.0–19	0.0–11
Canned vegetables	39	7.8–31	Trace	–	5.0–7.0	2.5
Fruits	$(0.1–1.9) \times 10^2$	0.7–14	Trace-30	4.0	2.0	11
Kidney beans	1.8×10^2	5.0	60	–	12	4.0
Baked beans	$(1.1–1.4) \times 10^2$	20	20	–	47	84
White rice	27–29	25	40	1.3×10^2	75	0.0
Pasta	31	39	Trace-40	48	$(2.1–2.2) \times 10^2$	42–56
Wheat breakfast biscuits	30–60	1.8×10^2	40	23	47	$(0.3–1.3) \times 10^2$
Bread	$(1.0–1.2) \times 10^2$	$(0.9–1.3) \times 10^2$	$(2.8–3.5) \times 10^2$	43–92	$(2.8–3.7) \times 10^2$	32–60
Milk	11–32	23–26	10	10–15	20–21	1.0–14
Cheese	18	70–79	1.2×10^2	74	1.4×10^2	23
Ice cream	23–29	45	–	15–17	26	6.3
Eggs	$(2.5–2.6) \times 10^2$	$(1.9–4.1) \times 10^2$	$(0.90–1.2) \times 10^2$	–	$(2.3–3.1) \times 10^2$	1.6×10^2
Oils	0.2–4.0	5.0–5.3	Trace	–	0	0
Beverages (fruit juice)	22–37	0.71–41	Trace-10	–	1.0–6.0	0.0–1.6
Chocolate	13–44	10	40	41	39	21
Canned fish (processed meat)	$(1.4–2.9) \times 10^2$	$(0.5–2.3) \times 10^2$	$(2.0–2.2) \times 10^2$	–	–	$(0.0–1.80) \times 10^2$
Chicken	2.5×10^2	$(1.2–2.8) \times 10^2$	60–70	–	$(1.9–2.8) \times 10^2$	$(1.4–1.5) \times 10^2$
Fish	1.4×10^2	$(1.2–6.3) \times 10^2$	$(2.0–5.0) \times 10^2$	–	$(1.3–5.0) \times 10^2$	$(2.0–5.1) \times 10^2$
Fresh meat	2.9×10^2	$(1.3–2.2) \times 10^2$	10	38	$(2.7–2.8) \times 10^2$	37–56

Table 5 Correlation of daily intake of selenium with food balance of KSA given by FAO

Food kind	Daily consumption of food (g)	Concentration (μg/kg)	Daily Se intake (μg/person/day)
Vegetables	290	5.1×10^1	14.7
Pumpkin	17	2.1×10^1	0.3
Carrots	0.3	1.9×10^2	0.1
Potatoes	48	5.10×10^1	2.4
Tomatoes	83	1.8×10^2	14.9
Dry dates	75	7.3×10^1	5.5
Cereal and cereal product	332	5.4×10^1	18.0
White cheese	50	1.8×10^1	0.9
Meat and meat products	135	2.5×10^2	33.4
Daily Se intake μg/person/day			90

The total daily intake of Se by Saudi's was 93 μg/person/day. Based upon the food balance sheet for KSA given by FAO (1994–1996), the estimated Se intake of Saudi population was 90 μg Se/person/day (Table 5). Estimated daily intakes of Se by populations in various countries including Saudi Arabia were compared (Table 6). Japanese (129 μg Se/person/day), Canadian (113–224 μg Se/person/day), USA (114 μg Se/person/day), and Saudi population (90.12–93.2 μg Se/person/day) had greater daily intakes of Se than other countries that received less than 85 μg Se/person/day (Table 6). The Greek population had the least daily intake of Se (39 μg Se/person/day). The mean daily intake of Se was 93 μg Se/person/day, which is similar to that reported for other regions of the world and greater than the RDA of 55 μg Se/person/day (DRI 2000). This average Se daily intake is greater than that derived from the food balance of KSA given by FAO, which was 90 μg Se/person/day (Table 5). The mean daily intake of Se in the KSA was also greater than that for people in other countries (Table 5).

