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SELENIUM CONCENTRATIONS IN EDIBLE PART OF DIFFERENT CROPS CONSUMED IN JORDAN

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ABSTRACT

This article focuses on the Selenium (Se) concentration of 143 plant species, including fruits, vegetables, cereals and herbs, from four different regions of Ma'an district in Jordan. Selenium concentration was determined by hydrid vapour generation combined with ICP optical emission spectrometry (HVG-ICP-OES) using a continuous flow system at the accredited laboratory of the Royal Scientific Society (RSS). All the values obtained were expressed in micrograms per kilogram (µg/kg) on a fresh wet weight (wet wt) basis for the edible parts of these plant species. Results showed that there was a wide variation in the selenium content of the analysed plant species ranging from 27.7±17.53 µg/kg wet weight (watermelon) to 525.1±190.44 µg/kg wet weight (garlic). The overall mean of all the plant species analysed was 194. 5± 146.14 µg/kg. The mean Se concentration of the soils in the locations where these plant species were grown was 1323 µg/kg with the concentration increasing at increased soil depth. In conclusion, the present study suggests that herbs and spices can be considered a rich source of Se (> 200 µg/kg), fruits and vegetables a moderate source (100-200 µg/kg), whilst cereals tended to have high Se concentration (an average of 198.2 µg/kg). Thus, herbs, spices, fruits, vegetables and cereals could be recommended as good sources of Se for the Jordanian.

***Key words**: cereals, fruits, herbs, Jordan, selenium concentration, spices, vegetables.*

1. INTRODUCTION

Selenium, previously considered as toxic element, is now known to be a micronutrient essential for human health. Se deficiency is associated with skeletal myopathies, cardiomyopathy, and impaired immune system function (Rayman, 2000 and Arthur *et al.*, 2003). In addition, potential roles of Se in relation to cancer (Clark *et al.,* 1996 and Combs, 2004;), immune and viral diseases (Beck *et al.,* 1995, Beck, 1996, Baum *et al.,* 1997, Taylor *et al.,* 1997, Beck and Levander, 1998; Arthur *et al.,* 2003 and Beck *et al.,* 2003) have been recognised.

Selenium enters the food chain through plants, which take it up from the soil and in many cases incorporate it into their proteins as either selenocysteine or selenomethionine. Humans and animals acquire Se in their diet through different sources such as meat, fish, broccoli, leafy plants, nuts, and Brazil nuts; however, the main source of Se for humans comes from cereal products such as wheat and wheat products (Brown and Arthur, 2001). The content of Se in plants depends on its availability in the soil which they are grown in. Se content of soil depends on important factors such as the soil pH, land contour, and microbial activity. These indices vary from one country to another (Sillanpaa and Jansson, 1992 and Diplock, 1993).

Reports concerning Se consumption were

reported from different countries; France, Egypt, UK, USA and others. Unfortunately little information is available about the Se content in plants in Jordan. Knowledge of the Se content of foods in Jordan would provide a nutritional tool to look for nutritional changes and their association with human health. The margin between a deficient (~0.02 mg/day), an adequate (~0.2mg/day) and toxic (~2.4mg/day) intake of Se is quite narrow (Haddadin *et al.,* 2001). This work was undertaken to determine the Se concentration in some crops grown locally in four regions of Ma'an District in order to establish whether plants grown in Ma'an, which supplies food for the citizens of southern Jordan contain an appropriate and beneficial level of Se.

2. MATERIALS AND METHODS

2.1. Experimental

A total of 143 plant species samples was collected in the summer of 2007 from 12 individual domestic farms that grow fruits, vegetables, cereals or herbs as shown in Map (1). The farms represent four different regions of Ma'an District, approximately 200 km south of Amman. Ma'an is relatively unpolluted area, since there are few industrial centres, low vehicular traffic and less inhabitants in comparison to Amman standards. All the plant species collected in this study were grown in soils that are mainly classified as grey desert soils and are characterized by a high content of soluble salts due to the prevailing arid conditions. The characteristics of each soil and the species of plants are listed in Tables (1) and (2).