Monitoring for intake of Se can also be done by measuring concentrations of Se in blood plasma or serum, whole blood, toenails or hair (Gibson 1990). The mean concentration of Se in blood serum had a range of 0.48×10^2–1.5×10^2 μg Se/l with a mean of $1.0 \times 10^2 \pm 30$ μg Se/l (Table 7). In the populations of adult Saudis from Riyadh, concentrations of Se in blood serum were correlated with the calculated daily intake of Se ($R = +0.38$, $P < 0.05$) (data not shown). These results are consistent with the results of previous studies that have reported that in populations receiving sufficient amount of Se in their diets, concentrations of Se in blood serum are usually between 0.6 and 1.2×10^2 μg Se/l (Elinder et al. 1994). While comparing concentrations of Se in blood

Table 6 Comparison of the estimated selenium intake for populations in various countries

No.	Country	Se intake (μg/day)	References
1	Netherlands	72	Van Dokkum et al. (1989)
2	Sweden	44	Becker and Kumpulainen (1991)
3	Canada	113–224	Health Canada (1992)
4	Italy	51	Amodio-Cocchieri et al. (Amodio-Cocchieri et al. 1995)
5	Japan	129	Hirai et al. (1996)
6	Egypt	49	Hussein and Bruggeman (1999)
7	UK	29–39	Food Standards Agency (FSA) (2008)
8	China	69	Zhang et al. (2001)
9	USA	114	Department of Health, Human Services (DHHS) (2002)
10	Australia	58–85	Food Standards Australia and New Zealand (FSANZ) (2003)
11	Greece	39	Pappa et al. (2006)
12	Korea	57.5	Choi et al. (2009)
13	Saudi Arabia	90–93	This study

Table 7 Comparison of mean concentration of selenium (Se) in blood serum of healthy adult Saudis in Riyadh, Kingdom of Saudi Arabia with that of other countries

Population group (age and characteristics)	Mean Se (μg/l)	Se range (μg/l)	Area (country)	Reference
General population	$1.0 \times 10^2 \pm 30$	$(0.48\text{-}1.5) \times 10^2$	Riyadh city	This study
Health adult individuals	$0.75 \times 10^2 \pm 27.3$	$(0.30\text{–}1.8) \times 10^2$	Granada (South-eastern Spain)	Navarro et al. (1995)
General population	1.26×10^2		Singapore	Hughes et al. (1998)
Healthy individuals from 6 to 75 years old	$0.8 \times 10^2 \pm 25$	$(0.08\text{–}1.8) \times 10^2$	Canary Islands (Spain)	Díaz-Romero et al. (2001)
Adult population (20–40 years old)	1.0×10^2	$(0.4\text{–}1.9) \times 10^2$	Mumbai (India)	Raghunath et al. (2002)
Healthy volunteers aged 19–74 years old	$0.7 \times 10^2 \pm 39$	$0.2\text{–}1.3 \times 10^2$	Lower Silesian region (Poland)	Luty-Frackiewicz et al. (2002)
Healthy adult subject aged 24–45 years old	$0.90 \times 10^2 \pm 16$		Bydgoszcz (Poland)	Czuczejko et al. (2003)
Healthy volunteers (mean age: 39.6 years)	$0.7 \times 10^2 \pm 10$	$0.57\text{–}0.95 \times 10^2$	Rio de Janeiro (Brazil)	Da Cunha et al. (2003)
Healthy Caucasian volunteers sampled once a month during 1 year (23–69 years)	0.9×10^2	$(0.5\text{–}1.2) \times 10^2$	Antwerp region (Belgium)	Van Cauwenbergh et al. (2004)
Healthy volunteers recruited from blood donor aged 43.2 ± 1.7 years old	$2.2 \times 10^2 \pm 7.4$		Taiwan (China)	Ko et al. (2005)
Healthy individuals aged >16 years old	$1.0 \times 10^2 \pm 13.0$	$(0.8\text{–}1.4) \times 10^2$	Tehran (Iran)	Safaralizadeh et al. (2005)
Healthy adult blood donors aged 20–45 years old	$0.9 \times 10^2 \pm 20$	$(0.4\text{–}1.2) \times 10^2$	Czech Republic	Batáriová et al. (2005)
Healthy individuals aged 18–65 years old	$0.9 \times 10^2 \pm 24$	$0.42\text{–}1.8 \times 10^2$	Vienna (Austria)	Gundacker et al. (2006)
Healthy adult individuals aged 48.5 ± 13.2 years old	$1.3 \times 10^2 \pm 22$		Taiwan (China)	Lin et al. (2006)

serum among countries is difficult due to difference in analytical methods (Hatano et al. 1984), it is useful to integrate differences in diets and bioavailability. The mean concentration of Se in blood serum of $1.0 \times 10^2 \pm 30$ for the Saudi population was greater than that reported for Spain (0.75×10^2 μg Se/l), Poland (0.67×10^2 μg Se/l), Brazil (0.73×10^2 μg Se/l), and the Czech republic (0.84×10^2 μg Se/l). Concentrations of Se in blood serum of Saudis living in Riyadh were similar to those reported for India (1.0×10^2 μg Se/l) and Iran (1.0×10^2 μg Se/l), but less than those reported for Singapore (1.26×10^2 μg Se/l) and Taiwan (2.16×10^2 μg Se/l) (Table 7).

In conclusion, based on daily intakes of Se and concentrations of Se observed in blood serum, Saudis are consuming sufficient quantities of Se to not be deficient, but not enough to be toxic.

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References

Agency for Toxic Substances and Disease Registry (ATSDR). (2003). *Toxicological profile for selenium*. US Dept Health and Human Serv. http://www.atsdr.cdc.gov.

Amodio-Cocchieri, R., Arneses, A., Roncioni, A., & Vestri, G. (1995). Evaluation of the selenium content of the traditional Italian diet. *International Journal of Food Sciences and Nutrition, 46*, 149.

Barclay, M. N. I., MacPherson, A., & Dixon, J. (1995). Selenium content of a range of U.K. foods. *Journal of Food Composition and Analysis, 8*, 307–318.

Batáriová, A., Cerna, M., Spevácková, V., Cejchanová, M., Benes, B., & Smíd, J. (2005). Whole blood selenium

content in healthy adults in the Czech Republic. *Science of the Total Environment, 338*, 183–188.

Becker, W., & Kumpulainen, J. (1991). Contents of essential and toxic mineral elements in Swedish Market-basket diets in 1987. *Brazilian Journal of Nutrition, 66*, 151–160.

Bratakos, M. S., & Ioannou, P. V. (1989). The regional distribution of selenium in Greek cereals. *Science of the Total Environment, 84*, 237–247.

Brown, K. M., & Arthur, J. R. (2001). Selenium, selenoproteins and human health: a review. *Public Health Nutrition, 4*, 593–599.

Bukhari, I. H., Hassan, M. N., Haleem, A., & Maqbool, M. B. (2005). Role of metals (Cadmium and lead) in patients of hypertension and their relationship with ischemic heart disease. *Research Journal of Agriculture and Biological Sciences, 1*, 190–194.

Cepelak, I., & Dodig, S. (2003). Glutathione and oxidative stress. *Biochemical Medicine, 13*, 93–100.

Chen, C., Yu, H., Zhao, J., Li, B., Qu, L., Liu, S., et al. (2006). The roles of serum selenium and selenoproteins on mercury toxicity in environmental and occupational exposure. *Environmental Health Perspective, 114*, 297–301.

Choi, Y., Kim, J., Lee, H., Kim, C., Hwang, K., Park, H.-K., et al. (2009). Selenium content in representative Korean foods. *Journal of Food Composition and Analysis, 22*, 117–122.

Chukwujindu Iwegbue, M. A., Nwozo, S. O., Ossai, E. K., & Nwajei, G. E. (2008). Heavy metal composition of some imported canned fruit drinks in Nigeria. *American Journal of Food Technology, 3*, 220–223.

Czuczejko, J., Zachara, B. A., Stauback-Tpoczwska, E., Halota, W., & Kedziora, J. (2003). Selenium, glutathione and glutathione peroxidases in blood of patients with chronic liver diseases. *Acta Biochimica Polonica, 50*, 1147–1154.

Da Cunha, S., Manes Albanesi Filho, F., Senra Antelo, D., & Miranda de Souza, M. (2003). Serum sample levels of selenium and copper in Rio de Janeiro city. *Science of the Total Environment, 301*, 51–54.