Table (1): Selected properties in the soil samples of Ma'an district of Jordan.

Location	Location no.	pH [a]	Ec [a] (μs/cm)	OC [b] (%)	$CaCO_3$ [c](%)
Shamia	L1& L2	7.74-8.21	0.42-2.91	0.10-0.22	33.59-51.87
Dabet Al-karim	L3- L6	8.29-8.58	0.10-4.30	0.03-0.06	32.09-35.37
Adruh	L7& L8	8.41-8.93	1.01-9.80	0.02-0.21	35.89-47.45
Mahata	L9- L12	8.71-8.91	0.31-0.66	0.03-0.12	29.83-41.51

[a] pH and Ec (Electrical conductivity) of the soils in water (1:5, W/V) were measured using pH-Ec meter model 4330 (Jenway, UK).
[b] OC (Organic carbon) contents were measured by thermal conductivity detector (Multi EA® 2000 C analyzer).
[c] $CaCO_3$ (Calcium carbonates) were determined using calcimeter model 08.53 (Ei Jkel Kamp Agrisearch Equipment).

2.2. Methods

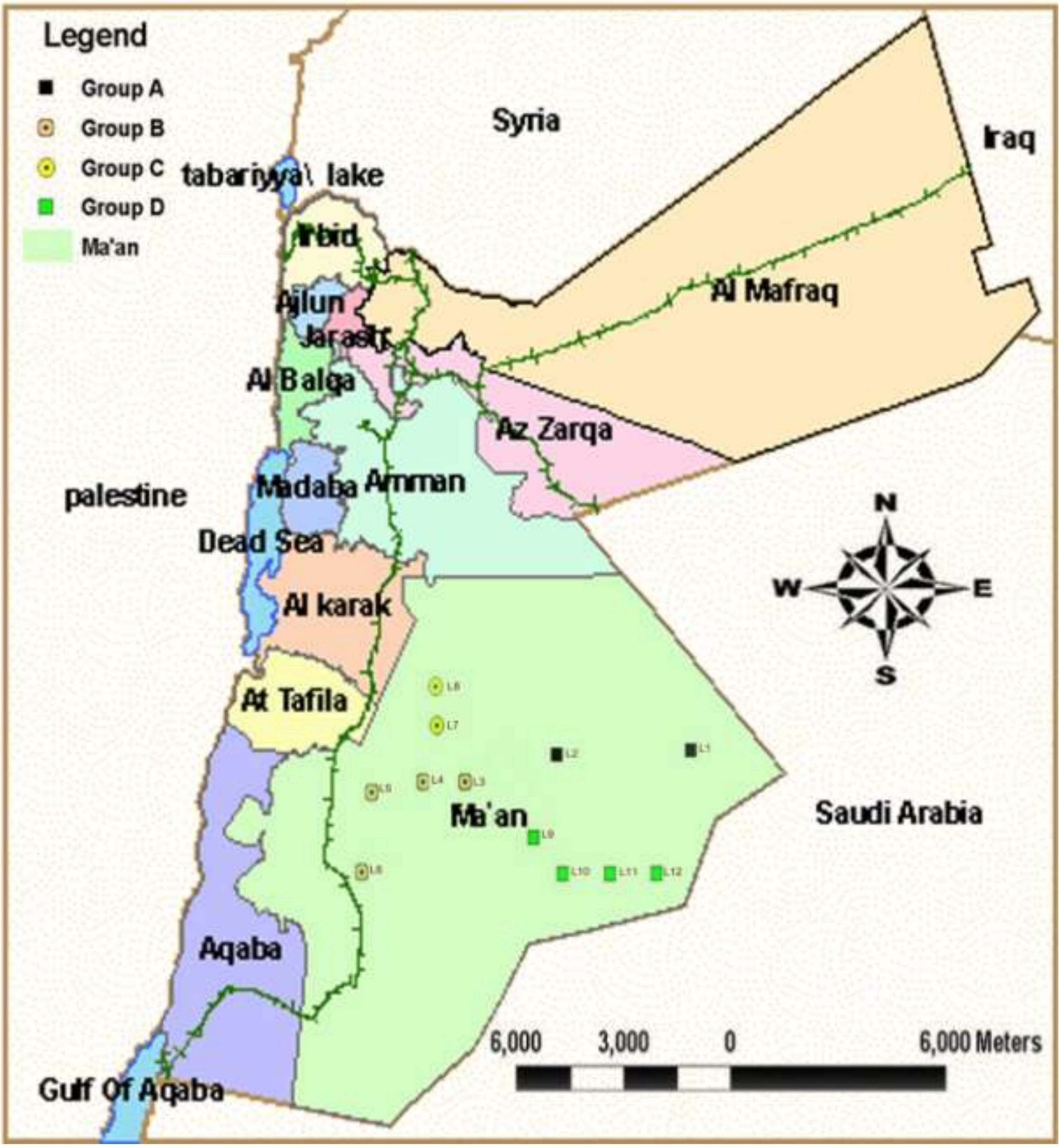
The edible parts of the plant species samples were homogenized using a kitchen blender to obtain uniform material which could be readily subsampled for digestion for subsequent Se analysis.