Department of Health and Human Services (DHHS). (2002). Dietary intake of macronutrients, micronutrients and other dietary constituents: United States, 1988–1994. In *Vital and Health Statistics* (p. 104), Series 11, Number 245. Maryland: DHHS Publication.

Díaz-Romero, C. D., López-Blanco, F. L., Henríquez-Sánchez, P. H., Rodríguez-Rodríguez, E., & Serra-Majem, L. S. (2001). Serum selenium concentration in a representative sample of the Canadian population. *Science of the Total Environment, 269*, 65–73.

Dietary Reference Intakes (DRI) (2000). Applications in dietary assessments. *National Research Council*. Washington: National Academy Press. pp. 284–319.

Dodig, S., & Cepelak, I. (2004). The facts and controverses about selenium. *Acta Pharmaceutica, 54*, 261–276.

Dumont, E., Vanhaecke, F., & Cornelis, R. (2006). Selenium speciation from food source to metabolites: a critical review. *Analytical and Bioanalytical Chemistry, 385*, 1304–1323.

Edem, C. A., Grace, I., Vincent, O., Rebbeca, E., & Matilda, O. (2009). A comparative evaluation of heavy metals in commercial wheat flours sold in Calabar-Nigeria. *Pakistan Journal of Nutrition, 8*, 585–587.

Elinder, C. G., Friberg, L., Nordberg, G. F., Kjellström, T., & Oberdörster, G. (1994). *Biological monitoring of metals*. Geneva: World Health Organization.

European Commission, Health and Consumer Protection Directorate-general, Scientific Committee on Food. (2000). Opinion of the Scientific Committee on Food on the Tolerable Upper Intake Level of Selenium, Bruxelles, CF/CS/NUT/UPPLEV/25 Final. November 28.

Food Standards Agency (FSA). (2008). Revised review of selenium. EVM/99/17. Revised August 2002. Retrieved 2008–12. http://www.food.gov.uk/multimedia/pdfs/selenium.pdf.

Food Standards Australia and New Zealand (FSANZ). (2003). The 20th Australian Total Diet Survey.

Gibson, R. S. (1990). *Principles of nutritional assessment*. New York: Oxford University Press.

Goldhaber, S. B. (2003). Trace element risk assessment: Essentiality versus toxicity. *Regulatory Toxicology and Pharmacology, 38*, 232–242.

Gundacker, C., Komarnicki, G., Zödl, B., Forster, C., Schuster, E., & Wittmann, K. (2006). Whole blood mercury and selenium concentrations in a selected Austrian population: Does gender matter? *Science of the Total Environment, 372*, 76–86.

Hageddorm, B. (2008). Acid digestion of waters for total recoverable metals. Environmental Protection Agency (EPA) 3005.

Hatano, S., Nishi, Y., & Usiu, T. (1984). Plasma selenium concentration in healthy Japanese children and adults determined by flameless atomic absorption spectrophotometry. *Journal of Pediatric Gastroenterology and Nutrition, 3*, 426–431.

Hathcock, J. N., (1997). Vitamins and minerals: efficacy and safety. *The American Journal of Clinical Nutrition*, *66*, 427–437.

Health Canada (1992). Guidelines for Canadian drinking water quality: Supporting document–selenium, April, 1979. Updated December 1992. Available online at http://www.hc-sc.gc.ca/ewhsemt/pubs/water-eau/doc_sup-appui/selenium/index_e.html.

Health Canada. (2004). Federal contaminated site risk assessment in Canada. Part II: Health Canada toxicological reference values. September, 2004.

Health Canada. (2006). Dietary Reference Intake Tables. ISBN: 0-662-41134-X. http://www.hc-sc.gc.ca/fn-an/nutrition/reference/table/index-eng.php.

Hirai, K., Noda, K., & Danbara, H. (1996). Selenium intake based on representative diets in Japan, 1957 to 1989. *Nutrition Research, 16*, 1471–1477.

Holland, B., Welch, A. A., Unwin, I. D., Buss, D. H., Paul, A. A., & Southgate, D. A. T. (1991). *The composition of foods*. Cambridge: Royal Society of Chemistry/Ministry of Agriculture, Fisheries and Food.

Hughes, K., Chua, L. H., & Ong, C. N. (1998). Serum selenium in the general population of Singapore, 1993–1995. *Annals Academy of Medicine Singapore, 27*, 520–523.

Hussein, L., & Bruggeman, J. (1999). Selenium analysis of selected Egyptian foods and estimated daily intakes among a population group. *Food Chemistry, 65*, 527–532.

IOM. (1998). *Dietary reference intakes: Dietary reference intakes for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, pantothenic acid, biotin and choline* (p. 284). Washington: National Academy Press.

Jameson, R. R., & Diamond, A. M. (2004). A regulatory role for Sec tRNASerSec in selenoprotein synthesis. *RNA, 10*, 1142–1152.

Kápolina, E., Shah, M., Caruso, J. A., & Fedor, P. (2007). Selenium speciation studies in Se-enriched chives (*Allium schoenoprasum*) by HPLC-ICP-MS. *Food Chemistry, 101*, 1398–1406.

Klapec, T., Mandic, M. L., Grgic, J., Primorac, L. J., Perl, A., & Krstanovic, V. (2004). Selenium in selected foods grown or purchased in eastern Croatia. *Food Chemistry, 8*, 445–452.

Ko, W., Guo, C., Yeh, M., Lin, L., & Hsu, G. (2005). Blood micronutrient, oxidative stress, and viral load in patients with chronic hepatitis C. *World Journal of Gastroenterology, 11*, 4697–4702.

Lawrence, G. S., & Chapman, P. M. (2007). Human health risks of selenium-contaminated fish: A case study for risk assessment of essential elements. *Human and Ecological Risk Assessment, 13*, 1192–1213.

Lin, C., Huang, J., Tsai, L., & Huang, Y. (2006). Selenium, iron, copper, and zinc levels and copper-to-zinc ratios in serum of patients at different stages of viral hepatic diseases. *Biological Trace Element Research, 109*, 15–23.

Luty-Frackiewicz, A., Jheton, Z., & Januszewska, L. (2002). Effect of smoking and alcohol consumption on the serum selenium level of lower Silesian population. *Science of the Total Environment, 285*, 89–95.

Marro, N. (1996). *The 1994 Australian market basket survey*. Canberra: Australia New Zealand Food Authority.

McNaughton, S. A., & Marks, G. C. (2002). Selenium content of Australian foods: A review of literature values. *Journal of Food Composition and Analysis, 15*, 169–182.

NAS (United States National Academies of Science). (2000). *Dietary reference intakes for vitamin C, vitamin E, selenium and carotenoids*. Institute of Medicine. http://books.nap.edu/openbook.php?record_id=9810&page=284.

Navarro, M., Lopez, H., Ruiz, M. L., González, S., Perez, V., & Lopez, M. C. (1995). Determination of selenium in serum by hydride generation atomic absorption spectrometry for calculation of daily dietary intake. *Science of the Total Environment, 175*, 245–253.

New Zealand Institute for Crop and Food Research Limited. (2000). *Food files 2000: New Zealand food composition database*. Christchurch: Ministry of Health.

Pappa, E. C., Pappas, A. C., & Surai, P. F. (2006). Selenium content in selected foods from the Greek market and estimation of the daily intake. *Science of the Total Environment, 372*, 100–108.

Raghunath, R., Triphathi, R. M., Mahapatra, S., & Sadasivan, S. (2002). Selenium levels in biological matrices in adult population of Mumbai. *Science of the Total Environment, 285*, 21–27.

Ramesh, A., Devi, B. A., Hasewaga, H., Maki, T., & Ueda, K. (2007). Nanometer-sized alumina coated with chromotropic acid as solid phase metal extractant from environmental samples and determination by inductively coupled plasma atomic emission spectrometry. *Microchemical Journal, 86*, 124–130.

Safaralizadeh, R., Kardar, G. A., Pourpak, Z., Moin, M., Zare, A., & Teimourian, S. (2005). Serum concentration of selenium in healthy individuals living in Tehran. *Nutrition Journal, 4*, 1–4.