For Se determination, 5-10 g. wet weight of finely ground homogenized materials were digested with 25-30ml of nitric acid (65-68 %, extra pure grade, Scharlaw, Spain) and 3-5 ml of hydrogen peroxide (30 %, extra pure grade, Scharlaw, Spain). This treatment destroys organic material and releases the Se (Subratty *et al.,* 2004). Total Se in the digest solutions was then determined by hydride vapour generation combined with ICP optical emission spectrometry (HVG-ICP-OES) using a continuous flow system Shimadzu ICPS-7510 (Japan) at the accredited laboratory of the Royal Scientific Society (RSS); all Se analyses were performed in duplicate. The standard solutions of Se used for calibration were produced by diluting a stock standard solution of Se dioxide (1000 mg/l Se traceable to SRM from NIST (CertiPUR, Merck No. 0528489). Working standards were prepared on the day of use. Selenium concentration in various food samples was expressed as microgram per kilogram (μg/kg) edible portion on a fresh wet weight (wet wt) basis. All collected data were analysed using SPSS, version 16.

The efficacy of the digestion procedure using nitric acid and hydrogen peroxide was checked by determination of Se in certified reference soil material, standardized samples by in–house standard addition method and in some real samples.

The continuous flow hydride generator was applied to the determination of the Se hydride forming element in soil standard reference sample from the U.S. Department of Energy, Mixed-Analyte Performance Evaluation Program (MAPEP-07-MaS17). The plant samples matrices were standardized by spiking with the aqueous standard solution of Se element using in-house standard addition method (Yadav *et al.,* 2008). These samples were also spiked with the analyzed element to check the recovery and the accuracy of the method where the analyte element's concentration is near or below the method detection limit.

Composite soil samples (covering a depth from 0-60cm) were taken from selected location on each farm that grows fruits, vegetables,



Map (1): Sampling locations of soils located in four different region groups (group A; Shamia area, group B; Dabet Al-karim area, group C; Adruh area, and group D; Mahatta area) of Ma'an district in Jordan represented by 12 Locations (L 1- L12).

cereals, herbs, and spices. They were air-dried at room temperature and passed through a 2-mm mesh sieve. One-two grams of air dried, finely ground, pulverized, and homogenized materials were extracted and digested with 25 ml of aqua regia (a mixture of concentrated HCl and HNO_3 (3:1)); hydrochloric acid (37%, extra pure grade, Scharlaw, Spain), nitric acid (65-68%, extra pure grade, Scharlaw, Spain) and 3-5 ml of hydrogen peroxide (30%, extra pure grade, Scharlaw, Spain) were also added then heated for 30 min to 80°C. The mixture was filtered through Whatman filter paper No. 42. The filtrate was diluted to the 100 ml volume with deionised water. This method is a wet digestion technique that extracts and frees Se. All Se analyses performed in the laboratory were carried out in duplicate samples. Total selenium in the soil samples was then measured as before by hydride vapour generation.

3. RESULTS AND DISCUSSION

The means for Se concentrations in the 143 plant species are expressed as microgram per kilogram (μg/kg) edible portion on a wet weight (wet wt) basis as shown in Table (2). Wide variations were found in the Se concentration of the analyzed plant species ranging from 27.7±17.53 μg/kg wet weight (watermelon) to 525.1±190.44 μg/kg wet weight (garlic). In general, herbs and spices (*e.g.* garlic, thyme, sage, mint, green tea and others) appeared to contain the highest concentration of Se - over 200 μg/kg which is approximately twice as much as in the fruits. Mean values of Se concentration for all plant species were as follows: fruits, 143.2; vegetables, 184.8; cereals, 198.2; herbs and spices, 242.5μg/kg. The overall mean of all the plant species was (194. 5± 146.14) μg/kg. On average, herbs are considered to be the richest sources of Se while fruits, vegetables and cereals in particular, contained moderate amounts of Se. As shown in Table (3) the mean Se concentration in soil samples was 1281 μg/kg. The highest overall (1318 μg/kg) levels of Se were recorded in samples from a depth of 60 cm, followed by an overall figure of 1291μg/kg at depth 20 cm, 1266 μg/kg at depth 40 cm, and 1250 μg/kg at the surface, where as the highest individual (1960 μg/kg) was recorded at depth 20 cm. In general there was a relatively high selenium concentration in tested soil samples in different depths and locations. The relative standard deviation (R.S.D) for Se determination was within 5%.

The Se concentration in various plant species of the present study was compared to the findings of Se in fruits, vegetables, herbs and spices reported by many authors (Simonoff *et al.*, 1988, Donovan *et al.*, 1991; Barclay, *et al.*, 1995; Hussein and Bruggeman, 1999, Sirichakwal *et al.*, 2005; Smrkolj *et al.*, 2005 and Ventura *et al.*, 2007;) from different countries respectively (UK, Thailand, Egypt, France, Malawi, Portugal, and Solvenia). The Se levels in all plant species were higher in the present study than in any other report and we hypothesise that this is due to the Se content and availability in the soil of the area of Jordan.

A high variation in the Se concentration was found among the analysed plant species samples grown in Jordanian soils. Several studies have shown that Se content of plant foods presumably reflecting the content and the availability of Se in soil (Lorenz, 1978, Yang *et al.*, 1983 and Levander, 1986), the geography of the area (Abuereish and Lahham, 1987, Sillanpaa and Jansson, 1992, Haddadin *et al.*, 2001 and Subratty *et al.*, 2004), as well as the nature of plants themselves (Morris and Levander, 1970; Olson *et al.*, 1970, Thorn *et al.*, 1978 and Thomson and Robinson, 1990). The distribution of Se concentration in soil collected from 12 individual domestic farms from four different regions of Ma'an ranged from 1192-1542 (1281) μg/kg. In general this variation in Se concentration with soil depth and locations may be an important factor underlying the variation of the Se level in the studied plant foods. Present data are in a good agreement with those of Tahi group (Sirichakwal *et al.*, 2005).

Regarding the nature of plant themselves, plants containing low moisture, *i.e.* herbs and spices were found to contain higher levels of Se, probably due to low moisture content of these plants, where as low Se levels were found in plants containing high moisture, *i.e.*, fruits and vegetables (Donovan *et al.*, 1991). Furthermore, protein rich food, *i.e*., cereals grown in the areas under study tended to have high Se concentration. These findings are in accordance with other reports (Morris and Levander1970, Thorn *et al.*, 1978 and Thomson and Robinson, 1990).

According to the classification of Thomson and Robinson (1990), Molnar *et al*. (1995) and Subratty *et al*. (2004), our results indicated that herbs and spices are considered to be rich source for Se (> 200 μg/kg). While fruits and vegetables contain moderate concentrations of Se (100-200 μg/kg).