Salama, K. A., & Radwan, M. A. (2005). Heavy metals (Cd, Pb) and trace elements (Cu, Zn) contents in some foodstuffs from the Egyptian market. *Emirates Journal of Agricultural Sciences, 17*, 34–42.

Shell Canada Energy, Intrinsik Environmental Sciences Inc., Jacques Whitford Axys Ltd. (1999). *Potential human health impacts related to selenium in fish from the North Saskatchewan River*. Calgary, Alberta, Canada, March. http://www-static.shell.com/static/can-en/downloads/aboutshell/aosp/sirs_qa3_att_mar09.pdf.

Sirichakwal, P. P., Puwastien, P., Polngam, J., & Kongkachuichai, R. (2005). Selenium content of Thai foods. *Journal of Food Composition and Analysis, 18*, 47–59.

Stranges, S., Marshall, J. R., Natarajan, R., Donahue, R. P., Trevisan, M., Cappuccio, F. P., et al. (2007). Effects of long-term selenium supplementation on the incidence of type 2 diabetes. A randomized trial. *Annals of Internal Medicine, 147*, 217–223.

Tülay, O., Serife, T., Vedat, Y., Senol, K., & Didem, A. (2009). Determination of lead and cadmium in food samples by the coprecipitation method. *Food Chemistry, 113*, 1314–1317.

United States Department of Agriculture (1999). USDA Nutrient Database for Standard Reference, Release 13. Nutrient Data Laboratory Homepage on the World Wide Web. http://www.nal.usda.gov/fnic/foodcomp/Data/SR13/sr.html.

U.S. EPA. (1991). Ambient Water Quality Criteria for selenium.

U.S. EPA. (1995). Ambient Water Quality Criteria for selenium.

Uden, P. C., Boakye, H. T., Kahakachchi, C., & Tyson, J. F. (2004). Selective detection and identification of Se containing compounds review and recent developments. *Journal of Chromatography. A, 1050*, 85.

Ursini, F., Heim, S., Kiess, M., Maiorino, M., Roveri, A., Wissing, J., et al. (1999). Dual function of the selenoprotein PHGPx during sperm maturation. *Science, 285*, 1393–1396.

Van Cauwenbergh, R. V., Robberectht, H., & Va Vlaslaer, V. (2004). Comparison of the serum selenium content of healthy adults living in the Antwerp region (Belgium) with recent literature data. *Journal of Trace Elements in Medicine and Biology, 18*, 99–112.

van de Wiel, H. J. (2003). *Determination of elements by ICP-AES and ICP-MS*. Bilthoven: National Institute of Public Health and the Environment (RIVM).

van der Torre, H. W., van Dokkum, W., Schaafsma, G., Wedel, M., & Ockhuizen, T. (1991). Effect of various levels of selenium in wheat and meat on blood Se status indices and on selenium balance in Dutch men. *British Journal of Nutrition, 65*, 69–80.

van Dokkum, W., De Vo, R. H., Muy, Th., & Wesstra, J. A. (1989). Minerals and trace elements in total diets in the Netherlands. *British Journal of Nutrition, 61*, 7–15.

Ventura, M. G., Stibilj, V., Freitas, M. C., & Pacheco, A. M. G. (2009). Determination of ultratrace levels of selenium in fruit and vegetable samples grown and consumed in Portugal. *Food Chemistry, 115*, 200–206.

Welz, B., & Melcher, M. (1985). Decomposition of marine biological tissues for determination of arsenic, selenium and mercury using hydride-generation and cold-vapor

atomic absorption spectrometries. *Analytical Chemistry, 57*, 427–431.

Yang, G., Zhou, R., Yin, S., Gu, L., Yan, B., Liu, Y., Liu, Y., & Li, X. (1989). Studies of safe maximal daily dietary selenium intake in a seleniferous area in China. I. Selenium intake and tissue selenium levels of the inhabitants. *Journal of Trace Elements and Elecrolytes in Health and Disease*, *3*, 77–87.

Zhang, Z. W., Shimbo, S., Qu, J. B., Watanabe, T., Nakatsuka, H., Matsuda-Inoguchi, N., et al. (2001). *Biological Trace Elements Research, 80*, 125–138.