Cereals tended to have high Se concentration (an average of 198.2 μg/kg). Thus, herbs, spices, fruits, vegetables and cereals could be recommended as good sources of Se for the Jordanian.

Extensive experiments have shown that the use of Se-enriched fertilizers leads to improvement of the Se content of plants in low Se areas and consequently correct Se deficiency in foods (Kasfosz and Szymczyk, 1984, Varo *et al.*, 1988 and Arthur, 2003;;). On the other hand, other groups of certain fertilizers (sulphate, phosphorous, nitrogenous) were reported to lower Se uptake (Simonoff *et al.,* 1988). It would be interesting to carry out further studies on the effects of supplementation of soil fertilizers on plant Se status in Jordan.

Finally, in order to relate our findings to the human diet in the future it will be important to assess Se status (*e.g.* serum Se, GPX enzymatic activity) and plasma antioxidant capacity in

Table (2): Mean selenium concentration in various kinds of fruits, vegetables, herbs and spices forming part of the Jordanian diet expressed in microgram per kilogram (μg/kg) on a fresh wet weight (wet wt) basis for the edible parts of these plant species.

Plant parts	Mean (μg/kg)	No.	Standard deviation
Fruits:			
Plums- flesh	135.2	2	121.55
Raspberry- flesh	153.5	2	179.78
Pear- flesh	92.9	3	126.49
Apple- flesh	150.7	9	114.73
Peach- flesh without stones	162.9	1	.
Pomegranate- arils	139.6	3	110.48
Watermelon- sweet interior flesh	27.7	3	17.53
Grapes- berries	162.9	9	106.84
Apricot- flesh without stones	170.8	2	137.56
Fig- stem tissues and flower parts	325.9	1	.
Mean (μg/kg)	143.2	35	109.41
Vegetables:			
Jews mallow- leaves	202.0	3	86.30
Potato- skin and flesh	107.4	3	38.40
Squash- skin and flesh	179.7	9	78.04
Cabbage- the leafy head	96.0	2	122.47
Eggplant- skin and flesh	272.0	7	280.10
Okra- green seed pods	158.1	3	98.59
Tomato- skin, flesh and juice	174.5	9	100.63
Cucumber- skin and flesh	206.9	5	26.89
Snake cucumber- skin and flesh	189.8	4	202.60
Cauliflower- flowers	45.2	2	30.04
Peas- green seed pods	301.8	1	.
Mean (μg/kg)	184.8	48	140.37
Herbs and spices:			
Rocket- leaves	200.8	3	79.62
Hibiscus- flowers	176.8	2	225.79
Green tea- leaves	125.4	3	88.10
Onion- bulbs	162.5	4	88.92
Spring onion- leaves	198.8	3	76.34
Parsley- leaves	172.5	3	85.47
Chili pepper- flesh tissues	168.7	5	109.77
Sweet pepper- flesh tissues	164.0	2	163.97
Garlic- bulbs	525.1	4	190.44
Thyme- leaves	476.7	2	230.25
Sage- leaves	228.3	5	193.75
Mint- leaves	326.0	6	129.94
Rosemary- leaves	30.6	1	.
Eucalyptus- leaves	235.0	3	280.87
Mean (μg/kg)	242.5	46	177.40
Cereals:			
Barley- fresh grains	207.7	3	73.75
Corn- fresh grains	157.3	8	41.89
Wheat- fresh grains	297.9	3	84.15
Mean (μg/kg)	198.2	14	78.85
Total	194.5	143	146.14

Table (3): Average values for total selenium at various locations within the study area.

Location	0cm	20cm	40cm	60cm	No.	Mean (μg/g)
1	1.25	1. 54	1.4 5	1.23	4	1.367
2	1.09	1.20	1.40	1.41	4	1.275
3	1. 50	1.36	1. 67	1. 64	4	1.542
4	1. 56	1.30	1.14	1.11	4	1.277
5	1.38	1.28	1.43	1. 61	4	1.437
6	1.18	1.38	1.21	1.24	4	1.252
7	1.26	1.08	1.23	1.26	4	1.207
8	0.90	1.96	0.89	1.01	4	1.192
9	1.01	0.99	1.06	1.20	4	1.065
10	1. 68	1.10	1.24	1.08	4	1.275
11	1.11	1.17	1.23	1. 50	4	1.252
12	1.08	1.14	1.20	1. 53	4	1.237
Mean (μg/g)	1.250	1.291	1.263	1. 318	48	1.281

Note: Values are shown for soil samples taken from different depths (0-60 cm). The locations cited refer to individuals farms and where more than one soil sample was taken on a farm, the” location" values are mean for all samples for that farm.

normal Jordanian population. It would also be interesting to evaluate the Se content of complete meals, hospital diet, food from animal sources, as well as irrigated and drinking water since there is no information available concerning these items. Since it is emerging that genetic factors influence Se metabolism (Hesketh, 2008) it would be useful to complement such studies with an analysis of relevant genetic polymorphisms.

In conclusion, Measurements of food and soil Se using hydride vapour generation combined with ICP optical emission spectrometry (HVG-ICP-OES) suggest that a well balanced diet with a high intake of vegetables, fruits, cereals and herbs, would be a reliable source of Se intake in the Jordanian diet.

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تقدير عنصر السيلينيوم في عديد من الأنواع النباتية المزروعة في الأردن

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ملخص

تم تقدير تركيز عنصر السيلينيوم في 143 نوعا نباتيا كانت مزروعة في أربع مناطق زراعية موجودة في مدينة معان الواقعة جنوب الأردن، شملت هذه الأنواع النباتية أنواعا مختلفة من الفاكهة، الخضروات، الحبوب والأعشاب. تم تقدير تركيز عنصر السيلينيوم في هذه الأنواع النباتية على أساس الوزن الطازج من الجزء الذي يؤكل منها و ذلك بواسطة جهاز طيف الامتصاص الذري و قد تم ذلك في مختبرات الجمعية العلمية الملكية. أشارت نتائج هذه الدراسة الى أن هناك تبايناً كبيراً في تركيز هذه الأنواع النباتية من عنصر السيلينيوم، حيث تراوح تركيز هذه الأصناف النباتية من هذا العنصر مابين 17.35±27.7 ميكروجرام/كجم (وزن طازج) في نبات البطيخ الى 190.44±525.1 ميكروجرام /كجم (وزن طازج) في نبات الثوم، بينما كان المتوسط الكلي لتركيز عنصر السيلينيوم في جميع الأنواع النباتية المدروسة يعادل 146.14±194.5 ميكروجرام/كجم. تبين من هذه الدراسة أن متوسط تركيز عنصر السيلينيوم في الأتربة التي نمت بها جميع هذه الأنواع النباتية قد وصل الى 1323 ميكروجرام/كجم، اذ أن تركيزعنصر السيلينيوم يزداد مع زيادة عمق التربة، و بناءاً على نتائج هذه الدراسة يمكن اعتبار أن الأعشاب النباتية مصدراً غنياً بالسيلينيوم (أكثر من 200 ميكروجرام/كجم)، بينما الفاكهة و الخضروات يمكن اعتبارها مصدرٌ متوسطٌ للسيلينيوم (100- 200ميكروجرام/كجم)، بينما كان يتجه محتوى الحبوب من السيلينيوم الى التركيز العالي (بمتوسط مقداره 198,2ميكروجرام/كجم) كما هو في المجموعة الأولى. كما بينت هذه الدراسة أن هذه الأنواع النباتية من الفاكهة و الخضروات و الحبوب و الأعشاب يمكن أن يوصى بها كمصادر غذائية جيدة في محتواها من عنصر السيلينيوم لدى أفراد المجتمع الأردني.

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (62) العدد الاول (يناير 2011):118-125.